# Table of contents

## Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Get Started</td>
<td>3</td>
</tr>
<tr>
<td>1.1 Introduction</td>
<td>3</td>
</tr>
<tr>
<td>1.2 What You Need</td>
<td>3</td>
</tr>
<tr>
<td>1.2.1 Hardware</td>
<td>90</td>
</tr>
<tr>
<td>1.2.2 Software</td>
<td>91</td>
</tr>
<tr>
<td>1.3 Installation</td>
<td>91</td>
</tr>
<tr>
<td>1.3.1 IDE</td>
<td>91</td>
</tr>
<tr>
<td>1.3.2 Manual Installation</td>
<td>91</td>
</tr>
<tr>
<td>1.4 Build Your First Project</td>
<td>122</td>
</tr>
<tr>
<td>1.5 Uninstall ESP-IDF</td>
<td>122</td>
</tr>
<tr>
<td>2 API Reference</td>
<td>123</td>
</tr>
<tr>
<td>2.1 API Conventions</td>
<td>123</td>
</tr>
<tr>
<td>2.1.1 Error Handling</td>
<td>123</td>
</tr>
<tr>
<td>2.1.2 Configuration Structures</td>
<td>123</td>
</tr>
<tr>
<td>2.1.3 Private APIs</td>
<td>125</td>
</tr>
<tr>
<td>2.1.4 Components in Example Projects</td>
<td>125</td>
</tr>
<tr>
<td>2.1.5 API Stability</td>
<td>125</td>
</tr>
<tr>
<td>2.2 Application Protocols</td>
<td>126</td>
</tr>
<tr>
<td>2.2.1 ASIO port</td>
<td>126</td>
</tr>
<tr>
<td>2.2.2 ESP-Modbus</td>
<td>126</td>
</tr>
<tr>
<td>2.2.3 ESP-MQTT</td>
<td>127</td>
</tr>
<tr>
<td>2.2.4 ESP-TLS</td>
<td>145</td>
</tr>
<tr>
<td>2.2.5 ESP HTTP Client</td>
<td>160</td>
</tr>
<tr>
<td>2.2.6 ESP Local Control</td>
<td>177</td>
</tr>
<tr>
<td>2.2.7 ESP Serial Slave Link</td>
<td>186</td>
</tr>
<tr>
<td>2.2.8 ESP x509 Certificate Bundle</td>
<td>203</td>
</tr>
<tr>
<td>2.2.9 HTTP Server</td>
<td>205</td>
</tr>
<tr>
<td>2.2.10 HTTPS Server</td>
<td>232</td>
</tr>
<tr>
<td>2.2.11 ICMP Echo</td>
<td>236</td>
</tr>
<tr>
<td>2.2.12 mDNS Service</td>
<td>241</td>
</tr>
<tr>
<td>2.2.13 Mbed TLS</td>
<td>241</td>
</tr>
<tr>
<td>2.2.14 IP Network Layer</td>
<td>243</td>
</tr>
<tr>
<td>2.3 Bluetooth API</td>
<td>243</td>
</tr>
<tr>
<td>2.3.1 BT COMMON</td>
<td>243</td>
</tr>
<tr>
<td>2.3.2 BT LE</td>
<td>252</td>
</tr>
<tr>
<td>2.3.3 CLASSIC BT</td>
<td>380</td>
</tr>
<tr>
<td>2.3.4 Controller &amp; VHCI</td>
<td>522</td>
</tr>
<tr>
<td>2.3.5 ESP-BLE-MESH</td>
<td>531</td>
</tr>
<tr>
<td>2.3.6 NimBLE-based host APIs</td>
<td>813</td>
</tr>
<tr>
<td>2.4 Error Codes Reference</td>
<td>815</td>
</tr>
<tr>
<td>2.5 Networking APIs</td>
<td>822</td>
</tr>
<tr>
<td>2.5.1 Wi-Fi</td>
<td>822</td>
</tr>
<tr>
<td>2.5.2 Ethernet</td>
<td>956</td>
</tr>
<tr>
<td>2.5.3 Thread</td>
<td>988</td>
</tr>
<tr>
<td>Section</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>2.10.6</td>
<td>eFuse Manager</td>
</tr>
<tr>
<td>2.10.7</td>
<td>Error Codes and Helper Functions</td>
</tr>
<tr>
<td>2.10.8</td>
<td>ESP HTTPS OTA</td>
</tr>
<tr>
<td>2.10.9</td>
<td>Event Loop Library</td>
</tr>
<tr>
<td>2.10.10</td>
<td>FreeRTOS (Overview)</td>
</tr>
<tr>
<td>2.10.11</td>
<td>FreeRTOS (ESP-IDF)</td>
</tr>
<tr>
<td>2.10.12</td>
<td>FreeRTOS (Supplemental Features)</td>
</tr>
<tr>
<td>2.10.13</td>
<td>Heap Memory Allocation</td>
</tr>
<tr>
<td>2.10.14</td>
<td>Memory Management for MMU Supported Memory</td>
</tr>
<tr>
<td>2.10.15</td>
<td>Heap Memory Debugging</td>
</tr>
<tr>
<td>2.10.16</td>
<td>High Resolution Timer (ESP Timer)</td>
</tr>
<tr>
<td>2.10.17</td>
<td>Internal and Unstable APIs</td>
</tr>
<tr>
<td>2.10.18</td>
<td>Inter-Processor Call</td>
</tr>
<tr>
<td>2.10.19</td>
<td>Interrupt allocation</td>
</tr>
<tr>
<td>2.10.20</td>
<td>Logging library</td>
</tr>
<tr>
<td>2.10.21</td>
<td>Miscellaneous System APIs</td>
</tr>
<tr>
<td>2.10.22</td>
<td>Over The Air Updates (OTA)</td>
</tr>
<tr>
<td>2.10.23</td>
<td>Performance Monitor</td>
</tr>
<tr>
<td>2.10.24</td>
<td>Power Management</td>
</tr>
<tr>
<td>2.10.25</td>
<td>POSIX Threads Support</td>
</tr>
<tr>
<td>2.10.26</td>
<td>Random Number Generation</td>
</tr>
<tr>
<td>2.10.27</td>
<td>Sleep Modes</td>
</tr>
<tr>
<td>2.10.28</td>
<td>SoC Capabilities</td>
</tr>
<tr>
<td>2.10.29</td>
<td>System Time</td>
</tr>
<tr>
<td>2.10.30</td>
<td>The himem allocation API</td>
</tr>
<tr>
<td>2.10.31</td>
<td>ULP Coprocessor programming</td>
</tr>
<tr>
<td>2.10.32</td>
<td>Watchdogs</td>
</tr>
<tr>
<td>3</td>
<td>Hardware Reference</td>
</tr>
<tr>
<td>4</td>
<td>API Guides</td>
</tr>
<tr>
<td>4.1</td>
<td>Application Level Tracing library</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Overview</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Modes of Operation</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Configuration Options and Dependencies</td>
</tr>
<tr>
<td>4.1.4</td>
<td>How to Use This Library</td>
</tr>
<tr>
<td>4.2</td>
<td>Application Startup Flow</td>
</tr>
<tr>
<td>4.2.1</td>
<td>First stage bootloader</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Second stage bootloader</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Application startup</td>
</tr>
<tr>
<td>4.3</td>
<td>BluFi</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Overview</td>
</tr>
<tr>
<td>4.3.2</td>
<td>The BluFi Flow</td>
</tr>
<tr>
<td>4.3.3</td>
<td>The Flow Chart of BluFi</td>
</tr>
<tr>
<td>4.3.4</td>
<td>The Frame Formats Defined in BluFi</td>
</tr>
<tr>
<td>4.3.5</td>
<td>The Security Implementation of ESP32</td>
</tr>
<tr>
<td>4.3.6</td>
<td>GATT Related Instructions</td>
</tr>
<tr>
<td>4.4</td>
<td>Bootloader</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Bootloader Compatibility</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Log Level</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Factory Reset</td>
</tr>
<tr>
<td>4.4.4</td>
<td>Boot from Test Firmware</td>
</tr>
<tr>
<td>4.4.5</td>
<td>Rollback</td>
</tr>
<tr>
<td>4.4.6</td>
<td>Watchdog</td>
</tr>
<tr>
<td>4.4.7</td>
<td>Bootloader Size</td>
</tr>
<tr>
<td>4.4.8</td>
<td>Fast Boot from Deep-Sleep</td>
</tr>
<tr>
<td>4.4.9</td>
<td>Custom Bootloader</td>
</tr>
<tr>
<td>4.5</td>
<td>Build System</td>
</tr>
</tbody>
</table>
4.5.1 Overview ................................................................. 2306
4.5.2 Using the Build System ............................................ 2307
4.5.3 Example Project ..................................................... 2309
4.5.4 Project CMakeLists File ........................................... 2309
4.5.5 Component CMakeLists Files ..................................... 2311
4.5.6 Component Configuration ........................................ 2313
4.5.7 Preprocessor Definitions .......................................... 2313
4.5.8 Component Requirements ......................................... 2313
4.5.9 Overriding Parts of the Project ................................. 2317
4.5.10 Configuration-Only Components ............................... 2318
4.5.11 Debugging CMak e .................................................. 2318
4.5.12 Example Component CMakeLists ............................... 2319
4.5.13 Custom Sdkconfig Defaults ...................................... 2323
4.5.14 Flash Arguments .................................................. 2324
4.5.15 Building the Bootloader ......................................... 2324
4.5.16 Writing Pure CMake Components .............................. 2324
4.5.17 Using Third-Party CMake Projects with Components ....... 2325
4.5.18 Using Prebuilt Libraries with Components .................. 2325
4.5.19 Using ESP-IDF in Custom CMake Projects ..................... 2326
4.5.20 ESP-IDF CMake Build System API .............................. 2326
4.5.21 File Globbing & Incremental Builds ......................... 2330
4.5.22 Build System Metadata .......................................... 2331
4.5.23 Build System Internals .......................................... 2332
4.5.24 Migrating from ESP-IDF GNU Make System .................. 2333
4.6 RF Coexistence .......................................................... 2335
4.6.1 Overview ............................................................. 2335
4.6.2 Supported Coexistence Scenario for ESP32 .................... 2335
4.6.3 Coexistence Mechanism and Policy ............................. 2335
4.6.4 How to Use the Coexistence Feature ......................... 2337
4.7 Core Dump ............................................................... 2338
4.7.1 Overview ............................................................. 2338
4.7.2 Configurations ...................................................... 2338
4.7.3 Core Dump to Flash ................................................. 2339
4.7.4 Core Dump to UART ................................................ 2340
4.7.5 Core Dump Commands .............................................. 2341
4.7.6 ROM Functions in Backtraces ................................... 2341
4.7.7 Dumping Variables on Demand ................................... 2341
4.7.8 Running idf.py coredump-info and idf.py coredump-debug .... 2342
4.8 C++ Support ............................................................. 2344
4.8.1 esp-idf-cxx Component .......................................... 2344
4.8.2 C++ language standard .......................................... 2345
4.8.3 Multithreading ...................................................... 2345
4.8.4 Exception Handling ................................................. 2345
4.8.5 Runtime Type Information (RTTI) .............................. 2346
4.8.6 Developing in C++ ................................................ 2346
4.8.7 Limitations .......................................................... 2347
4.8.8 What to Avoid ..................................................... 2347
4.9 Deep Sleep Wake Stubs ............................................... 2347
4.9.1 Rules for Wake Stubs .............................................. 2348
4.9.2 Implementing A Stub .............................................. 2348
4.9.3 Loading Code Into RTC Memory ................................. 2348
4.9.4 Loading Data Into RTC Memory ................................ 2348
4.9.5 CRC Check For Wake Stubs ....................................... 2349
4.9.6 Example ............................................................. 2349
4.10 Error Handling .......................................................... 2349
4.10.1 Overview ........................................................... 2349
4.10.2 Error codes ......................................................... 2350
4.10.3 Converting error codes to error messages .................... 2350
4.10.4 ESP_ERROR_CHECK macro .................................................. 2350
4.10.5 ESP_ERROR_CHECK WITHOUT_ABORT macro ................. 2351
4.10.6 ESP_RETURN_ON_ERROR macro ........................................ 2351
4.10.7 ESP_GOTO_ON_ERROR macro .......................................... 2351
4.10.8 ESP_RETURN_ON_FALSE macro ........................................... 2351
4.10.9 ESP_GOTO_ON_FALSE macro ............................................. 2351
4.10.10 CHECK MACROS Examples ............................................ 2351
4.10.11 Error handling patterns ................................................. 2352
4.10.12 C++ Exceptions ............................................................ 2353
4.11 ESP-BLE-MESH ................................................................. 2353
  4.11.1 Getting Started with ESP-BLE-MESH ......................... 2353
  4.11.2 ESP-BLE-MESH Examples ............................................ 2361
  4.11.3 ESP-BLE-MESH Demo Videos ....................................... 2361
  4.11.4 ESP-BLE-MESH FAQ .................................................... 2361
  4.11.5 Related Documents ..................................................... 2361
4.12 ESP-WIFI-MESH ............................................................... 2390
  4.12.1 Overview ................................................................. 2390
  4.12.2 Introduction .............................................................. 2390
  4.12.3 ESP-WIFI-MESH Concepts ............................................ 2391
  4.12.4 Building a Network .................................................... 2397
  4.12.5 Managing a Network ................................................... 2402
  4.12.6 Data Transmission ..................................................... 2405
  4.12.7 Channel Switching ..................................................... 2407
  4.12.8 Performance ............................................................. 2410
  4.12.9 Further Notes ........................................................... 2411
4.13 Support for External RAM .................................................. 2411
  4.13.1 Introduction .............................................................. 2411
  4.13.2 Hardware ................................................................. 2411
  4.13.3 Configuring External RAM ........................................... 2411
  4.13.4 Restrictions .............................................................. 2413
  4.13.5 Failure to Initialize .................................................. 2413
  4.13.6 Chip Revisions .......................................................... 2413
4.14 Fatal Errors ................................................................. 2414
  4.14.1 Overview ................................................................. 2414
  4.14.2 Panic Handler ............................................................. 2414
  4.14.3 Register Dump and Backtrace ....................................... 2415
  4.14.4 GDB Stub ................................................................. 2417
  4.14.5 RTC Watchdog Timeout .............................................. 2418
  4.14.6 Guru Meditation Timeout ........................................... 2418
  4.14.7 Other Fatal Errors ..................................................... 2420
4.15 Flash Encryption ........................................................... 2422
  4.15.1 Introduction ............................................................. 2423
  4.15.2 Relevant eFuses .......................................................... 2423
  4.15.3 Flash Encryption Process ............................................ 2424
  4.15.4 Flash Encryption Configuration .................................... 2424
  4.15.5 Possible Failures ....................................................... 2430
  4.15.6 ESP32 Flash Encryption Status ..................................... 2432
  4.15.7 Reading and Writing Data in Encrypted Flash ................ 2432
  4.15.8 Updating Encrypted Flash .......................................... 2433
  4.15.9 Disabling Flash Encryption ........................................ 2433
  4.15.10 Key Points About Flash Encryption ............................. 2434
  4.15.11 Limitations of Flash Encryption ................................ 2434
  4.15.12 Flash Encryption and Secure Boot .............................. 2435
  4.15.13 Advanced Features ................................................... 2435
  4.15.14 Technical Details ..................................................... 2437
4.16 Hardware Abstraction ..................................................... 2437
  4.16.1 Architecture ............................................................ 2438
  4.16.2 LL (Low Level) Layer ................................................ 2439
4.16.3 HAL (Hardware Abstraction Layer) .................................................. 2440
4.17 High Priority Interrupts ................................................................. 2441
  4.17.1 Interrupt Priorities ................................................................ 2441
  4.17.2 Notes ....................................................................................... 2442
4.18 JTAG Debugging ............................................................................. 2442
  4.18.1 Introduction ............................................................................. 2443
  4.18.2 How it Works? ......................................................................... 2443
  4.18.3 Selecting JTAG Adapter ............................................................ 2444
  4.18.4 Setup of OpenOCD ................................................................. 2444
  4.18.5 Configuring ESP32 Target ....................................................... 2445
  4.18.6 Launching Debugger ............................................................... 2450
  4.18.7 Debugging Examples .............................................................. 2450
  4.18.8 Building OpenOCD from Sources ......................................... 2450
  4.18.9 Tips and Quirks ...................................................................... 2455
  4.18.10 Related Documents .............................................................. 2460
4.19 Linker Script Generation ................................................................. 2485
  4.19.1 Overview ................................................................................. 2485
  4.19.2 Quick Start .............................................................................. 2486
  4.19.3 Linker Script Generation Internals .......................................... 2489
4.20 lwIP .................................................................................................. 2495
  4.20.1 Supported APIs ....................................................................... 2495
  4.20.2 BSD Sockets API ................................................................... 2496
  4.20.3 Netconn API ........................................................................... 2499
  4.20.4 lwIP FreeRTOS Task .............................................................. 2500
  4.20.5 IPv6 Support ........................................................................... 2500
  4.20.6 esp-lwip custom modifications .............................................. 2501
  4.20.7 Performance Optimization ...................................................... 2502
4.21 Memory Types ................................................................................ 2503
  4.21.1 DRAM (Data RAM) ................................................................. 2503
  4.21.2 IRAM (Instruction RAM) ......................................................... 2504
  4.21.3 IROM (code executed from flash) .......................................... 2505
  4.21.4 DROM (data stored in flash) ................................................. 2505
  4.21.5 RTC Slow memory ................................................................ 2505
  4.21.6 RTC FAST memory ................................................................. 2506
  4.21.7 DMA Capable Requirement ................................................... 2506
  4.21.8 DMA Buffer in the Stack ....................................................... 2506
4.22 OpenThread .................................................................................... 2507
  4.22.1 Modes of the OpenThread stack ............................................ 2507
  4.22.2 How to Write an OpenThread Application .............................. 2507
  4.22.3 The OpenThread Border Router ............................................ 2509
4.23 Partition Tables ............................................................................... 2509
  4.23.1 Overview ............................................................................... 2509
  4.23.2 Built-in Partition Tables ......................................................... 2509
  4.23.3 Creating Custom Tables ......................................................... 2510
  4.23.4 Generating Binary Partition Table ......................................... 2512
  4.23.5 Partition Size Checks ............................................................. 2513
  4.23.6 Flashing the Partition Table ................................................... 2513
  4.23.7 Partition Tool (parttool.py) ..................................................... 2513
4.24 Performance .................................................................................. 2515
  4.24.1 How to Optimize Performance .............................................. 2515
  4.24.2 Guides .................................................................................... 2515
4.25 Reproducible Builds ...................................................................... 2534
  4.25.1 Introduction ............................................................................ 2534
  4.25.2 Reasons for non-reproducible builds ...................................... 2535
  4.25.3 Enabling reproducible builds in ESP-IDF ................................ 2535
  4.25.4 How reproducible builds are achieved .................................. 2535
  4.25.5 Reproducible builds and debugging ...................................... 2535
  4.25.6 Factors which still affect reproducible builds ......................... 2536
5 Migration Guides

5.1 ESP-IDF 5.x Migration Guide
This is the documentation for Espressif IoT Development Framework (esp-idf). ESP-IDF is the official development framework for the ESP32, ESP32-S, ESP32-C and ESP32-H Series SoCs.

This document describes using ESP-IDF with the ESP32 SoC.
Chapter 1

Get Started

This document is intended to help you set up the software development environment for the hardware based on the ESP32 chip by Espressif. After that, a simple example will show you how to use ESP-IDF (Espressif IoT Development Framework) for menu configuration, then for building and flashing firmware onto an ESP32 board.

**Note:** This is documentation for stable version v5.1.2 of ESP-IDF. Other ESP-IDF Versions are also available.

1.1 Introduction

ESP32 is a system on a chip that integrates the following features:

- Wi-Fi (2.4 GHz band)
- Bluetooth
- Dual high performance Xtensa® 32-bit LX6 CPU cores
- Ultra Low Power co-processor
- Multiple peripherals

Powered by 40 nm technology, ESP32 provides a robust, highly integrated platform, which helps meet the continuous demands for efficient power usage, compact design, security, high performance, and reliability.

Espressif provides basic hardware and software resources to help application developers realize their ideas using the ESP32 series hardware. The software development framework by Espressif is intended for development of Internet-of-Things (IoT) applications with Wi-Fi, Bluetooth, power management and several other system features.

1.2 What You Need

1.2.1 Hardware

- An ESP32 board.
- USB cable - USB A / micro USB B.
- Computer running Windows, Linux, or macOS.

**Note:** Currently, some of the development boards are using USB Type C connectors. Be sure you have the correct cable to connect your board!

If you have one of ESP32 official development boards listed below, you can click on the link to learn more about the hardware.
**Chapter 1. Get Started**

**ESP32-DevKitC V4 Getting Started Guide**

This guide shows how to start using the ESP32-DevKitC V4 development board.

**What You Need**

- *ESP32-DevKitC V4 board*
- USB A / micro USB B cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section *Start Application Development*.

**Overview**

ESP32-DevKitC V4 is a small-sized ESP32-based development board produced by Espressif. Most of the I/O pins are broken out to the pin headers on both sides for easy interfacing. Developers can either connect peripherals with jumper wires or mount ESP32-DevKitC V4 on a breadboard.

To cover a wide range of user requirements, the following versions of ESP32-DevKitC V4 are available:

- different ESP32 modules
  - ESP32-WROOM-DA
  - ESP32-WROOM-32E
  - ESP32-WROOM-32UE
  - ESP32-WROOM-32D
  - ESP32-WROOM-32U
  - ESP32-SOLO-1
  - ESP32-WROVER-E
  - ESP32-WROVER-IE
- male or female pin headers.

For details please refer to ESP Product Selector.

**Functional Description**

The following figure and the table below describe the key components, interfaces and controls of the ESP32-DevKitC V4 board.

![ESP32-DevKitC V4 diagram](image)

Fig. 1: ESP32-DevKitC V4 with ESP32-WROOM-32 module soldered
## Chapter 1. Get Started

### Key Component

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROOM-32</td>
<td>A module with ESP32 at its core. For more information, see <a href="#">ESP32-WROOM-32 Datasheet</a>.</td>
</tr>
<tr>
<td>EN</td>
<td>Reset button.</td>
</tr>
<tr>
<td>Boot</td>
<td>Download button. Holding down <strong>Boot</strong> and then pressing <strong>EN</strong> initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>USB-to-UART Bridge</td>
<td>Single USB-UART bridge chip provides transfer rates of up to 3 Mbps.</td>
</tr>
<tr>
<td>Micro USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the ESP32-WROOM-32 module.</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>Turns on when the USB or an external 5V power supply is connected to the board. For details see the schematics in <a href="#">Related Documents</a>.</td>
</tr>
<tr>
<td>I/O</td>
<td>Most of the pins on the ESP module are broken out to the pin headers on the board. You can program ESP32 to enable multiple functions such as PWM, ADC, DAC, I2C, I2S, SPI, etc.</td>
</tr>
</tbody>
</table>

### Power Supply Options

There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V / GND header pins
- 3V3 / GND header pins

**Warning:** The power supply must be provided using **one and only one of the options above**, otherwise the board and/or the power supply source can be damaged.

### Header Block

The two tables below provide the **Name** and **Function** of I/O header pins on both sides of the board, as shown in *ESP32-DevKitC V4 with ESP32-WROOM-32 module soldered*.

**J2**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3V3</td>
<td>P</td>
<td>3.3 V power supply</td>
</tr>
<tr>
<td>2</td>
<td>EN</td>
<td>I</td>
<td>CHIP_PU, Reset</td>
</tr>
<tr>
<td>3</td>
<td>VP</td>
<td>I</td>
<td>GPIO36, ADC1 CH0, S VP</td>
</tr>
<tr>
<td>4</td>
<td>VN</td>
<td>I</td>
<td>GPIO39, ADC1 CH3, S VN</td>
</tr>
<tr>
<td>5</td>
<td>IO34</td>
<td>I</td>
<td>GPIO34, ADC1 CH6, VDET_1</td>
</tr>
<tr>
<td>6</td>
<td>IO35</td>
<td>I</td>
<td>GPIO35, ADC1 CH7, VDET_2</td>
</tr>
<tr>
<td>7</td>
<td>IO32</td>
<td>I/O</td>
<td>GPIO32, ADC1 CH4, TOUCH_CH9, XTL_32K_P</td>
</tr>
<tr>
<td>8</td>
<td>IO33</td>
<td>I/O</td>
<td>GPIO33, ADC1 CH5, TOUCH_CH8, XTL_32K_N</td>
</tr>
<tr>
<td>9</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, ADC1 CH8, DAC_1</td>
</tr>
<tr>
<td>10</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, ADC2 CH9, DAC_2</td>
</tr>
<tr>
<td>11</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2 CH7, TOUCH_CH7</td>
</tr>
<tr>
<td>12</td>
<td>IO14</td>
<td>I/O</td>
<td>GPIO14, ADC2 CH6, TOUCH_CH6, MTMS</td>
</tr>
<tr>
<td>13</td>
<td>IO12</td>
<td>I/O</td>
<td>GPIO12, ADC2 CH5, TOUCH_CH5, MTDI</td>
</tr>
<tr>
<td>14</td>
<td>GND</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>15</td>
<td>IO13</td>
<td>I/O</td>
<td>GPIO13, ADC2 CH4, TOUCH_CH4, MTCK</td>
</tr>
<tr>
<td>16</td>
<td>D2</td>
<td>I/O</td>
<td>GPIO9, D2</td>
</tr>
<tr>
<td>17</td>
<td>D3</td>
<td>I/O</td>
<td>GPIO10, D3</td>
</tr>
<tr>
<td>18</td>
<td>CMD</td>
<td>I/O</td>
<td>GPIO11, CMD</td>
</tr>
<tr>
<td>19</td>
<td>5V</td>
<td>P</td>
<td>5 V power supply</td>
</tr>
</tbody>
</table>

---

1. P: Power supply; I: Input; O: Output.
2. The pins D0, D1, D2, D3, CMD and CLK are used internally for communication between ESP32 and SPI flash memory. They are grouped on both sides near the USB connector. Avoid using these pins, as it may disrupt access to the SPI flash memory / SPI RAM.
## Pin Layout

### Note on C15

The component C15 may cause the following issues on earlier ESP32-DevKitC V4 boards:

1. The pins GPIO16 and GPIO17 are available for use only on the boards with the modules ESP32-WROOM and ESP32-SOLO-1. The boards with ESP32-WROVER modules have the pins reserved for internal use.

---

**Table: ESP32-DevKitC Pin Layout**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>IO23</td>
<td>I/O</td>
<td>GPIO23</td>
</tr>
<tr>
<td>3</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22</td>
</tr>
<tr>
<td>4</td>
<td>TX</td>
<td>I/O</td>
<td>GPIO1, U0TXD</td>
</tr>
<tr>
<td>5</td>
<td>RX</td>
<td>I/O</td>
<td>GPIO3, U0RXD</td>
</tr>
<tr>
<td>6</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21</td>
</tr>
<tr>
<td>7</td>
<td>GND</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>8</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19</td>
</tr>
<tr>
<td>9</td>
<td>IO18</td>
<td>I/O</td>
<td>GPIO18</td>
</tr>
<tr>
<td>10</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5</td>
</tr>
<tr>
<td>11</td>
<td>IO17</td>
<td>I/O</td>
<td>GPIO17(^3)</td>
</tr>
<tr>
<td>12</td>
<td>IO16</td>
<td>I/O</td>
<td>GPIO16(^3)</td>
</tr>
<tr>
<td>13</td>
<td>IO4</td>
<td>I/O</td>
<td>GPIO4, ADC2_CH0, TOUCH_CH0</td>
</tr>
<tr>
<td>14</td>
<td>IO0</td>
<td>I/O</td>
<td>GPIO0, ADC2_CH1, TOUCH_CH1, Boot</td>
</tr>
<tr>
<td>15</td>
<td>IO2</td>
<td>I/O</td>
<td>GPIO2, ADC2_CH2, TOUCH_CH2</td>
</tr>
<tr>
<td>16</td>
<td>IO15</td>
<td>I/O</td>
<td>GPIO15, ADC2_CH3, TOUCH_CH3, MTDO</td>
</tr>
<tr>
<td>17</td>
<td>D1</td>
<td>I/O</td>
<td>GPIO8, D1</td>
</tr>
<tr>
<td>18</td>
<td>D0</td>
<td>I/O</td>
<td>GPIO7, D0</td>
</tr>
<tr>
<td>19</td>
<td>CLK</td>
<td>I/O</td>
<td>GPIO6, CLK(^3)</td>
</tr>
</tbody>
</table>

---

**Fig. 2: ESP32-DevKitC Pin Layout (click to enlarge)**
Chapter 1. Get Started

• The board may boot into Download mode
• If you output clock on GPIO0, C15 may impact the signal

In case these issues occur, please remove the component. The figure below shows the location of C15 highlighted in yellow.

![Location of C15 (yellow) on ESP32-DevKitC V4 board](image)

**Fig. 3:** Location of C15 (yellow) on ESP32-DevKitC V4 board

**Start Application Development**  Before powering up your ESP32-DevKitC V4, please make sure that the board is in good condition with no obvious signs of damage.

After that, proceed to **Get Started**, where Section **Installation** will quickly help you set up the development environment and then flash an example project onto your board.

![Dimensions of ESP32-DevKitC board with ESP32-WROOM-32 module soldered - back](image)

**Fig. 4:** Dimensions of ESP32-DevKitC board with ESP32-WROOM-32 module soldered - back (click to enlarge)

**Board Dimensions**
Related Documents

- ESP32-DevKitC V4 schematics (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROOM-32 Datasheet (PDF)
- ESP32-WROOM-32D and ESP32-WROOM-32U Datasheet (PDF)
- ESP32-WROOM-DA Datasheet (PDF)
- ESP32-WROVER Datasheet (PDF)
- ESP32-WROVER-B Datasheet (PDF)
- ESP Product Selector

For further design documentation for the board, please contact us at sales@espressif.com.

ESP32-DevKitC V2 Getting Started Guide

This guide shows how to start using the ESP32-DevKitC V2 development board.

What You Need

- **ESP32-DevKitC V2 board**
- USB A / micro USB B cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section *Start Application Development*.

**Overview**  ESP32-DevKitC V2 is a small-sized ESP32-based development board produced by *Espressif*. Most of the I/O pins are broken out to the pin headers on both sides for easy interfacing. Developers can either connect peripherals with jumper wires or mount ESP32-DevKitC V4 on a breadboard.

**Functional Description**  The following figure and the table below describe the key components, interfaces and controls of the ESP32-DevKitC V2 board.

![ESP-WROOM-32]

Fig. 5: ESP32-DevKitC V2 board layout
### Key Component

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROOM-32</td>
<td>Standard module with ESP32 at its core. For more information, see ESP32-WROOM-32 Datasheet</td>
</tr>
<tr>
<td>EN</td>
<td>Reset button.</td>
</tr>
<tr>
<td>Boot</td>
<td>Download button. Holding down <strong>Boot</strong> and then pressing <strong>EN</strong> initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Micro USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and ESP32-WROOM-32.</td>
</tr>
<tr>
<td>I/O</td>
<td>Most of the pins on the ESP module are broken out to the pin headers on the board. You can program ESP32 to enable multiple functions such as PWM, ADC, DAC, I2C, I2S, SPI, etc.</td>
</tr>
</tbody>
</table>

### Power Supply Options
There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V / GND header pins
- 3.3V / GND header pins

**Warning:** The power supply must be provided using **one and only one of the options above**, otherwise the board and/or the power supply source can be damaged.

### Start Application Development
Before powering up your ESP32-DevKitC V2, please make sure that the board is in good condition with no obvious signs of damage.

After that, proceed to **Get Started**, where Section **Installation** will quickly help you set up the development environment and then flash an example project onto your board.

### Related Documents
- ESP32-DevKitC schematics (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROOM-32 Datasheet (PDF)

### ESP-WROVER-KIT V4.1 Getting Started Guide

This guide shows how to get started with the ESP-WROVER-KIT V4.1 development board and also provides information about its functionality and configuration options.

### What You Need

- *ESP-WROVER-KIT V4.1 board*
- USB 2.0 cable (A to Micro-B)
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section **Start Application Development**.

### Overview
ESP-WROVER-KIT is an ESP32-based development board produced by Espressif.

ESP-WROVER-KIT features the following integrated components:

- ESP32-WROVER-E module
- LCD screen
- microSD card slot
Another distinguishing feature is the embedded FTDI FT2232HL chip, an advanced multi-interface USB bridge. This chip enables to use JTAG for direct debugging of ESP32 through the USB interface without a separate JTAG debugger. ESP-WROVER-KIT makes development convenient, easy, and cost-effective.

Most of the ESP32 I/O pins are broken out to the board’s pin headers for easy access.

**Note:** ESP32’s GPIO16 and GPIO17 are used as chip select and clock signals for PSRAM. By default, the two GPIOs are not broken out to the board’s pin headers in order to ensure reliable performance.

---

**Functionality Overview** The block diagram below shows the main components of ESP-WROVER-KIT and their interconnections.

![ESP-WROVER-KIT block diagram](image)

**Functional Description** The following two figures and the table below describe the key components, interfaces, and controls of the ESP-WROVER-KIT board.

![ESP-WROVER-KIT board layout - front](image)

The table below provides description in the following manner:

- Starting from the first picture’s top right corner and going clockwise
- Then moving on to the second picture
<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FT2232HL</td>
<td>The FT2232HL chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232HL also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232HL chip enhances user-friendliness in terms of application development and debugging. See ESP-WROVER-KIT V4.1 schematic.</td>
</tr>
<tr>
<td>32.768 kHz</td>
<td>External precision 32.768 kHz crystal oscillator serves as a clock with low-power consumption while the chip is in Deep-sleep mode.</td>
</tr>
<tr>
<td>0R</td>
<td>Zero-ohm resistor intended as a placeholder for a current shunt, can be desoldered or replaced with a current shunt to facilitate the measurement of ESP32’s current consumption in different modes.</td>
</tr>
<tr>
<td>ESP32-WROVER-E module</td>
<td>This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>Diagnostic LEDs</td>
<td>Four red LEDs connected to the GPIO pins of FT2232HL. Intended for future use.</td>
</tr>
<tr>
<td>UART</td>
<td>Serial port. The serial TX/RX signals of FT2232HL and ESP32 are broken out to the inward and outward sides of JP2 respectively. By default, these pairs of pins are connected with jumpers. To use ESP32’s serial interface, remove the jumpers and connect another external serial device to the respective pins.</td>
</tr>
<tr>
<td>SPI</td>
<td>By default, ESP32 uses its SPI interface to access flash and PSRAM memory inside the module. Use these pins to connect ESP32 to another SPI device. In this case, an extra chip select (CS) signal is needed. Please note that the voltage of this interface is 3.3 V.</td>
</tr>
<tr>
<td>CTS/RTS</td>
<td>Serial port flow control signals: the pins are not connected to the circuitry by default. To enable them, short the respective pins of JP14 with jumpers.</td>
</tr>
<tr>
<td>JTAG</td>
<td>JTAG interface. JTAG signals of FT2232HL and ESP32 are broken out to the inward and outward sides of JP2 respectively. By default, these pairs of pins are disconnected. To enable JTAG, short the respective pins with jumpers as shown in Section Setup Options.</td>
</tr>
<tr>
<td>USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Power Switch</td>
<td>Power On/Off Switch. Toggling toward the Boot button powers the board on, toggling away from Boot powers the board off.</td>
</tr>
<tr>
<td>Power Selector</td>
<td>Power supply selector interface. The board can be powered either via USB or via the 5V Input interface. Select the power source with a jumper. For more details, see Section Setup Options, jumper header JP7.</td>
</tr>
</tbody>
</table>
**Setup Options**  There are three jumper blocks available to set up the board functionality. The most frequently required options are listed in the table below.
<table>
<thead>
<tr>
<th>Header</th>
<th>Jumper Setting</th>
<th>Description of Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP7</td>
<td></td>
<td>Power ESP-WROVER-KIT via an external power supply</td>
</tr>
<tr>
<td>JP7</td>
<td></td>
<td>Power ESP-WROVER-KIT via USB</td>
</tr>
<tr>
<td>JP2</td>
<td></td>
<td>Enable JTAG functionality</td>
</tr>
<tr>
<td>JP2</td>
<td></td>
<td>Enable UART communication</td>
</tr>
</tbody>
</table>
**Allocation of ESP32 Pins** Some pins or terminals of ESP32 are allocated for use with the onboard or external hardware. If that hardware is not used, e.g., nothing is plugged into the Camera (JP4) header, then these GPIOs can be used for other purposes.

Some of the pins, such as GPIO0 or GPIO2, have multiple functions and some of them are shared among onboard and external peripheral devices. Certain combinations of peripherals cannot work together. For example, it is not possible to do JTAG debugging of an application that is using SD card, because several pins are shared by JTAG and the SD card slot.

In other cases, peripherals can coexist under certain conditions. This is applicable to, for example, LCD screen and SD card that share only a single pin GPIO21. This pin is used to provide D/C (Data/Control) signal for the LCD as well as the Card Detect signal read from the SD card slot. If the card detect functionality is not essential, then it may be disabled by removing R167, so both LCD and SD may operate together.

For more details on which pins are shared among which peripherals, please refer to the table in the next section.

**Main I/O Connector / JP1** The JP1 connector consists of 14x2 male pins whose functions are shown in the middle two “I/O” columns of the table below. The two “Shared With” columns on both sides describe where else on the board a certain GPIO is used.

<table>
<thead>
<tr>
<th>Shared With</th>
<th>I/O</th>
<th>I/O</th>
<th>Shared With</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td>3.3V</td>
<td>GND</td>
<td>n/a</td>
</tr>
<tr>
<td>NC/XTAL</td>
<td>IO32</td>
<td>IO33</td>
<td>NC/XTAL</td>
</tr>
<tr>
<td>JTAG, microSD</td>
<td>IO12</td>
<td>IO13</td>
<td>JTAG, microSD</td>
</tr>
<tr>
<td>Camera</td>
<td>IO26</td>
<td>IO25</td>
<td>Camera, LCD</td>
</tr>
<tr>
<td>Camera</td>
<td>IO35</td>
<td>IO34</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>IO39</td>
<td>IO36</td>
<td>Camera</td>
</tr>
<tr>
<td>JTAG</td>
<td>EN</td>
<td>IO23</td>
<td>Camera, LCD</td>
</tr>
<tr>
<td>Camera, LCD</td>
<td>IO22</td>
<td>IO21</td>
<td>Camera, LCD, microSD</td>
</tr>
<tr>
<td>Camera, LCD</td>
<td>IO19</td>
<td>IO18</td>
<td>Camera, LCD</td>
</tr>
<tr>
<td>Camera, LCD</td>
<td>IO5</td>
<td>IO17</td>
<td>PSRAM</td>
</tr>
<tr>
<td>PSRAM</td>
<td>IO16</td>
<td>IO4</td>
<td>LED, Camera, microSD</td>
</tr>
<tr>
<td>Camera, LED, Boot</td>
<td>IO0</td>
<td>IO2</td>
<td>LED, microSD</td>
</tr>
<tr>
<td>JTAG, microSD</td>
<td>IO15</td>
<td>5V</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- NC/XTAL - 32.768 kHz Oscillator
- JTAG - JTAG/JP2
- Boot - Boot button/SW2
- Camera - Camera/JP4
- LED - RGB LED
- microSD - microSD Card/J4
- LCD - LCD/UI5
- PSRAM - ESP32-WROVER-E’s PSRAM

**32.768 kHz Oscillator**

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GPIO32</td>
</tr>
<tr>
<td>2 GPIO33</td>
</tr>
</tbody>
</table>

**Note:** Since GPIO32 and GPIO33 are connected to the oscillator by default, they are not connected to the JP1 I/O connector to maintain signal integrity. This allocation may be changed from the oscillator to JP1 by desoldering the zero-ohm resistors from positions R11 or R23 and re-soldering them to positions R12 or R24.
### SPI Flash/JP2

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CLK/GPIO6</td>
<td>TRST_N</td>
</tr>
<tr>
<td>2 SD0/GPIO7</td>
<td>TMS</td>
</tr>
<tr>
<td>3 SD1/GPIO8</td>
<td>TDO</td>
</tr>
<tr>
<td>4 SD2/GPIO9</td>
<td>TDI</td>
</tr>
<tr>
<td>5 SD3/GPIO10</td>
<td>TCK</td>
</tr>
</tbody>
</table>

**Note:** SPI Flash pins are used to access the internal flash memory. Therefore, they are not available to connect external SPI devices. Those pins are exposed for monitoring or for advanced usage only.

### Important: The module’s flash bus is connected to the jumper block JP2 through zero-ohm resistors R140 ~ R145. If the flash memory needs to operate at the frequency of 80 MHz, for reasons such as improving the integrity of bus signals, you can desolder these resistors to disconnect the module’s flash bus from the pin header JP2.

### JTAG/JP2

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 EN</td>
<td>TRST_N</td>
</tr>
<tr>
<td>2 MTMS/GPIO14</td>
<td>TMS</td>
</tr>
<tr>
<td>3 MTDO/GPIO15</td>
<td>TDO</td>
</tr>
<tr>
<td>4 MTDI/GPIO12</td>
<td>TDI</td>
</tr>
<tr>
<td>5 MTCK/GPIO13</td>
<td>TCK</td>
</tr>
</tbody>
</table>

### Camera/JP4

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>Camera Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 n/a</td>
<td>3.3V</td>
</tr>
<tr>
<td>2 n/a</td>
<td>Ground</td>
</tr>
<tr>
<td>3 GPIO27</td>
<td>SIO_C/SCCB Clock</td>
</tr>
<tr>
<td>4 GPIO26</td>
<td>SIO_D/SCCB Data</td>
</tr>
<tr>
<td>5 GPIO25</td>
<td>VSYNC/Vertical Sync</td>
</tr>
<tr>
<td>6 GPIO23</td>
<td>HREF/Horizontal Reference</td>
</tr>
<tr>
<td>7 GPIO22</td>
<td>PCLK/Pixel Clock</td>
</tr>
<tr>
<td>8 GPIO21</td>
<td>XCLK/System Clock</td>
</tr>
<tr>
<td>9 GPIO35</td>
<td>D7/Pixel Data Bit 7</td>
</tr>
<tr>
<td>10 GPIO34</td>
<td>D6/Pixel Data Bit 6</td>
</tr>
<tr>
<td>11 GPIO39</td>
<td>D5/Pixel Data Bit 5</td>
</tr>
<tr>
<td>12 GPIO36</td>
<td>D4/Pixel Data Bit 4</td>
</tr>
<tr>
<td>13 GPIO19</td>
<td>D3/Pixel Data Bit 3</td>
</tr>
<tr>
<td>14 GPIO18</td>
<td>D2/Pixel Data Bit 2</td>
</tr>
<tr>
<td>15 GPIO5</td>
<td>D1/Pixel Data Bit 1</td>
</tr>
<tr>
<td>16 GPIO4</td>
<td>D0/Pixel Data Bit 0</td>
</tr>
<tr>
<td>17 GPIO0</td>
<td>RESET/Camera Reset</td>
</tr>
<tr>
<td>18 n/a</td>
<td>PWDN/Camera Power Down</td>
</tr>
</tbody>
</table>

- Signals D0 .. D7 denote camera data bus

### RGB LED

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>RGB LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 GPIO0</td>
<td>Red</td>
</tr>
<tr>
<td>2 GPIO2</td>
<td>Green</td>
</tr>
<tr>
<td>3 GPIO4</td>
<td>Blue</td>
</tr>
</tbody>
</table>
**microSD Card**

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>microSD Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDI/GPIO12</td>
<td>DATA2</td>
</tr>
<tr>
<td>MTCK/GPIO13</td>
<td>CD/DATA3</td>
</tr>
<tr>
<td>MTDO/GPIO15</td>
<td>CMD</td>
</tr>
<tr>
<td>MTMS/GPIO14</td>
<td>CLK</td>
</tr>
<tr>
<td>GPIO2</td>
<td>DATA0</td>
</tr>
<tr>
<td>GPIO4</td>
<td>DATA1</td>
</tr>
<tr>
<td>GPIO21</td>
<td>Card Detect</td>
</tr>
</tbody>
</table>

**LCD/U5**

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>LCD Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO18</td>
<td>RESET</td>
</tr>
<tr>
<td>GPIO19</td>
<td>SCL</td>
</tr>
<tr>
<td>GPIO21</td>
<td>D/C</td>
</tr>
<tr>
<td>GPIO22</td>
<td>CS</td>
</tr>
<tr>
<td>GPIO23</td>
<td>SDA</td>
</tr>
<tr>
<td>GPIO25</td>
<td>SDO</td>
</tr>
<tr>
<td>GPIO5</td>
<td>Backlight</td>
</tr>
</tbody>
</table>

**Start Application Development**  Before powering up your ESP-WROVER-KIT, please make sure that the board is in good condition with no obvious signs of damage.

**Initial Setup**  Please set only the following jumpers shown in the pictures below:

- Select USB as the power source using the jumper block JP7.
- Enable UART communication using the jumper block JP2.

Do not install any other jumpers.

Turn the **Power Switch** to ON, and the **5 V Power On LED** should light up.

**Now to Development**  Please proceed to *Get Started*, where Section *Installation* will quickly help you set up the development environment and then flash an example project onto your board.

A Board Support Package can be found in **IDF Component Registry**.
The application examples that use some hardware specific to your ESP-WROVER-KIT can be found below:

- On-board LCD example: peripherals/spi_master/lcd
- SD card slot example: storage/sd_card
- Camera connector example: https://github.com/espressif/esp32-camera

Related Documents

- ESP-WROVER-KIT V4.1 schematic (PDF)
- ESP-WROVER-KIT V4.1 layout (DXF) may be opened online with Autodesk Viewer
- ESP32 Datasheet (PDF)
- ESP32-WROVER-E Datasheet (PDF)
- JTAG Debugging
- Hardware Reference

ESP-WROVER-KIT V3 Getting Started Guide

This guide shows how to get started with the ESP-WROVER-KIT V3 development board and also provides information about its functionality and configuration options. For the description of other ESP-WROVER-KIT versions, please check Hardware Reference.

What You Need

- ESP-WROVER-KIT V3 board
- USB 2.0 cable (A to Micro-B)
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section Start Application Development.

Overview  
ESP-WROVER-KIT is an ESP32-based development board produced by Espressif. This board features an integrated LCD screen and microSD card slot.

ESP-WROVER-KIT comes with the following ESP32 modules:

- ESP32-WROOM-32
- ESP32-WROVER series

Its another distinguishing feature is the embedded FTDI FT2232HL chip - an advanced multi-interface USB bridge. This chip enables to use JTAG for direct debugging of ESP32 through the USB interface without a separate JTAG debugger. ESP-WROVER-KIT makes development convenient, easy, and cost-effective.

Most of the ESP32 I/O pins are broken out to the board’s pin headers for easy access.

Note: The version with the ESP32-WROVER module uses ESP32’s GPIO16 and GPIO17 as chip select and clock signals for PSRAM. By default, the two GPIOs are not broken out to the board’s pin headers in order to ensure reliable performance.

Functionality Overview  
The block diagram below shows the main components of ESP-WROVER-KIT and their interconnections.

Functional Description  
The following two figures and the table below describe the key components, interfaces, and controls of the ESP-WROVER-KIT board.

The table below provides description in the following manner:

- Starting from the first picture’s top right corner and going clockwise
- Then moving on to the second picture
Fig. 9: ESP-WROVER-KIT block diagram

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.768 kHz</td>
<td>External precision 32.768 kHz crystal oscillator serves as a clock with low-power consumption while the chip is in Deep-sleep mode.</td>
</tr>
<tr>
<td>0R</td>
<td>Zero-ohm resistor intended as a placeholder for a current shunt, can be desoldered or replaced with a current shunt to facilitate the measurement of ESP32’s current consumption in different modes.</td>
</tr>
<tr>
<td>ESP32 Module</td>
<td>Either ESP32-WROOM-32 or ESP32-WROVER with an integrated ESP32. The ESP32-WROVER module features all the functions of ESP32-WROOM-32 and integrates an external 32-MBit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>FT2232</td>
<td>The FT2232 chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232 also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232 chip enhances user-friendliness in terms of application development and debugging. See ESP-WROVER-KIT V3 schematic.</td>
</tr>
<tr>
<td>UART</td>
<td>Serial port. The serial TX/RX signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP11 respectively. By default, these pairs of pins are connected with jumpers. To use ESP32’s serial interface, remove the jumpers and connect another external serial device to the respective pins.</td>
</tr>
<tr>
<td>SPI</td>
<td>By default, ESP32 uses its SPI interface to access flash and PSRAM memory inside the module. Use these pins to connect ESP32 to another SPI device. In this case, an extra chip select (CS) signal is needed. Please note that the interface voltage for the version with ESP32-WROVER is 1.8V, while that for the version with ESP32-WROOM-32 is 3.3V.</td>
</tr>
<tr>
<td>CTS/RTS</td>
<td>Serial port flow control signals: the pins are not connected to the circuitry by default. To enable them, short the respective pins of JP14 with jumpers.</td>
</tr>
<tr>
<td>JTAG</td>
<td>JTAG interface. JTAG signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP8 respectively. By default, these pairs of pins are disconnected. To enable JTAG, short the respective pins with jumpers as shown in Section Setup Options.</td>
</tr>
<tr>
<td>EN</td>
<td>Reset button.</td>
</tr>
<tr>
<td>Boot</td>
<td>Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>USB</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>Power Key</td>
<td>Power On/Off Switch. Toggling toward USB powers the board on, toggling away from USB powers the board off.</td>
</tr>
<tr>
<td>Power Select</td>
<td>Power supply interface. Can be powered either via USB or via the 5V Input interface. Select the power source with a jumper. For more details, see Section Setup Options. jumper header JP7.</td>
</tr>
</tbody>
</table>
Fig. 10: ESP-WROVER-KIT board layout - front
Fig. 11: ESP-WROVER-KIT board layout - back
Setup Options  There are five jumper blocks available to set up the board functionality. The most frequently required options are listed in the table below.
<table>
<thead>
<tr>
<th>Header</th>
<th>Jumper Setting</th>
<th>Description of Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP7</td>
<td></td>
<td>Power ESP-WROVER-KIT via an external power supply</td>
</tr>
<tr>
<td>JP7</td>
<td></td>
<td>Power ESP-WROVER-KIT via USB</td>
</tr>
<tr>
<td>JP8</td>
<td></td>
<td>Enable JTAG functionality</td>
</tr>
<tr>
<td>JP11</td>
<td></td>
<td>Enable UART communication</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

Allocation of ESP32 Pins  Some pins / terminals of ESP32 are allocated for use with the onboard or external hardware. If that hardware is not used, e.g., nothing is plugged into the Camera (JP4) header, then these GPIOs can be used for other purposes.

Some of the pins, such as GPIO0 or GPIO2, have multiple functions and some of them are shared among onboard and external peripheral devices. Certain combinations of peripherals cannot work together. For example, it is not possible to do JTAG debugging of an application that is using SD card, because several pins are shared by JTAG and the SD card slot.

In other cases, peripherals can coexist under certain conditions. This is applicable to, for example, LCD screen and SD card that share only a single pin GPIO21. This pin is used to provide D/C (Data / Control) signal for the LCD as well as the CD (Card Detect) signal read from the SD card slot. If the card detect functionality is not essential, then it may be disabled by removing R167, so both LCD and SD may operate together.

For more details on which pins are shared among which peripherals, please refer to the table in the next section.

Main I/O Connector / JP1  The JP1 connector consists of 14x2 male pins whose functions are shown in the middle two “I/O” columns of the table below. The two “Shared With” columns on both sides describe where else on the board a certain GPIO is used.

<table>
<thead>
<tr>
<th>Shared With</th>
<th>I/O</th>
<th>I/O</th>
<th>Shared With</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td>3.3V</td>
<td>GND</td>
<td>n/a</td>
</tr>
<tr>
<td>NC/XTAL</td>
<td>IO32</td>
<td>IO33</td>
<td>NC/XTAL</td>
</tr>
<tr>
<td>JTAG, microSD</td>
<td>IO12</td>
<td>IO13</td>
<td>JTAG, microSD</td>
</tr>
<tr>
<td>JTAG, microSD</td>
<td>IO14</td>
<td>IO27</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>IO26</td>
<td>IO25</td>
<td>Camera, LCD</td>
</tr>
<tr>
<td>Camera</td>
<td>IO35</td>
<td>IO34</td>
<td>Camera</td>
</tr>
<tr>
<td>Camera</td>
<td>IO39</td>
<td>IO36</td>
<td>Camera</td>
</tr>
<tr>
<td>JTAG</td>
<td>EN</td>
<td>IO23</td>
<td>Camera, LCD</td>
</tr>
<tr>
<td>Camera, LCD</td>
<td>IO22</td>
<td>IO21</td>
<td>Camera, LCD, microSD</td>
</tr>
<tr>
<td>Camera, LCD</td>
<td>IO19</td>
<td>IO18</td>
<td>Camera, LCD</td>
</tr>
<tr>
<td>Camera, LCD</td>
<td>IO5</td>
<td>IO17</td>
<td>PSRAM</td>
</tr>
<tr>
<td>PSRAM</td>
<td>IO16</td>
<td>IO4</td>
<td>LED, Camera, microSD</td>
</tr>
<tr>
<td>Camera, LED, Boot</td>
<td>IO0</td>
<td>IO2</td>
<td>LED, microSD</td>
</tr>
<tr>
<td>JTAG, microSD</td>
<td>IO15</td>
<td>5V</td>
<td></td>
</tr>
</tbody>
</table>

Legend:

- NC/XTAL - 32.768 kHz Oscillator
- JTAG - JTAG / JP8
- Boot - Boot button / SW2
- Camera - Camera / JP4
- LED - RGB LED
- microSD - microSD Card / J4
- LCD - LCD / U5
- PSRAM - only in case ESP32-WROVER is installed

32.768 kHz Oscillator

<table>
<thead>
<tr>
<th>.</th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO32</td>
</tr>
<tr>
<td>2</td>
<td>GPIO33</td>
</tr>
</tbody>
</table>

Note:  Since GPIO32 and GPIO33 are connected to the oscillator by default, they are not connected to the JP1 I/O connector to maintain signal integrity. This allocation may be changed from the oscillator to JP1 by desoldering the zero-ohm resistors from positions R11 / R23 and re-soldering them to positions R12 / R24.
Chapter 1. Get Started

### SPI Flash / JP13

<table>
<thead>
<tr>
<th></th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CLK / GPIO6</td>
</tr>
<tr>
<td>2</td>
<td>SD0 / GPIO7</td>
</tr>
<tr>
<td>3</td>
<td>SD1 / GPIO8</td>
</tr>
<tr>
<td>4</td>
<td>SD2 / GPIO9</td>
</tr>
<tr>
<td>5</td>
<td>SD3 / GPIO10</td>
</tr>
<tr>
<td>6</td>
<td>CMD / GPIO11</td>
</tr>
</tbody>
</table>

**Important:** The module’s flash bus is connected to the jumper block JP13 through zero-ohm resistors R140 ~ R145. If the flash memory needs to operate at the frequency of 80 MHz, for reasons such as improving the integrity of bus signals, you can desolder these resistors to disconnect the module’s flash bus from the pin header JP13.

### JTAG / JP8

<table>
<thead>
<tr>
<th></th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EN</td>
</tr>
<tr>
<td>2</td>
<td>TRST_N</td>
</tr>
<tr>
<td>3</td>
<td>MTMS / GPIO14</td>
</tr>
<tr>
<td>4</td>
<td>TMS</td>
</tr>
<tr>
<td>5</td>
<td>MTDO / GPIO15</td>
</tr>
<tr>
<td>6</td>
<td>TDO</td>
</tr>
<tr>
<td>7</td>
<td>MTDI / GPIO12</td>
</tr>
<tr>
<td>8</td>
<td>TDI</td>
</tr>
<tr>
<td>9</td>
<td>MTCK / GPIO13</td>
</tr>
<tr>
<td>10</td>
<td>TCK</td>
</tr>
</tbody>
</table>

### Camera / JP4

<table>
<thead>
<tr>
<th></th>
<th>Camera Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.3V</td>
</tr>
<tr>
<td>2</td>
<td>Ground</td>
</tr>
<tr>
<td>3</td>
<td>GPIO27 / SIO_C / SCCB Clock</td>
</tr>
<tr>
<td>4</td>
<td>GPIO26 / SIO_D / SCCB Data</td>
</tr>
<tr>
<td>5</td>
<td>GPIO25 / VSYNC / Vertical Sync</td>
</tr>
<tr>
<td>6</td>
<td>GPIO23 / HREF / Horizontal Reference</td>
</tr>
<tr>
<td>7</td>
<td>GPIO22 / PCLK / Pixel Clock</td>
</tr>
<tr>
<td>8</td>
<td>GPIO21 / XCLK / System Clock</td>
</tr>
<tr>
<td>9</td>
<td>GPIO35 / D7 / Pixel Data Bit 7</td>
</tr>
<tr>
<td>10</td>
<td>GPIO34 / D6 / Pixel Data Bit 6</td>
</tr>
<tr>
<td>11</td>
<td>GPIO39 / D5 / Pixel Data Bit 5</td>
</tr>
<tr>
<td>12</td>
<td>GPIO36 / D4 / Pixel Data Bit 4</td>
</tr>
<tr>
<td>13</td>
<td>GPIO19 / D3 / Pixel Data Bit 3</td>
</tr>
<tr>
<td>14</td>
<td>GPIO18 / D2 / Pixel Data Bit 2</td>
</tr>
<tr>
<td>15</td>
<td>GPIO5 / D1 / Pixel Data Bit 1</td>
</tr>
<tr>
<td>16</td>
<td>GPIO4 / D0 / Pixel Data Bit 0</td>
</tr>
<tr>
<td>17</td>
<td>GPIO0 / RESET / Camera Reset</td>
</tr>
<tr>
<td>18</td>
<td>PWDN / Camera Power Down</td>
</tr>
</tbody>
</table>

- Signals D0 .. D7 denote camera data bus

### RGB LED

<table>
<thead>
<tr>
<th></th>
<th>RGB LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO0 / Red</td>
</tr>
<tr>
<td>2</td>
<td>GPIO2 / Green</td>
</tr>
<tr>
<td>3</td>
<td>GPIO4 / Blue</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

microSD Card

<table>
<thead>
<tr>
<th></th>
<th>ESP32 Pin</th>
<th>microSD Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MTDI / GPIO12</td>
<td>DATA2</td>
</tr>
<tr>
<td>2</td>
<td>MTCK / GPIO13</td>
<td>CD / DATA3</td>
</tr>
<tr>
<td>3</td>
<td>MTDO / GPIO15</td>
<td>CMD</td>
</tr>
<tr>
<td>4</td>
<td>MTMS / GPIO14</td>
<td>CLK</td>
</tr>
<tr>
<td>5</td>
<td>GPIO2</td>
<td>DATA0</td>
</tr>
<tr>
<td>6</td>
<td>GPIO4</td>
<td>DATA1</td>
</tr>
<tr>
<td>7</td>
<td>GPIO21</td>
<td>CD</td>
</tr>
</tbody>
</table>

LCD / U5

<table>
<thead>
<tr>
<th></th>
<th>ESP32 Pin</th>
<th>LCD Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO18</td>
<td>RESET</td>
</tr>
<tr>
<td>2</td>
<td>GPIO19</td>
<td>SCL</td>
</tr>
<tr>
<td>3</td>
<td>GPIO21</td>
<td>D/C</td>
</tr>
<tr>
<td>4</td>
<td>GPIO22</td>
<td>CS</td>
</tr>
<tr>
<td>5</td>
<td>GPIO23</td>
<td>SDA</td>
</tr>
<tr>
<td>6</td>
<td>GPIO25</td>
<td>SDO</td>
</tr>
<tr>
<td>7</td>
<td>GPIO5</td>
<td>Backlight</td>
</tr>
</tbody>
</table>

**Start Application Development** Before powering up your ESP-WROVER-KIT, please make sure that the board is in good condition with no obvious signs of damage.

**Initial Setup** Please set only the following jumpers shown in the pictures below:

- Select USB as the power source using the jumper block JP7.
- Enable UART communication using the jumper block JP11.

Do not install any other jumpers.

Turn the **Power Switch** to ON, the **5V Power On LED** should light up.

**Now to Development** Please proceed to **Get Started**, where Section **Installation** will quickly help you set up the development environment and then flash an example project onto your board.
Related Documents

- ESP-WROVER-KIT V3 schematic (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROVER Datasheet (PDF)
- ESP32-WROOM-32 Datasheet (PDF)
- JTAG Debugging
- Hardware Reference

ESP-WROVER-KIT V2 Getting Started Guide

This guide shows how to get started with the ESP-WROVER-KIT V2 development board and also provides information about its functionality and configuration options. For the description of other ESP-WROVER-KIT versions, please check Hardware Reference.

What You Need

- ESP-WROVER-KIT V2 board
- USB 2.0 cable (A to Micro-B)
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section Start Application Development.

Overview

ESP-WROVER-KIT is an ESP32-based development board produced by Espressif. This board features an integrated LCD screen and microSD card slot.

ESP-WROVER-KIT comes with the following ESP32 modules:

- ESP32-WROOM-32
- ESP32-WROVER series

It is another distinguishing feature is the embedded FTDI FT2232HL chip - an advanced multi-interface USB bridge. This chip enables to use JTAG for direct debugging of ESP32 through the USB interface without a separate JTAG debugger. ESP-WROVER-KIT makes development convenient, easy, and cost-effective.

Most of the ESP32 I/O pins are broken out to the board’s pin headers for easy access.

Note: The version with the ESP32-WROVER module uses ESP32’s GPIO16 and GPIO17 as chip select and clock signals for PSRAM. By default, the two GPIOs are not broken out to the board’s pin headers in order to ensure reliable performance.

Functionality Overview

The block diagram below shows the main components of ESP-WROVER-KIT and their interconnections.

Functional Description

The following two figures and the table below describe the key components, interfaces, and controls of the ESP-WROVER-KIT board.

The table below provides description in the following manner:

- Starting from the first picture’s top right corner and going clockwise
- Then moving on to the second picture
Fig. 12: ESP-WROVER-KIT block diagram

Fig. 13: ESP-WROVER-KIT board layout - front
Fig. 14: ESP-WROVER-KIT board layout - back
<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32.768 kHz</td>
<td>External precision 32.768 kHz crystal oscillator serves as a clock with low-power consumption while the chip is in Deep-sleep mode.</td>
</tr>
<tr>
<td>ESP32 Module</td>
<td>Either ESP32-WROOM-32 or ESP32-WROVER with an integrated ESP32. The ESP32-WROVER module features all the functions of ESP32-WROOM-32 and integrates an external 32-MBit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>CTS/RTS</td>
<td>Serial port flow control signals: the pins are not connected to the circuitry by default. To enable them, short the respective pins of JP14 with jumpers.</td>
</tr>
<tr>
<td>UART</td>
<td>Serial port. The serial TX/RX signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP11 respectively. By default, these pairs of pins are connected with jumpers. To use ESP32’s serial interface, remove the jumpers and connect another external serial device to the respective pins.</td>
</tr>
<tr>
<td>SPI</td>
<td>By default, ESP32 uses its SPI interface to access flash and PSRAM memory inside the module. Use these pins to connect ESP32 to another SPI device. In this case, an extra chip select (CS) signal is needed. Please note that the interface voltage for the version with ESP32-WROVER is 1.8V, while that for the version with ESP32-WROOM-32 is 3.3V.</td>
</tr>
<tr>
<td>JTAG</td>
<td>JTAG interface. JTAG signals of FT2232 and ESP32 are broken out to the inward and outward sides of JP8 respectively. By default, these pairs of pins are disconnected. To enable JTAG, short the respective pins with jumpers as shown in Section Setup Options.</td>
</tr>
<tr>
<td>FT2232</td>
<td>The FT2232 chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232 features USB-to-UART and USB-to-JTAG functionalities.</td>
</tr>
<tr>
<td>EN</td>
<td>Reset button.</td>
</tr>
<tr>
<td>Boot</td>
<td>Download button. Holding down <strong>Boot</strong> and then pressing <strong>EN</strong> initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>USB</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>Power Select</td>
<td>Power supply selector interface. The board can be powered either via USB or via the 5 V Input interface. Select the power source with a jumper. For more details, see Section <strong>Setup Options</strong>, jumper header JP7.</td>
</tr>
<tr>
<td>Power Key</td>
<td>Power On/Off Switch. Toggling toward <strong>USB</strong> powers the board on, toggling away from <strong>USB</strong> powers the board off.</td>
</tr>
<tr>
<td>5V Input</td>
<td>The 5 V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).</td>
</tr>
<tr>
<td>LDO</td>
<td>NCP1117(1 A): 5V-to-3.3V LDO. NCP1117 can provide a maximum current of 1 A. The LDO on the board has a fixed output voltage. Although, the user can install an LDO with adjustable output voltage. For details, please refer to ESP-WROVER-KIT V2 schematic.</td>
</tr>
<tr>
<td>Camera</td>
<td>Camera interface, a standard OV7670 camera module.</td>
</tr>
<tr>
<td>RGB</td>
<td>Red, green and blue (RGB) light emitting diodes (LEDs), can be controlled by pulse width modulation (PWM).</td>
</tr>
<tr>
<td>I/O</td>
<td>All the pins on the ESP32 module are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc.</td>
</tr>
<tr>
<td>microSD Card</td>
<td>microSD card slot for data storage: when ESP32 enters the download mode, GPIO2 cannot be held high. However, a pull-up resistor is required on GPIO2 to enable the microSD Card. By default, GPIO2 and the pull-up resistor R153 are disconnected. To enable the SD Card, use jumpers on JP1 as shown in Section <strong>Setup Options.</strong></td>
</tr>
<tr>
<td>LCD</td>
<td>Support for mounting and interfacing a 3.2” SPI (standard 4-wire Serial Peripheral Interface) LCD, as shown on figure ESP-WROVER-KIT board layout - back.</td>
</tr>
</tbody>
</table>

**Setup Options**  There are five jumper blocks available to set up the board functionality. The most frequently required options are listed in the table below.
<table>
<thead>
<tr>
<th>Header</th>
<th>Jumper Setting</th>
<th>Description of Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP1</td>
<td></td>
<td>Enable pull up for the microSD Card</td>
</tr>
<tr>
<td>JP1</td>
<td></td>
<td>Assert GPIO2 low during each download (by jumping it to GPIO0)</td>
</tr>
<tr>
<td>JP7</td>
<td></td>
<td>Power ESP-WROVER-KIT via an external power supply</td>
</tr>
<tr>
<td>JP7</td>
<td></td>
<td>Power ESP-WROVER-KIT via USB</td>
</tr>
</tbody>
</table>

---

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Espressif Systems 30

Release v5.1.2
Chapter 1. Get Started

**Start Application Development**  Before powering up your ESP-WROVER-KIT, please make sure that the board is in good condition with no obvious signs of damage.

**Initial Setup**  Please set only the following jumpers shown in the pictures below:

- Select USB as the power source using the jumper block JP7.
- Enable UART communication using the jumper block JP11.

Do not install any other jumpers.

Turn the **Power Switch** to ON, the **5V Power On LED** should light up.

**Now to Development**  Please proceed to *Get Started*, where Section *Installation* will quickly help you set up the development environment and then flash an example project onto your board.

**Related Documents**

- ESP-WROVER-KIT V2 schematic (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROVER Datasheet (PDF)
- ESP32-WROOM-32 Datasheet (PDF)
- JTAG Debugging
- Hardware Reference

**ESP32-PICO-KIT V4 / V4.1 Getting Started Guide**

This guide shows how to get started with the ESP32-PICO-KIT V4/V4.1 mini development board. For the description of other ESP32-PICO-KIT versions, please check *Hardware Reference*.

This particular description covers ESP32-PICO-KIT V4 and V4.1. The difference is the upgraded USB-UART bridge from CP2102 in V4 with up to 1 Mbps transfer rates to CP2102N in V4.1 with up to 3 Mbps transfer rates.

**What You Need**

- ESP32-PICO-KIT mini development board
- USB 2.0 A to Micro B cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section *Start Application Development*. 
Overview

ESP32-PICO-KIT is an ESP32-based mini development board produced by Espressif. The core of this board is ESP32-PICO-D4 - a System-in-Package (SiP) module with complete Wi-Fi and Bluetooth functionalities. Compared to other ESP32 modules, ESP32-PICO-D4 integrates the following peripheral components in one single package, which otherwise would need to be installed separately:

- 40 MHz crystal oscillator
- 4 MB flash
- Filter capacitors
- RF matching links

This setup reduces the costs of additional external components as well as the cost of assembly and testing and also increases the overall usability of the product.

The development board features a USB-UART Bridge circuit which allows developers to connect the board to a computer’s USB port for flashing and debugging.

All the IO signals and system power on ESP32-PICO-D4 are led out to two rows of 20 x 0.1” header pads on both sides of the development board for easy access. For compatibility with Dupont wires, 2 x 17 header pads are populated with two rows of male pin headers. The remaining 2 x 3 header pads beside the antenna are not populated. These pads may be populated later by the user if required.

Note:

1. There are two versions of ESP32-PICO-KIT boards, respectively with male headers and female headers. In this guide, the male header version is taken as an example.
2. The 2 x 3 pads not populated with pin headers are connected to the flash memory embedded in the ESP32-PICO-D4 SiP module. For more details, see module’s datasheet in Related Documents.

Functionality Overview

The block diagram below shows the main components of ESP32-PICO-KIT and their interconnections.

![Fig. 15: ESP32-PICO-KIT block diagram](image)

---

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**Functional Description**  The following figure and the table below describe the key components, interfaces, and controls of the ESP32-PICO-KIT board.

![ESP32-PICO-KIT board layout](image-url)

**Fig. 16:** ESP32-PICO-KIT board layout (with female headers)

Below is the description of the items identified in the figure starting from the top left corner and going clockwise.

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-PICO-D4</td>
<td>Standard ESP32-PICO-D4 module soldered to the ESP32-PICO-KIT board. The complete ESP32 system on a chip (ESP32 SoC) has been integrated into the SiP module, requiring only an external antenna with LC matching network, decoupling capacitors, and a pull-up resistor for EN signals to function properly.</td>
</tr>
<tr>
<td>LDO</td>
<td>5V-to-3.3V Low dropout voltage regulator (LDO).</td>
</tr>
<tr>
<td>USB-UART bridge</td>
<td>Single-chip USB-UART bridge: CP2102 in V4 provides up to 1 Mbps transfer rates and CP2102N in V4.1 offers up to 3 Mbps transfer rates.</td>
</tr>
<tr>
<td>Micro USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board. For details, see the schematics in Related Documents.</td>
</tr>
<tr>
<td>I/O</td>
<td>All the pins on ESP32-PICO-D4 are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc. For details, please see Section Pin Descriptions.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
</tbody>
</table>

**Power Supply Options**  There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V / GND header pins
- 3V3 / GND header pins

**Warning:** The power supply must be provided using one and only one of the options above, otherwise the board and/or the power supply source can be damaged.
Pin Descriptions  The two tables below provide the **Name** and **Function** of I/O header pins on both sides of the board, see *ESP32-PICO-KIT board layout (with female headers)*. The pin numbering and header names are the same as in the schematic given in *Related Documents*.
### Header J2

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FLASH_SD1 (FSD1)</td>
<td>I/O</td>
<td>GPIO8, SD_DATA1, SPID, HS1_DATA1 (See 1), U2CTS</td>
</tr>
<tr>
<td>2</td>
<td>FLASH_SD3 (FSD3)</td>
<td>I/O</td>
<td>GPIO7, SD_DATA0, SPIQ, HS1_DATA0 (See 1), U2RTS</td>
</tr>
<tr>
<td>3</td>
<td>FLASH_CLK (FCLK)</td>
<td>I/O</td>
<td>GPIO6, SD_CLK, SPICLK, HS1_CLK (See 1), U1CTS</td>
</tr>
<tr>
<td>4</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21, VSPIHD, EMAC_TX_EN</td>
</tr>
<tr>
<td>5</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22, VSPIWP, U0RTS, EMAC_TXD1</td>
</tr>
<tr>
<td>6</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19, VSPIQ, U0CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>7</td>
<td>IO23</td>
<td>I/O</td>
<td>GPIO23, VSPID, HS1_STROBE</td>
</tr>
<tr>
<td>8</td>
<td>IO18</td>
<td>I/O</td>
<td>GPIO18, VSPICLK, HS1_DATA7</td>
</tr>
<tr>
<td>9</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK</td>
</tr>
<tr>
<td>10</td>
<td>IO10</td>
<td>I/O</td>
<td>GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD</td>
</tr>
<tr>
<td>11</td>
<td>IO9</td>
<td>I/O</td>
<td>GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD</td>
</tr>
<tr>
<td>12</td>
<td>RXD0</td>
<td>I/O</td>
<td>GPIO3, U0RXD (See 3), CLK_OUT2</td>
</tr>
<tr>
<td>13</td>
<td>TXD0</td>
<td>I/O</td>
<td></td>
</tr>
</tbody>
</table>
### Header J3

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FLASH_CS (FCS)</td>
<td>I/O</td>
<td>GPIO16, HS1_DATA4, U2RXD, EMAC_CLK_OUT</td>
</tr>
<tr>
<td>2</td>
<td>FLASH_SD0 (FSD0)</td>
<td>I/O</td>
<td>GPIO17, HS1_DATA5, U2TXD, EMAC_CLK_OUT_180</td>
</tr>
<tr>
<td>3</td>
<td>FLASH_SD2 (FSD2)</td>
<td>I/O</td>
<td>GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS</td>
</tr>
<tr>
<td>4</td>
<td>SENSOR_VP (FSVP)</td>
<td>I</td>
<td>GPIO36, ADC1_CH0, RTC_GPIO0</td>
</tr>
<tr>
<td>5</td>
<td>SENSOR VN (FSVN)</td>
<td>I</td>
<td>GPIO39, ADC1_CH3, RTC_GPIO3</td>
</tr>
<tr>
<td>6</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0</td>
</tr>
<tr>
<td>7</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1</td>
</tr>
<tr>
<td>8</td>
<td>IO32</td>
<td>I/O</td>
<td>32K_XP, ADC1_CH4, TOUCH9, RTC_GPIO9</td>
</tr>
<tr>
<td>9</td>
<td>IO33</td>
<td>I/O</td>
<td>32K_XN, ADC1_CH5, TOUCH8, RTC_GPIO8</td>
</tr>
<tr>
<td>10</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV</td>
</tr>
<tr>
<td>11</td>
<td>IO14</td>
<td>I/O</td>
<td>ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK</td>
</tr>
<tr>
<td>12</td>
<td>IO12</td>
<td>I/O</td>
<td>ADC2_CH5, TOUCH8, RTC_GPIO8</td>
</tr>
<tr>
<td>13</td>
<td>IO13</td>
<td>I/O</td>
<td>ADC2_CH4, TOUCH9, RTC_GPIO9</td>
</tr>
<tr>
<td>14</td>
<td>IO15</td>
<td>I/O</td>
<td>ADC2_CH3, TOUCH3, RTC_GPIO13</td>
</tr>
<tr>
<td>15</td>
<td>IO2</td>
<td>I/O</td>
<td>ADC2_CH2, TOUCH2, RTC_GPIO12</td>
</tr>
<tr>
<td>16</td>
<td>IO4</td>
<td>I/O</td>
<td>ADC2_CH0, TOUCH0, RTC_GPIO10</td>
</tr>
<tr>
<td>17</td>
<td>IO0</td>
<td>I/O</td>
<td>CLK_OUT1, EMAC_TX_CLK</td>
</tr>
<tr>
<td>18</td>
<td>VDD33 (3V3)</td>
<td></td>
<td>3.3V power supply</td>
</tr>
<tr>
<td>19</td>
<td>GND</td>
<td></td>
<td>Ground</td>
</tr>
<tr>
<td>20</td>
<td>EXT_5V (5V)</td>
<td></td>
<td>5V power supply</td>
</tr>
</tbody>
</table>

**Notes:**
1. (See 1)
2a. 32K_XP
2b. 32K_XN
Note:

1. This pin is connected to the flash pin of ESP32-PICO-D4.
2. 32.768 kHz crystal oscillator: a) input, b) output.
3. This pin is connected to the pin of the USB bridge chip on the board.
4. The operating voltage of ESP32-PICO-KIT’s embedded SPI flash is 3.3 V. Therefore, the strapping pin MTDI should hold bit zero during the module power-on reset. If connected, please make sure that this pin is not held up on reset.

---

Pin Layout

**Start Application Development**  Before powering up your ESP32-PICO-KIT, please make sure that the board is in good condition with no obvious signs of damage.

After that, proceed to **Get Started**, where Section **Installation** will quickly help you set up the development environment and then flash an example project onto your board.

**Board Dimensions**  The dimensions are 52 x 20.3 x 10 mm (2.1” x 0.8” x 0.4”).

---

For the board physical construction details, please refer to its Reference Design listed below.
Chapter 1. Get Started

Fig. 19: ESP32-PICO-KIT dimensions - side (with male headers)

Related Documents
- ESP32-PICO-KIT V4 schematic (PDF)
- ESP32-PICO-KIT V4.1 schematic (PDF)
- ESP32-PICO-KIT Reference Design containing OrCAD schematic, PCB layout, gerbers and BOM
- ESP32-PICO-D4 Datasheet (PDF)
- Hardware Reference

ESP32-PICO-KIT V3 Getting Started Guide
This guide shows how to get started with the ESP32-PICO-KIT V3 mini development board. For the description of other ESP32-PICO-KIT versions, please check Hardware Reference.

What You Need
- ESP32-PICO-KIT V3 mini development board
- USB 2.0 A to Micro B cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section Start Application Development.

Overview
ESP32-PICO-KIT V3 is an ESP32-based mini development board produced by Espressif. The core of this board is ESP32-PICO-D4 - a System-in-Package (SiP) module.

The development board features a USB-UART Bridge circuit, which allows developers to connect the board to a computer’s USB port for flashing and debugging.

All the IO signals and system power on ESP32-PICO-D4 are led out to two rows of 20 x 0.1” header pads on both sides of the development board for easy access.

Functional Description
The following figure and the table below describe the key components, interfaces, and controls of the ESP32-PICO-KIT V3 board.

Below is the description of the items identified in the figure starting from the top left corner and going clockwise.
Fig. 20: ESP32-PICO-KIT V3 board layout
### Key Component | Description
---|---
**ESP32-PICO-D4** | Standard ESP32-PICO-D4 module soldered to the ESP32-PICO-KIT V3 board. The complete ESP32 system on a chip (ESP32 SoC) has been integrated into the SiP module, requiring only an external antenna with LC matching network, decoupling capacitors, and a pull-up resistor for EN signals to function properly.
**LDO** | 5V-to-3.3V Low dropout voltage regulator (LDO).
**USB-UART bridge** | Single-chip USB-UART bridge provides up to 1 Mbps transfers rates.
**Micro USB Port** | USB interface. Power supply for the board as well as the communication interface between a computer and the board.
**Power On LED** | This red LED turns on when power is supplied to the board.
**I/O** | All the pins on ESP32-PICO-D4 are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc.
**BOOT Button** | Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.
**EN Button** | Reset button.

**Start Application Development**  Before powering up your ESP32-PICO-KIT V3, please make sure that the board is in good condition with no obvious signs of damage.

After that, proceed to Get Started, where Section Installation will quickly help you set up the development environment and then flash an example project onto your board.

**Related Documents**
- [ESP32-PICO-KIT V3 schematic (PDF)](#)
- [ESP32-PICO-D4 Datasheet (PDF)](#)
- [Hardware Reference](#)

**ESP32-Ethernet-Kit V1.2 Getting Started Guide**

This guide shows how to get started with the ESP32-Ethernet-Kit development board and also provides information about its functionality and configuration options.

The *ESP32-Ethernet-Kit* is an Ethernet-to-Wi-Fi development board that enables Ethernet devices to be interconnected over Wi-Fi. At the same time, to provide more flexible power supply options, the ESP32-Ethernet-Kit also supports power over Ethernet (PoE).

**What You Need**
- [ESP32-Ethernet-Kit V1.2 board](#)
- USB 2.0 A to Micro B Cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section Start Application Development.

**Overview**  ESP32-Ethernet-Kit is an ESP32-based development board produced by *Espressif*.

It consists of two development boards, the Ethernet board A and the PoE board B. The *Ethernet board (A)* contains Bluetooth/Wi-Fi dual-mode ESP32-WROVER-E module and IP101GRI, a Single Port 10/100 Fast Ethernet Transceiver (PHY). The *PoE board (B)* provides power over Ethernet functionality. The A board can work independently, without the board B installed.

For the application loading and monitoring, the Ethernet board (A) also features FTDI FT2232H chip - an advanced multi-interface USB bridge. This chip enables to use JTAG for direct debugging of ESP32 through the USB interface without a separate JTAG debugger.
Fig. 21: ESP32-Ethernet-Kit V1.2 Overview (click to enlarge)
Fig. 22: ESP32-Ethernet-Kit V1.2 (click to enlarge)
**Functionality Overview**  
The block diagram below shows the main components of ESP32-Ethernet-Kit and their interconnections.

**Functional Description**  
The following figures and tables describe the key components, interfaces, and controls of the ESP32-Ethernet-Kit.

**Ethernet Board (A)**  
The table below provides description starting from the picture’s top right corner and going clockwise.
### Table 1: Table 1 Component Description

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROVER-E</td>
<td>This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>GPIO Header 2</td>
<td>Five unpopulated through-hole solder pads to provide access to selected GPIOs of ESP32. For details, see <a href="#">GPIO Header 2</a>.</td>
</tr>
<tr>
<td>Function Switch</td>
<td>A 4-bit DIP switch used to configure the functionality of selected GPIOs of ESP32. For details see <a href="#">Function Switch</a>.</td>
</tr>
<tr>
<td>Tx/Rx LEDs</td>
<td>Two LEDs to show the status of UART transmission.</td>
</tr>
<tr>
<td>FT2232H</td>
<td>The FT2232H chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232H also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232H chip enhances user-friendliness in terms of application development and debugging. See <a href="#">ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic</a>.</td>
</tr>
<tr>
<td>USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>Power Switch</td>
<td>Power On/Off Switch. Toggling the switch to <strong>5V0</strong> position powers the board on, toggling to <strong>GND</strong> position powers the board off.</td>
</tr>
<tr>
<td>5V Input</td>
<td>The 5 V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board, either from USB or 5 V Input.</td>
</tr>
<tr>
<td>DC/DC Converter</td>
<td>Provided DC 5 V to 3.3 V conversion, output current up to 2 A.</td>
</tr>
<tr>
<td>Board B Connectors</td>
<td>A pair male and female header pins for mounting the PoE board (B)</td>
</tr>
<tr>
<td>IP101GRI (PHY)</td>
<td>The physical layer (PHY) connection to the Ethernet cable is implemented using the IP101GRI chip. The connection between PHY and ESP32 is done through the reduced media-independent interface (RMII), a variant of the media-independent interface (MII) standard. The PHY supports the IEEE 802.3/802.3u standard of 10/100 Mbps.</td>
</tr>
<tr>
<td>RJ45 Port</td>
<td>Ethernet network data transmission port.</td>
</tr>
<tr>
<td>Magnetics Module</td>
<td>The Magnetics are part of the Ethernet specification to protect against faults and transients, including rejection of common mode signals between the transceiver IC and the cable.</td>
</tr>
<tr>
<td>Espressif Systems</td>
<td>The magnetics also provide galvanic isolation between the transceiver and the Ethernet device.</td>
</tr>
<tr>
<td>Link/Activity LEDs</td>
<td>Two LEDs (green and red) that respectively indicate the “Link” and “Activity” statuses of the PHY.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down <strong>BOOT</strong> and then pressing <strong>EN</strong> initiates Firmware Download.</td>
</tr>
</tbody>
</table>

---

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Chapter 1. Get Started

**Note:** Automatic firmware download is supported. If following steps and using software described in Section Start Application Development, users don’t need to do any operation with BOOT button or EN button.

**PoE Board (B)** This board converts power delivered over the Ethernet cable (PoE) to provide a power supply for the Ethernet board (A). The main components of the PoE board (B) are shown on the block diagram under Functionality Overview.

The PoE board (B) has the following features:
- Support for IEEE 802.3at
- Power output: 5 V, 1.4 A

To take advantage of the PoE functionality the **RJ45 Port** of the Ethernet board (A) should be connected with an Ethernet cable to a switch that supports PoE. When the Ethernet board (A) detects 5 V power output from the PoE board (B), the USB power will be automatically cut off.

![PoE Board Diagram](image)

Fig. 25: ESP32-Ethernet-Kit - PoE board (B) layout (click to enlarge)

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board A Connector</td>
<td>Four female (left) and four male (right) header pins for connecting the PoE board (B) to Ethernet board (A). The pins on the left accept power coming from a PoE switch. The pins on the right deliver 5 V power supply to the Ethernet board (A).</td>
</tr>
<tr>
<td>External Power Terminals</td>
<td>Optional power supply (26.6 ~ 54 V) to the PoE board (B).</td>
</tr>
</tbody>
</table>

**Setup Options** This section describes options to configure the ESP32-Ethernet-Kit hardware.

**Function Switch** When in On position, this DIP switch is routing listed GPIOs to FT2232H to provide JTAG functionality. When in Off position, the GPIOs may be used for other purposes.

<table>
<thead>
<tr>
<th>DIP SW</th>
<th>GPIO Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO13</td>
</tr>
<tr>
<td>2</td>
<td>GPIO12</td>
</tr>
<tr>
<td>3</td>
<td>GPIO15</td>
</tr>
<tr>
<td>4</td>
<td>GPIO14</td>
</tr>
</tbody>
</table>

**RMII Clock Selection** The ethernet MAC and PHY under RMII working mode need a common 50 MHz reference clock (i.e. RMII clock) that can be provided either externally, or generated from internal ESP32 APLL (not recommended).
**Chapter 1. Get Started**

**Note:** For additional information on the RMII clock selection, please refer to ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic, sheet 2, location D2.

**RMII Clock Sourced Externally by PHY** By default, the ESP32-Ethernet-Kit is configured to provide RMII clock for the IP101GRI PHY’s 50M_CLKO output. The clock signal is generated by the frequency multiplication of 25 MHz crystal connected to the PHY. For details, please see the figure below.

![Fig. 26: RMII Clock from IP101GRI PHY](image)

Please note that the PHY is reset on power up by pulling the RESET_N signal down with a resistor. ESP32 should assert RESET_N high with GPIO5 to enable PHY. Only this can ensure the power-up of system. Otherwise ESP32 may enter download mode (when the clock signal of REF_CLK_50M is at a high logic level during the GPIO0 power-upsampling phase).

**RMII Clock Sourced Internally from ESP32’s APLL** Another option is to source the RMII Clock from internal ESP32 APLL, see figure below. The clock signal coming from GPIO0 is first inverted, to account for transmission line delay, and then supplied to the PHY.

To implement this option, users need to remove or add some RC components on the board. For details please refer to ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic, sheet 2, location D2. Please note that if the APLL is already used for other purposes (e.g. I2S peripheral), then you have no choice but use an external RMII clock.
Chapter 1. Get Started

Fig. 27: RMI Clock from ESP Internal APLL

---

Espressif Systems

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**GPIO Allocation** This section describes allocation of ESP32 GPIOs to specific interfaces or functions of the ESP32-Ethernet-Kit.

**IP101GRI (PHY) Interface** The allocation of the ESP32 (MAC) pins to IP101GRI (PHY) is shown in the table below. Implementation of ESP32-Ethernet-Kit defaults to Reduced Media-Independent Interface (RMII).

<table>
<thead>
<tr>
<th>No.</th>
<th>ESP32 Pin (MAC)</th>
<th>IP101GRI (PHY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO21</td>
<td>TX_EN</td>
</tr>
<tr>
<td>2</td>
<td>GPIO19</td>
<td>TXD[0]</td>
</tr>
<tr>
<td>3</td>
<td>GPIO22</td>
<td>TXD[1]</td>
</tr>
<tr>
<td>4</td>
<td>GPIO25</td>
<td>RXD[0]</td>
</tr>
<tr>
<td>5</td>
<td>GPIO26</td>
<td>RXD[1]</td>
</tr>
<tr>
<td>6</td>
<td>GPIO27</td>
<td>CRS_DV</td>
</tr>
<tr>
<td>7</td>
<td>GPIO0</td>
<td>REF_CLK</td>
</tr>
</tbody>
</table>

*RMII Interface*

<table>
<thead>
<tr>
<th>No.</th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>GPIO23</td>
</tr>
<tr>
<td>9</td>
<td>GPIO18</td>
</tr>
</tbody>
</table>

*Serial Management Interface*

<table>
<thead>
<tr>
<th>No.</th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>GPIO5</td>
</tr>
</tbody>
</table>

*PHY Reset*

<table>
<thead>
<tr>
<th>No.</th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>GPIO17</td>
</tr>
<tr>
<td>12</td>
<td>GPIO16</td>
</tr>
<tr>
<td>13</td>
<td>GPIO4</td>
</tr>
<tr>
<td>14</td>
<td>GPIO2</td>
</tr>
<tr>
<td>15</td>
<td>GPIO13</td>
</tr>
<tr>
<td>16</td>
<td>GPIO12</td>
</tr>
<tr>
<td>17</td>
<td>GPIO15</td>
</tr>
<tr>
<td>18</td>
<td>GPIO14</td>
</tr>
<tr>
<td>19</td>
<td>GND</td>
</tr>
<tr>
<td>20</td>
<td>3V3</td>
</tr>
</tbody>
</table>

**Note:** The allocation of all pins under the ESP32’s RMII Interface is fixed and cannot be changed either through IO MUX or GPIO Matrix. REF_CLK can only be selected from GPIO0, GPIO16 or GPIO17 and it can not be changed through GPIO Matrix.

**GPIO Header 1** This header exposes some GPIOs that are not used elsewhere on the ESP32-Ethernet-Kit.

<table>
<thead>
<tr>
<th>No.</th>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO32</td>
</tr>
<tr>
<td>2</td>
<td>GPIO33</td>
</tr>
<tr>
<td>3</td>
<td>GPIO34</td>
</tr>
<tr>
<td>4</td>
<td>GPIO35</td>
</tr>
<tr>
<td>5</td>
<td>GPIO36</td>
</tr>
<tr>
<td>6</td>
<td>GPIO39</td>
</tr>
</tbody>
</table>

**GPIO Header 2** This header contains GPIOs that may be used for other purposes depending on scenarios described in column “Comments”.

<table>
<thead>
<tr>
<th>No.</th>
<th>ESP32 Pin</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO17</td>
<td>See note 1</td>
</tr>
<tr>
<td>2</td>
<td>GPIO16</td>
<td>See note 1</td>
</tr>
<tr>
<td>3</td>
<td>GPIO4</td>
<td>See note 1</td>
</tr>
<tr>
<td>4</td>
<td>GPIO2</td>
<td>See note 2</td>
</tr>
<tr>
<td>5</td>
<td>GPIO13</td>
<td>See note 2</td>
</tr>
<tr>
<td>6</td>
<td>GPIO12</td>
<td>See note 2</td>
</tr>
<tr>
<td>7</td>
<td>GPIO15</td>
<td>See note 2</td>
</tr>
<tr>
<td>8</td>
<td>GPIO14</td>
<td>See note 2</td>
</tr>
<tr>
<td>9</td>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>10</td>
<td>3V3</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>

**Note:**
1. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROVER-E module and therefore not available for use. If you need to use these pins, please solder a module without PSRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.

2. Functionality depends on the settings of the Function Switch.

---

**GPIO Allocation Summary**

<table>
<thead>
<tr>
<th>ESP32-WROVER-E</th>
<th>IP101GRI</th>
<th>UART</th>
<th>JTAG</th>
<th>GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_VP</td>
<td></td>
<td></td>
<td></td>
<td>IO36</td>
<td></td>
</tr>
<tr>
<td>S_VN</td>
<td></td>
<td></td>
<td></td>
<td>IO39</td>
<td></td>
</tr>
<tr>
<td>IO34</td>
<td></td>
<td></td>
<td></td>
<td>IO34</td>
<td></td>
</tr>
<tr>
<td>IO35</td>
<td></td>
<td></td>
<td></td>
<td>IO35</td>
<td></td>
</tr>
<tr>
<td>IO32</td>
<td></td>
<td></td>
<td></td>
<td>IO32</td>
<td></td>
</tr>
<tr>
<td>IO33</td>
<td></td>
<td></td>
<td></td>
<td>IO33</td>
<td></td>
</tr>
<tr>
<td>IO25</td>
<td>RXD[0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO26</td>
<td>RXD[1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO27</td>
<td>CRS_DV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO14</td>
<td></td>
<td>TMS</td>
<td></td>
<td>IO14</td>
<td></td>
</tr>
<tr>
<td>IO12</td>
<td></td>
<td>TDI</td>
<td></td>
<td>IO12</td>
<td></td>
</tr>
<tr>
<td>IO13</td>
<td></td>
<td>TCK</td>
<td></td>
<td>IO13</td>
<td></td>
</tr>
<tr>
<td>IO15</td>
<td></td>
<td>TDO</td>
<td></td>
<td>IO15</td>
<td></td>
</tr>
<tr>
<td>IO2</td>
<td></td>
<td></td>
<td></td>
<td>IO2</td>
<td></td>
</tr>
<tr>
<td>IO0</td>
<td></td>
<td>REF_CLK</td>
<td></td>
<td></td>
<td>See note 1</td>
</tr>
<tr>
<td>IO4</td>
<td></td>
<td></td>
<td></td>
<td>IO4</td>
<td></td>
</tr>
<tr>
<td>IO16</td>
<td></td>
<td></td>
<td></td>
<td>IO16 (NC)</td>
<td>See note 2</td>
</tr>
<tr>
<td>IO17</td>
<td></td>
<td></td>
<td></td>
<td>IO17 (NC)</td>
<td>See note 2</td>
</tr>
<tr>
<td>IO5</td>
<td></td>
<td>Reset_N</td>
<td></td>
<td></td>
<td>See note 1</td>
</tr>
<tr>
<td>IO18</td>
<td></td>
<td>MDIO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO19</td>
<td></td>
<td>TXD[0]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO21</td>
<td></td>
<td>TX_EN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXD0</td>
<td></td>
<td>RXD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXD0</td>
<td></td>
<td>TXD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO22</td>
<td></td>
<td>TXD[1]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO23</td>
<td></td>
<td>MDC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**

1. To prevent the power-on state of the GPIO0 from being affected by the clock output on the PHY side, the RESET_N signal to PHY defaults to low, turning the clock output off. After power-on you can control RESET_N with GPIO5 to turn the clock output on. See also *RMII Clock Sourced Externally by PHY*. For PHYs that cannot turn off the clock output through RESET_N, it is recommended to use a crystal module that can be disabled/enabled externally. Similarly like when using RESET_N, the oscillator module should be disabled by default and turned on by ESP32 after power-up. For a reference design please see ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic.

2. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROVER-E module and therefore not available for use. If you need to use these pins, please solder a module without PSRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.

---

**Start Application Development** Before powering up your ESP32-Ethernet-Kit, please make sure that the board is in good condition with no obvious signs of damage.

**Initial Setup**
Chapter 1. Get Started

1. Set the **Function Switch** on the *Ethernet board (A)* to its default position by turning all the switches to **ON**.
2. To simplify flashing and testing of the application, do not input extra signals to the board headers.
3. The *PoE board (B)* can now be plugged in, but do not connect external power to it.
4. Connect the *Ethernet board (A)* to the PC with a USB cable.
5. Turn the **Power Switch** from GND to 5V0 position, the **5V Power On LED** should light up.

**Now to Development**  Proceed to *Get Started*, where Section *Installation* will quickly help you set up the development environment and then flash an example project onto your board.

Move on to the next section only if you have successfully completed all the above steps.

**Configure and Load the Ethernet Example**  After setting up the development environment and testing the board, you can configure and flash the *ethernet/basic* example. This example has been created for testing Ethernet functionality. It supports different PHY, including **IP101GRI** installed on *ESP32-Ethernet-Kit V1.2* ([click to enlarge]).

**Summary of Changes from ESP32-Ethernet-Kit V1.1**

- Correct the placement of GPIO pin number marking on the board’s silkscreen besides the DIP switch.
- Values of C1, C2, C42, and C43 are updated to 20 pF. For more information, please check *ESP32-Ethernet-Kit V1.2 Ethernet board (A) schematic*.
- Replace ESP32-WROVER-B with ESP32-WROVER-E.

**Other Versions of ESP32-Ethernet-Kit**

- *ESP32-Ethernet-Kit V1.0 Getting Started Guide*
- *ESP32-Ethernet-Kit V1.1 Getting Started Guide*

**Related Documents**

- *ESP32-Ethernet-Kit V1.2 Ethernet Board (A) Schematic* (PDF)
- *ESP32-Ethernet-Kit PoE Board (B) Schematic* (PDF)
- *ESP32-Ethernet-Kit V1.2 Ethernet Board (A) PCB Layout* (PDF)
- *ESP32-Ethernet-Kit PoE Board (B) PCB Layout* (PDF)
- *ESP32 Datasheet* (PDF)
- *ESP32-WROVER-E Datasheet* (PDF)
- *JTAG Debugging*
- *Hardware Reference*

For other design documentation for the board, please contact us at sales@espressif.com.

**ESP32-Ethernet-Kit V1.0 Getting Started Guide**

This guide shows how to get started with the ESP32-Ethernet-Kit development board and also provides information about its functionality and configuration options.

The *ESP32-Ethernet-Kit* is an Ethernet-to-Wi-Fi development board that enables Ethernet devices to be interconnected over Wi-Fi. At the same time, to provide more flexible power supply options, the ESP32-Ethernet-Kit also supports power over Ethernet (PoE).

**What You Need**

- *ESP32-Ethernet-Kit V1.0 board*
- USB 2.0 A to Micro B Cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section *Start Application Development*. 
Overview  ESP32-Ethernet-Kit is an ESP32-based development board produced by Espressif. It consists of two development boards, the Ethernet board A and the PoE board B. The Ethernet board (A) contains Bluetooth / Wi-Fi dual-mode ESP32-WROVER-B module and IP101GRI, a Single Port 10/100 Fast Ethernet Transceiver (PHY). The PoE board (B) provides power over Ethernet functionality. The A board can work independently, without the board B installed.

For the application loading and monitoring the Ethernet board (A) also features FTDI FT2232H chip - an advanced multi-interface USB bridge. This chip enables to use JTAG for direct debugging of ESP32 through the USB interface without a separate JTAG debugger.

Functionality Overview  The block diagram below shows the main components of ESP32-Ethernet-Kit and their interconnections.

Functional Description  The following two figures and tables describe the key components, interfaces, and controls of the ESP32-Ethernet-Kit.

Ethernet Board (A)  The table below provides description starting from the picture’s top right corner and going clockwise.
Fig. 29: ESP32-Ethernet-Kit block diagram (click to enlarge)

Fig. 30: ESP32-Ethernet-Kit - Ethernet board (A) layout (click to enlarge)
### Key Component Description

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROVER-B</td>
<td>This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>GPIO Header 2</td>
<td>Five unpopulated through-hole solder pads to provide access to selected GPIOs of ESP32. For details, see GPIO Header 2.</td>
</tr>
<tr>
<td>Flow Control</td>
<td>A jumper header with access to the board signals. For details, see Flow Control.</td>
</tr>
<tr>
<td>Function Switch</td>
<td>A DIP switch used to configure the functionality of selected GPIOs of ESP32. For details, see Function Switch.</td>
</tr>
<tr>
<td>Tx/Rx LEDs</td>
<td>Two LEDs to show the status of UART transmission.</td>
</tr>
<tr>
<td>GPIO Header 3</td>
<td>Provides access to some GPIOs of ESP32 that can be used depending on the position of the Function Switch.</td>
</tr>
<tr>
<td>FT2232</td>
<td>The FT2232H chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232H also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232H chip enhances user-friendliness in terms of application development and debugging. See ESP32-Ethernet-Kit V1.0 Ethernet board (A) schematic.</td>
</tr>
<tr>
<td>USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>Power Switch</td>
<td>Power On/Off Switch. Toggling toward the Boot button powers the board on, toggling away from Boot powers the board off.</td>
</tr>
<tr>
<td>5V Input</td>
<td>The 5V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).</td>
</tr>
<tr>
<td>5V Power ON LED</td>
<td>This red LED turns on when power is supplied to the board, either from USB or 5V Input.</td>
</tr>
<tr>
<td>DC/DC Converter</td>
<td>Provided DC 5 V to 3.3 V conversion, output current up to 2A.</td>
</tr>
<tr>
<td>Board B Connectors</td>
<td>A pair male header pins for mounting the PoE board (B).</td>
</tr>
<tr>
<td>IP101GRI (PHY)</td>
<td>The physical layer (PHY) connection to the Ethernet cable is implemented using the IP101GRI chip. The connection between PHY and ESP32 is done through the reduced media-independent interface (RMII), a variant of the media-independent interface (MII) standard. The PHY supports the IEEE 802.3 / 802.3u standard of 10/100Mbps.</td>
</tr>
<tr>
<td>RJ45 Port</td>
<td>Ethernet network data transmission port.</td>
</tr>
<tr>
<td>Magnetics Module</td>
<td>The Magnetics are part of the Ethernet specification to protect against faults and transients, including rejection of common mode signals between the transceiver IC and the cable. The magnetics also provide galvanic isolation between the transceiver and the Ethernet device.</td>
</tr>
<tr>
<td>Link/Activity LEDs</td>
<td>Green and red LEDs (green and red) that respectively indicate the “Link” and “Activity” statuses of the PHY.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down BOOT and then pressing CH_PU initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>CH_PU Button</td>
<td>Reset button.</td>
</tr>
</tbody>
</table>
Chapter 1. Get Started

**PoE Board (B)** This board converts power delivered over the Ethernet cable (PoE) to provide a power supply for the Ethernet board (A). The main components of the PoE board (B) are shown on the block diagram under *Functionality Overview.*

The PoE board (B) has the following features:

- Support for IEEE 802.3at
- Power output: 5 V, 1.4 A

To take advantage of the PoE functionality the **RJ45 Port** of the Ethernet board (A) should be connected with an Ethernet cable to a switch that supports PoE. When the Ethernet board (A) detects 5 V power output from the PoE board (B), the USB power will be automatically cut off.

![Fig. 31: ESP32-Ethernet-Kit - PoE board (B) layout (click to enlarge)](image)

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board A Connector</td>
<td>Four female header pins for mounting this board onto Ethernet board (A).</td>
</tr>
<tr>
<td>External Power Terminals</td>
<td>Optional power supply to the PoE board (B).</td>
</tr>
</tbody>
</table>

**Setup Options** This section describes options to configure the ESP32-Ethernet-Kit hardware.

**Function Switch** The functions for specific GPIO pins can be selected with the **Function Switch**.

<table>
<thead>
<tr>
<th>DIP SW</th>
<th>GPIO Pin</th>
<th>Pin Functionality if DIP SW is ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO14</td>
<td>Connected to FT2232H to provide JTAG functionality</td>
</tr>
<tr>
<td>2</td>
<td>GPIO12</td>
<td>Connected to FT2232H to provide JTAG functionality</td>
</tr>
<tr>
<td>3</td>
<td>GPIO13</td>
<td>Connected to FT2232H to provide JTAG functionality</td>
</tr>
<tr>
<td>4</td>
<td>GPIO15</td>
<td>Connected to FT2232H to provide JTAG functionality</td>
</tr>
<tr>
<td>5</td>
<td>GPIO4</td>
<td>Connected to FT2232H to provide JTAG functionality</td>
</tr>
<tr>
<td>6</td>
<td>GPIO2</td>
<td>Connected to on-board 25 MHz oscillator</td>
</tr>
<tr>
<td>7</td>
<td>GPIO5</td>
<td>Connected to RESET_N input of IP101GRI</td>
</tr>
<tr>
<td>8</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

You can make a certain GPIO pin available for other purposes by putting its DIP SW to the Off position.

**Flow Control** This is a 2 x 2 jumper pin header intended for the UART flow control.

<table>
<thead>
<tr>
<th>Signal</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MTDO GPIO13, see also <strong>Function Switch</strong></td>
</tr>
<tr>
<td>2</td>
<td>MTCK GPIO15, see also <strong>Function Switch</strong></td>
</tr>
<tr>
<td>3</td>
<td>RTS RTS signal of FT2232H</td>
</tr>
<tr>
<td>4</td>
<td>CTS CTS signal of FT2232H</td>
</tr>
</tbody>
</table>

**GPIO Allocation** This section describes allocation of ESP32 GPIOs to specific interfaces or functions of the ESP32-Ethernet-Kit.
IP101GRI (PHY) Interface  The allocation of the ESP32 (MAC) pins to IP101GRI (PHY) is shown in the table below. Implementation of ESP32-Ethernet-Kit defaults to Reduced Media-Independent Interface (RMII).

<table>
<thead>
<tr>
<th>RMII Interface</th>
<th>ESP32 Pin (MAC)</th>
<th>IP101GRI (PHY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO21</td>
<td>TX_EN</td>
</tr>
<tr>
<td>2</td>
<td>GPIO19</td>
<td>TXD[0]</td>
</tr>
<tr>
<td>3</td>
<td>GPIO22</td>
<td>TXD[1]</td>
</tr>
<tr>
<td>4</td>
<td>GPIO25</td>
<td>RXD[0]</td>
</tr>
<tr>
<td>5</td>
<td>GPIO26</td>
<td>RXD[1]</td>
</tr>
<tr>
<td>6</td>
<td>GPIO27</td>
<td>CRS_DV</td>
</tr>
<tr>
<td>7</td>
<td>GPIO0</td>
<td>REF_CLK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Serial Management Interface</th>
<th>ESP32 Pin</th>
<th>MII Function</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>GPIO23</td>
<td>MDC</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>GPIO18</td>
<td>MDIO</td>
<td></td>
</tr>
<tr>
<td>PHY Reset</td>
<td>GPIO5</td>
<td>Reset_N</td>
<td></td>
</tr>
</tbody>
</table>

Note: Except for REF_CLK, the allocation of all pins under the RMII Interface is fixed and cannot be changed either through IOMUX or GPIO Matrix.

GPIO Header 1  This header exposes some GPIOs that are not used elsewhere on the ESP32-Ethernet-Kit.

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

GPIO Header 2  This header contains the GPIOs with specific MII functionality (except GPIO2), as opposed to Reduced Media-Independent Interface (RMII) functionality implemented on ESP32-Ethernet-Kit board by default, see IP101GRI (PHY) Interface. Depending on the situation, if MMI is used, specific Ethernet applications might require this functionality.

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>MII Function</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EMAC_CLK_180</td>
<td>See note 1</td>
</tr>
<tr>
<td>2</td>
<td>EMAC_CLK_OUT</td>
<td>See note 1</td>
</tr>
<tr>
<td>3</td>
<td>EMAC_TX_ER</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>n/a</td>
<td>See note 2</td>
</tr>
<tr>
<td>5</td>
<td>EMAC_RX_CLK</td>
<td>See note 2</td>
</tr>
</tbody>
</table>

Note:

1. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROVER-B module and therefore not available for use. If you need to use these pins, please solder a module without SPIRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.
2. Functionality depends on the settings of the Function Switch.
GPIO Header 3  The functionality of GPIOs connected to this header depends on the settings of the **Function Switch**.

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>GPIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO15</td>
</tr>
<tr>
<td>2</td>
<td>GPIO13</td>
</tr>
<tr>
<td>3</td>
<td>GPIO12</td>
</tr>
<tr>
<td>4</td>
<td>GPIO14</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
</tr>
<tr>
<td>6</td>
<td>3V3</td>
</tr>
</tbody>
</table>

### GPIO Allocation Summary

<table>
<thead>
<tr>
<th>ESP32-WROVER-B</th>
<th>IP101GRI</th>
<th>UART</th>
<th>JTAG</th>
<th>GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_VP</td>
<td>IO36</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S_VN</td>
<td>IO39</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO34</td>
<td>IO34</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO35</td>
<td>IO35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO32</td>
<td>IO32</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO33</td>
<td>IO33</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO25</td>
<td>RXD[0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO26</td>
<td>RXD[1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO27</td>
<td>CRS_DV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO14</td>
<td>TMS</td>
<td>IO14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO12</td>
<td>TDI</td>
<td>IO12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO13</td>
<td>RTS</td>
<td>TCK</td>
<td>IO13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO15</td>
<td>CTS</td>
<td>TDO</td>
<td>IO15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO2</td>
<td>IO2</td>
<td></td>
<td></td>
<td></td>
<td>See notes 1 and 3 below</td>
</tr>
<tr>
<td>IO0</td>
<td>REF_CLK</td>
<td></td>
<td></td>
<td></td>
<td>See notes 2 and 3 below</td>
</tr>
<tr>
<td>IO4</td>
<td>nTRST</td>
<td>IO4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO16</td>
<td>IO16 (NC)</td>
<td></td>
<td></td>
<td></td>
<td>See note 4 below</td>
</tr>
<tr>
<td>IO17</td>
<td>IO17 (NC)</td>
<td></td>
<td></td>
<td></td>
<td>See note 4 below</td>
</tr>
<tr>
<td>IO5</td>
<td>Reset_N</td>
<td>IO5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO18</td>
<td>MDIO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO19</td>
<td>TXD[0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO21</td>
<td>TX_EN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXD0</td>
<td>RXD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXD0</td>
<td>TXD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO22</td>
<td>TXD[1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO23</td>
<td>MDC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:**

1. GPIO2 is used to enable external oscillator of the PHY.
2. GPIO0 is a source of 50 MHz reference clock for the PHY. The clock signal is first inverted, to account for transmission line delay, and then supplied to the PHY.
3. To prevent affecting the power-on state of GPIO0 by the clock output on the PHY side, the PHY external oscillator is enabled using GPIO2 after ESP32 is powered up.
4. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROVER-B module and therefore not available for use. If you need to use these pins, please solder a module without SPIRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.

**Start Application Development**  Before powering up your ESP32-Ethernet-Kit, please make sure that the board is in good condition with no obvious signs of damage.

Espressif Systems 58  Release v5.1.2

Submit Document Feedback
Chapter 1. Get Started

Initial Setup

1. Set the **Function Switch** on the *Ethernet board (A)* to its default position by turning all the switches to **ON**.
2. To simplify flashing and testing the application, do not install any jumpers and do not connect any signals to the board headers.
3. The *PoE board (B)* can now be plugged in, but do not connect external power to it.
4. Connect the *Ethernet board (A)* to the PC with a USB cable.
5. Turn the **Power Switch** from GND to 5V0 position, the **5V Power On LED** should light up.

Now to Development  Proceed to *Get Started*, where Section *Installation* will quickly help you set up the development environment and then flash an example project onto your board.

To use the older GNU Make compilation system, please refer to *Installation* section.

Move on to the next section only if you have successfully completed all the above steps.

Configure and Load the Ethernet Example  After setting up the development environment and testing the board, you can configure and flash the *ethernet/basic* example. This example has been created for testing Ethernet functionality. It supports different PHY, including **IP101GRI** installed on *ESP32-Ethernet-Kit V1.0 board*.

Related Documents

- ESP32-Ethernet-Kit V1.0 Ethernet board (A) schematic (PDF)
- ESP32-Ethernet-Kit V1.0 PoE board (B) schematic (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROVER-B Datasheet (PDF)
- JTAG Debugging
- Hardware Reference

For other design documentation for the board, please contact us at sales@espressif.com.

ESP32-Ethernet-Kit V1.1 Getting Started Guide

This guide shows how to get started with the ESP32-Ethernet-Kit development board and also provides information about its functionality and configuration options.

The **ESP32-Ethernet-Kit** is an Ethernet-to-Wi-Fi development board that enables Ethernet devices to be interconnected over Wi-Fi. At the same time, to provide more flexible power supply options, the ESP32-Ethernet-Kit also supports power over Ethernet (PoE).

What You Need

- **ESP32-Ethernet-Kit V1.1 board**
- USB 2.0 A to Micro B Cable
- Computer running Windows, Linux, or macOS

You can skip the introduction sections and go directly to Section *Start Application Development*.

Overview  ESP32-Ethernet-Kit is an ESP32-based development board produced by *Espressif*.

It consists of two development boards, the Ethernet board A and the PoE board B. The *Ethernet board (A)* contains Bluetooth / Wi-Fi dual-mode ESP32-WROVER-B module and IP101GRI, a Single Port 10/100 Fast Ethernet Transceiver (PHY). The *PoE board (B)* provides power over Ethernet functionality. The A board can work independently, without the board B installed.

For the application loading and monitoring, the Ethernet board (A) also features FTDI FT2232H chip - an advanced multi-interface USB bridge. This chip enables to use JTAG for direct debugging of ESP32 through the USB interface without a separate JTAG debugger.
Fig. 32: ESP32-Ethernet-Kit V1.1
**Functionality Overview**  
The block diagram below shows the main components of ESP32-Ethernet-Kit and their interconnections.

![ESP32-Ethernet-Kit block diagram](image)

Fig. 33: ESP32-Ethernet-Kit block diagram (click to enlarge)

**Functional Description**  
The following figures and tables describe the key components, interfaces, and controls of the ESP32-Ethernet-Kit.

**Ethernet Board (A)**  
The table below provides description starting from the picture’s top right corner and going clockwise.

---

---
### Table 3: Table 1 Component Description

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-WROVER-B</td>
<td>This ESP32 module features 64-Mbit PSRAM for flexible extended storage and data processing capabilities.</td>
</tr>
<tr>
<td>GPIO Header 2</td>
<td>Five unpopulated through-hole solder pads to provide access to selected GPIOs of ESP32. For details, see GPIO Header 2.</td>
</tr>
<tr>
<td>Function Switch</td>
<td>A 4-bit DIP switch used to configure the functionality of selected GPIOs of ESP32. Please note that placement of GPIO pin number marking on the board’s silkscreen besides the DIP switch is incorrect. For details and correct pin allocation see Function Switch.</td>
</tr>
<tr>
<td>Tx/Rx LEDs</td>
<td>Two LEDs to show the status of UART transmission.</td>
</tr>
<tr>
<td>FT2232H</td>
<td>The FT2232H chip serves as a multi-protocol USB-to-serial bridge which can be programmed and controlled via USB to provide communication with ESP32. FT2232H also features USB-to-JTAG interface which is available on channel A of the chip, while USB-to-serial is on channel B. The FT2232H chip enhances user-friendliness in terms of application development and debugging. See ESP32-Ethernet-Kit V1.1 Ethernet board (A) schematic.</td>
</tr>
<tr>
<td>USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>Power Switch</td>
<td>Power On/Off Switch. Toggling the switch to 5V0 position powers the board on, toggling to GND position powers the board off.</td>
</tr>
<tr>
<td>5V Input</td>
<td>The 5 V power supply interface can be more convenient when the board is operating autonomously (not connected to a computer).</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board, either from USB or 5 V Input.</td>
</tr>
<tr>
<td>DC/DC Converter</td>
<td>Provided DC 5 V to 3.3 V conversion, output current up to 2 A.</td>
</tr>
<tr>
<td>Board B Connectors</td>
<td>A pair male and female header pins for mounting the PoE board (B).</td>
</tr>
<tr>
<td>IP101GRI (PHY)</td>
<td>The physical layer (PHY) connection to the Ethernet cable is implemented using the IP101GRI chip. The connection between PHY and ESP32 is done through the reduced media-independent interface (RMII), a variant of the media-independent interface (MII) standard. The PHY supports the IEEE 802.3 / 802.3u standard of 10/100 Mbps.</td>
</tr>
<tr>
<td>RJ45 Port</td>
<td>Ethernet network data transmission port.</td>
</tr>
<tr>
<td>Magnetics Module</td>
<td>The Magnetics are part of the Ethernet specification to protect against faults and transients, including rejection of common mode signals between the transceiver IC and the cable. The magnetics also provide galvanic isolation between the transceiver and the Ethernet device.</td>
</tr>
</tbody>
</table>
**PoE Board (B)** This board converts power delivered over the Ethernet cable (PoE) to provide a power supply for the Ethernet board (A). The main components of the PoE board (B) are shown on the block diagram under *Functionality Overview*.

The PoE board (B) has the following features:

- Support for IEEE 802.3at
- Power output: 5 V, 1.4 A

To take advantage of the PoE functionality the **RJ45 Port** of the Ethernet board (A) should be connected with an Ethernet cable to a switch that supports PoE. When the Ethernet board (A) detects 5 V power output from the PoE board (B), the USB power will be automatically cut off.

![Fig. 35: ESP32-Ethernet-Kit - PoE board (B) layout (click to enlarge)](image)

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Board A Connector</td>
<td>Four female (left) and four male (right) header pins for connecting the PoE board (B) to Ethernet board (A). The pins on the left accept power coming from a PoE switch. The pins on the right deliver 5 V power supply to the Ethernet board (A).</td>
</tr>
<tr>
<td>External Power Terminals</td>
<td>Optional power supply (26.6 ~ 54 V) to the PoE board (B).</td>
</tr>
</tbody>
</table>

**Setup Options** This section describes options to configure the ESP32-Ethernet-Kit hardware.

**Function Switch** When in On position, this DIP switch is routing listed GPIOs to FT2232H to provide JTAG functionality. When in Off position, the GPIOs may be used for other purposes.

<table>
<thead>
<tr>
<th>DIP SW</th>
<th>GPIO Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO13</td>
</tr>
<tr>
<td>2</td>
<td>GPIO12</td>
</tr>
<tr>
<td>3</td>
<td>GPIO15</td>
</tr>
<tr>
<td>4</td>
<td>GPIO14</td>
</tr>
</tbody>
</table>

**Note:** Placement of GPIO pin number marking on the board’s silkscreen besides the DIP switch is incorrect. Please use instead the pin order as in the table above.

**RMII Clock Selection** The ethernet MAC and PHY under RMII working mode need a common 50 MHz reference clock (i.e. RMII clock) that can be provided either externally, or generated from internal ESP32 APPL.

**Note:** For additional information on the RMII clock selection, please refer to *ESP32-Ethernet-Kit V1.1 Ethernet board (A) schematic*, sheet 2, location D2.
RMII Clock Sourced Externally by PHY  By default, the ESP32-Ethernet-Kit is configured to provide RMII clock for the IP101GRIPHY’s 50M_CLKO output. The clock signal is generated by the frequency multiplication of 25 MHz crystal connected to the PHY. For details, please see the figure below.

Please note that the PHY is reset on power up by pulling the RESET_N signal down with a resistor. ESP32 should assert RESET_N high with GPIO5 to enable PHY. Only this can ensure the power-up of system. Otherwise ESP32 may enter download mode (when the clock signal of REF_CLK_50M is at a high logic level during the GPIO0 power-upsampling phase).

RMII Clock Sourced Internally from ESP32’s APLL  Another option is to source the RMII Clock from internal ESP32 APLL, see figure below. The clock signal coming from GPIO0 is first inverted, to account for transmission line delay, and then supplied to the PHY.

To implement this option, users need to remove or add some RC components on the board. For details please refer to ESP32-Ethernet-Kit V1.1 Ethernet board (A) schematic, sheet 2, location D2. Please note that if the APLL is already used for other purposes (e.g. I2S peripheral), then you have no choice but use an external RMII clock.

GPIO Allocation  This section describes allocation of ESP32 GPIOs to specific interfaces or functions of the ESP32-Ethernet-Kit.
Fig. 37: RMI Clock from ESP Internal APLL
**IP101GRI (PHY) Interface**  The allocation of the ESP32 (MAC) pins to IP101GRI (PHY) is shown in the table below. Implementation of ESP32-Ethernet-Kit defaults to Reduced Media-Independent Interface (RMII).

<table>
<thead>
<tr>
<th>RMII Interface</th>
<th>ESP32 Pin (MAC)</th>
<th>IP101GRI (PHY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPIO21</td>
<td>TX_EN</td>
</tr>
<tr>
<td>2</td>
<td>GPIO19</td>
<td>TXD[0]</td>
</tr>
<tr>
<td>3</td>
<td>GPIO22</td>
<td>TXD[1]</td>
</tr>
<tr>
<td>4</td>
<td>GPIO25</td>
<td>RXD[0]</td>
</tr>
<tr>
<td>5</td>
<td>GPIO26</td>
<td>RXD[1]</td>
</tr>
<tr>
<td>6</td>
<td>GPIO27</td>
<td>CRS_DV</td>
</tr>
<tr>
<td>7</td>
<td>GPIO0</td>
<td>REF_CLK</td>
</tr>
</tbody>
</table>

**Serial Management Interface**

<table>
<thead>
<tr>
<th></th>
<th>ESP32 Pin</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>GPIO23</td>
<td>MDC</td>
</tr>
<tr>
<td>9</td>
<td>GPIO18</td>
<td>MDIO</td>
</tr>
</tbody>
</table>

**PHY Reset**

<table>
<thead>
<tr>
<th></th>
<th>ESP32 Pin</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>GPIO5</td>
<td>Reset_N</td>
</tr>
</tbody>
</table>

**Note:** Except for REF_CLK, the allocation of all pins under the ESP32’s RMII Interface is fixed and cannot be changed either through IOMUX or GPIO Matrix.

**GPIO Header 1**  This header exposes some GPIOs that are not used elsewhere on the ESP32-Ethernet-Kit.

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO32</td>
</tr>
<tr>
<td>GPIO33</td>
</tr>
<tr>
<td>GPIO34</td>
</tr>
<tr>
<td>GPIO35</td>
</tr>
<tr>
<td>GPIO36</td>
</tr>
<tr>
<td>GPIO39</td>
</tr>
</tbody>
</table>

**GPIO Header 2**  This header contains GPIOs that may be used for other purposes depending on scenarios described in column “Comments”.

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO17</td>
<td>See note 1</td>
</tr>
<tr>
<td>GPIO16</td>
<td>See note 1</td>
</tr>
<tr>
<td>GPIO4</td>
<td></td>
</tr>
<tr>
<td>GPIO2</td>
<td></td>
</tr>
<tr>
<td>GPIO13</td>
<td>See note 2</td>
</tr>
<tr>
<td>GPIO12</td>
<td>See note 2</td>
</tr>
<tr>
<td>GPIO15</td>
<td>See note 2</td>
</tr>
<tr>
<td>GPIO14</td>
<td>See note 2</td>
</tr>
<tr>
<td>GND</td>
<td>Ground</td>
</tr>
<tr>
<td>3V3</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>

**Note:**

1. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROOM-32D module and therefore not available for use. If you need to use these pins, please solder a module without PSRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.
2. Functionality depends on the settings of the *Function Switch*.
## GPIO Allocation Summary

<table>
<thead>
<tr>
<th>ESP32-WROVER-B</th>
<th>IP101GRI</th>
<th>UART</th>
<th>JTAG</th>
<th>GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>S_VP</td>
<td></td>
<td></td>
<td></td>
<td>IO36</td>
<td></td>
</tr>
<tr>
<td>S_VN</td>
<td></td>
<td></td>
<td></td>
<td>IO39</td>
<td></td>
</tr>
<tr>
<td>IO34</td>
<td></td>
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<td></td>
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<td>IO35</td>
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<td>IO32</td>
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<td>IO33</td>
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<td>IO33</td>
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<td>IO25</td>
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<td>IO26</td>
<td>RXD[1]</td>
<td></td>
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</tr>
<tr>
<td>IO27</td>
<td>CRS_DV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO14</td>
<td></td>
<td>TMS</td>
<td></td>
<td>IO14</td>
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<td>TDI</td>
<td></td>
<td>IO12</td>
<td></td>
</tr>
<tr>
<td>IO13</td>
<td>RTS</td>
<td>TCK</td>
<td></td>
<td>IO13</td>
<td></td>
</tr>
<tr>
<td>IO15</td>
<td>CTS</td>
<td>TDO</td>
<td></td>
<td>IO15</td>
<td></td>
</tr>
<tr>
<td>IO2</td>
<td></td>
<td></td>
<td></td>
<td>IO2</td>
<td></td>
</tr>
<tr>
<td>IO0</td>
<td>REF_CLK</td>
<td></td>
<td></td>
<td></td>
<td>See note 1</td>
</tr>
<tr>
<td>IO4</td>
<td></td>
<td></td>
<td></td>
<td>IO4</td>
<td></td>
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<tr>
<td>IO16</td>
<td></td>
<td></td>
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<td>IO16 (NC)</td>
<td>See note 2</td>
</tr>
<tr>
<td>IO17</td>
<td></td>
<td></td>
<td></td>
<td>IO17 (NC)</td>
<td>See note 2</td>
</tr>
<tr>
<td>IO5</td>
<td>Reset_N</td>
<td></td>
<td></td>
<td></td>
<td>See note 1</td>
</tr>
<tr>
<td>IO18</td>
<td></td>
<td>MDIO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO19</td>
<td></td>
<td>TXD[0]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO21</td>
<td></td>
<td>TX_EN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RXD0</td>
<td></td>
<td>RXD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TXD0</td>
<td></td>
<td>TXD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO22</td>
<td></td>
<td>TXD[1]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IO23</td>
<td></td>
<td></td>
<td></td>
<td>MDC</td>
<td></td>
</tr>
</tbody>
</table>

### Note:

1. To prevent the power-on state of the GPIO0 from being affected by the clock output on the PHY side, the RESET_N signal to PHY defaults to low, turning the clock output off. After power-on you can control RESET_N with GPIO5 to turn the clock output on. See also [RMII Clock SourcedExternally by PHY](#). For PHYs that cannot turn off the clock output through RESET_N, it is recommended to use a crystal module that can be disabled / enabled externally. Similarly like when using RESET_N, the oscillator module should be disabled by default and turned on by ESP32 after power-up. For a reference design please see [ESP32-Ethernet-Kit V1.1 Ethernet board (A) schematic](#).

2. The ESP32 pins GPIO16 and GPIO17 are not broken out to the ESP32-WROVER-B module and therefore not available for use. If you need to use these pins, please solder a module without PSRAM memory inside, e.g. the ESP32-WROOM-32D or ESP32-SOLO-1.

---

### Start Application Development

Before powering up your ESP32-Ethernet-Kit, please make sure that the board is in good condition with no obvious signs of damage.

### Initial Setup

1. Set the **Function Switch** on the *Ethernet board (A)* to its default position by turning all the switches to **ON**.
2. To simplify flashing and testing of the application, do not input extra signals to the board headers.
3. The **PoE board (B)** can now be plugged in, but do not connect external power to it.
4. Connect the *Ethernet board (A)* to the PC with a USB cable.
5. Turn the **Power Switch** from GND to 5V0 position, the **5V Power On LED** should light up.

**Now to Development**  Proceed to *Get Started*, where Section *Installation* will quickly help you set up the development environment and then flash an example project onto your board.

Move on to the next section only if you have successfully completed all the above steps.

**Configure and Load the Ethernet Example**  After setting up the development environment and testing the board, you can configure and flash the *ethernet/basic* example. This example has been created for testing Ethernet functionality. It supports different PHY, including **IP101GRI** installed on *ESP32-Ethernet-Kit V1.1*.

**Summary of Changes from ESP32-Ethernet-Kit V1.0**

- The original inverted clock provided to the PHY by ESP32 using GPIO0 has been replaced by a clock generated on PHY side. The PHY’s clock is connected to the ESP32 with same GPIO0. The GPIO2 which was originally used to control the active crystal oscillator on the PHY side, can now be used for other purposes.
- On power up, the ESP32 boot strapping pin GPIO0 may be affected by clock generated on the PHY side. To resolve this issue the PHY’s Reset-N signal is pulled low using resistor R17 and effectively turning off the PHY’s clock output. The Reset-N signal can then pulled high by ESP32 using GPIO5.
- Removed FT2232H chip’s external SPI Flash U6.
- Removed flow control jumper header J4.
- Removed nTRST JTAG signal. The corresponding GPIO4 can now be used for other purposes.
- Pull-up resistor R68 on the GPIO15 line is moved to the MTDO side of JTAG.
- To make the A and B board connections more foolproof (reduce chances of plugging in the B board in reverse orientation), the original two 4-pin male rows on board A were changed to one 4-pin female row and one 4-pin male row. Corresponding male and female 4-pins rows were installed on board B.

**Other Versions of ESP32-Ethernet-Kit**

- **ESP32-Ethernet-Kit V1.0 Getting Started Guide**

**Related Documents**

- ESP32-Ethernet-Kit V1.1 Ethernet board (A) schematic (PDF)
- ESP32-Ethernet-Kit V1.0 PoE board (B) schematic (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROVER-B Datasheet (PDF)
- JTAG Debugging
- Hardware Reference

For other design documentation for the board, please contact us at sales@espressif.com.

**ESP32-DevKitS(-R)**

This user guide provides information on ESP32-DevKitS(-R), an ESP32-based flashing board produced by Espressif. ESP32-DevKitS(-R) is a combination of two board names: ESP32-DevKitS and ESP32-DevKitS-R. S stands for springs, and R stands for WROVER.
Chapter 1. Get Started

The document consists of the following major sections:

- **Getting Started**: Provides an overview of ESP32-DevKitS(-R) and hardware/software setup instructions to get started.
- **Hardware Reference**: Provides more detailed information about ESP32-DevKitS(-R)’s hardware.
- **Related Documents**: Gives links to related documentation.

**Getting Started**  This section describes how to get started with ESP32-DevKitS(-R). It begins with a few introductory sections about ESP32-DevKitS(-R), then Section *How to Flash a Board* provides instructions on how to mount a module onto ESP32-DevKitS(-R), get it ready, and flash firmware onto it.

**Overview**  ESP32-DevKitS(-R) is Espressif’s flashing board designed specifically for ESP32. It can be used to flash an ESP32 module without soldering the module to the power supply and signal lines. With a module mounted, ESP32-DevKitS(-R) can also be used as a mini development board like ESP32-DevKitC.

ESP32-DevKitS and ESP32-DevKitS-R boards vary only in layout of spring pins to fit the following ESP32 modules.

- **ESP32-DevKitS**:
  - ESP32-WROOM-32
  - ESP32-WROOM-32D
  - ESP32-WROOM-32U
  - ESP32-SOLO-1
  - ESP32-WROOM-32E
  - ESP32-WROOM-32UE

- **ESP32-DevKitS-R**:
  - ESP32-WROVER (PCB & IPEX)
  - ESP32-WROVER-B (PCB & IPEX)
  - ESP32-WROVER-E
  - ESP32-WROVER-IE

For information about above modules, please refer to [ESP32 Series Modules](#).

**Description of Components**
Chapter 1. Get Started

Fig. 38: ESP32-DevKitS - front

Fig. 39: ESP32-DevKitS-R - front
### Key Component

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Pins</td>
<td>Click the module in. The pins will fit into the module’s castellated holes.</td>
</tr>
<tr>
<td>2.54 mm Female Headers</td>
<td>These female headers are connected to pins of the module mounted on this board. For description of female headers, please refer to <a href="#">Header Blocks</a>.</td>
</tr>
<tr>
<td>USB-to-UART Bridge</td>
<td>Single-chip USB to UART bridge provides transfer rates of up to 3 Mbps.</td>
</tr>
<tr>
<td>LDO</td>
<td>5V-to-3.3V low-dropout voltage regulator (LDO).</td>
</tr>
<tr>
<td>Micro-USB Connector/Micro USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
<tr>
<td>Boot Button</td>
<td>Download button. Holding down <strong>Boot</strong> and then pressing <strong>EN</strong> initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Power On LED</td>
<td>Turns on when the USB or power supply is connected to the board.</td>
</tr>
</tbody>
</table>

### How to Flash a Board

Before powering up your ESP32-DevKitS(-R), please make sure that it is in good condition with no obvious signs of damage.

### Required Hardware

- An ESP32 module of your choice
- USB 2.0 cable (Standard-A to Micro-B)
- Computer running Windows, Linux, or macOS

### Hardware Setup

Please mount a module of your choice onto your ESP32-DevKitS(-R) according to the following steps:

- Gently put your module on the ESP32-DevKitS(-R) board. Make sure that castellated holes on your module are aligned with spring pins on the board.
- Press your module down into the board until it clicks.
- Check whether all spring pins are inserted into castellated holes. If there are some misaligned spring pins, place them into castellated holes with tweezers.

### Software Setup

#### Preferred Method

The ESP-IDF development framework provides a preferred way of flashing binaries onto ESP32-DevKitS(-R). Please proceed to [Get Started](#), where Section [Installation](#) will quickly help you set up the development environment and then flash an application example onto your ESP32-DevKitS(-R).

#### Alternative Method

As an alternative, Windows users can flash binaries using the [Flash Download Tool](#). Just download it, unzip it, and follow the instructions inside the `doc` folder.

#### Note:

1. To flash binary files, ESP32 should be set to Firmware Download mode. This can be done either by the flash tool automatically, or by holding down the Boot button and tapping the EN button.
2. After flashing binary files, the Flash Download Tool restarts your ESP32 module and boots the flashed application by default.

### Board Dimensions

### Contents and Packaging
Chapter 1. Get Started

Fig. 40: ESP32-DevKitS board dimensions - back

Fig. 41: ESP32-DevKitS-R board dimensions - back
**Retail orders**  If you order a few samples, each ESP32-DevKitS(-R) comes in an individual package in either antistatic bag or any packaging depending on a retailer. 


**Wholesale Orders**  If you order in bulk, the boards come in large cardboard boxes. 

For wholesale orders, please go to https://www.espressif.com/en/contact-us/sales-questions.

**Hardware Reference**

**Block Diagram**  A block diagram below shows the components of ESP32-DevKitS(-R) and their interconnections.

![Block Diagram](Fig.42: ESP32-DevKitS(-R) (click to enlarge)"

**Power Supply Options**  There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V and GND header pins
- 3V3 and GND header pins

It is advised to use the first option: micro USB port.
Table 5 - continued from previous page

<table>
<thead>
<tr>
<th>Label</th>
<th>Signal</th>
</tr>
</thead>
<tbody>
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<td>L10</td>
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<td>L11</td>
<td>27</td>
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<td>L12</td>
<td>14</td>
</tr>
<tr>
<td>L13</td>
<td>12</td>
</tr>
<tr>
<td>L14</td>
<td>GND</td>
</tr>
<tr>
<td>L15</td>
<td>13</td>
</tr>
<tr>
<td>L16</td>
<td>D2</td>
</tr>
<tr>
<td>L17</td>
<td>D3</td>
</tr>
<tr>
<td>L18</td>
<td>CMD</td>
</tr>
<tr>
<td>L19</td>
<td>5V</td>
</tr>
<tr>
<td>R1</td>
<td>GND</td>
</tr>
<tr>
<td>R2</td>
<td>23</td>
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<td>R3</td>
<td>22</td>
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<td>R4</td>
<td>TX</td>
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<tr>
<td>R5</td>
<td>RX</td>
</tr>
<tr>
<td>R6</td>
<td>21</td>
</tr>
<tr>
<td>R7</td>
<td>GND</td>
</tr>
<tr>
<td>R8</td>
<td>19</td>
</tr>
<tr>
<td>R9</td>
<td>18</td>
</tr>
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<td>R10</td>
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<td>R11</td>
<td>17</td>
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<td>R12</td>
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<td>R13</td>
<td>4</td>
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<td>R15</td>
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<td>15</td>
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<tr>
<td>R17</td>
<td>D1</td>
</tr>
<tr>
<td>R18</td>
<td>D0</td>
</tr>
<tr>
<td>R19</td>
<td>CLK</td>
</tr>
</tbody>
</table>

Header Blocks  For the image of header blocks, please refer to Description of Components.

Related Documents

- ESP32-DevKitS(-R) Schematics (PDF)
- ESP32 Datasheet (PDF)
- ESP32-WROOM-32 Datasheet (PDF)
- ESP32-WROOM-32D & ESP32-WROOM-32U Datasheet (PDF)
- ESP32-SOLO-1 Datasheet (PDF)
- ESP32-WROVER Datasheet (PDF)
- ESP32-WROVER-B Datasheet (PDF)
- ESP Product Selector

ESP32-PICO-KIT-1

Overview  ESP32-PICO-KIT-1 is an ESP32-based development board produced by Espressif.

The core of this board is ESP32-PICO-V3 - a System-in-Package (SiP) module with complete Wi-Fi and Bluetooth functionalities. Compared to other ESP32 modules, ESP32-PICO-V3 integrates the following peripheral components in one single package, which otherwise would need to be installed separately:
• 40 MHz crystal oscillator
• 4 MB flash
• Filter capacitors
• RF matching network

This setup reduces the costs of additional external components as well as the cost of assembly and testing and also increases the overall usability of the product.

The development board features a USB-to-UART Bridge circuit which allows developers to connect the board to a computer’s USB port for flashing and debugging.

All the IO signals and system power on ESP32-PICO-V3 are led out to two rows of 18 x 0.1” header pads on both sides of the development board for easy access. For compatibility with Dupont wires, all header pads are populated with two rows of male pin headers.

Note: ESP32-PICO-KIT-1 comes with male headers by default.

ESP32-PICO-KIT-1 provides the users with hardware for development of applications based on the ESP32, making it easier for users to explore ESP32 functionalities.

This guide covers:

• Getting Started: Provides an overview of the ESP32-PICO-KIT-1 and software setup instructions to get started.
• Contents and Packaging: Provides information about packaging and contents for retail and wholesale orders.
• Hardware Reference: Provides more detailed information about the ESP32-PICO-KIT-1’s hardware.
• Hardware Revision Details: Covers revision history, known issues, and links to user guides for previous versions of the ESP32-PICO-KIT-1.
• Related Documents: Gives links to related documentation.

Getting Started This section describes how to get started with the ESP32-PICO-KIT-1. It begins with a few introductory sections about the ESP32-PICO-KIT-1, then Section Start Application Development provides instructions on how to flash firmware onto the ESP32-PICO-KIT-1.

Description of Components The following figure and the table below describe the key components, interfaces, and controls of the ESP32-PICO-KIT-1 board.

Below is the description of the items identified in the figure starting from the top left corner and going clockwise.

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-PICO-V3</td>
<td>Standard ESP32-PICO-V3 module soldered to the ESP32-PICO-KIT-1 board. The complete ESP32 system on a chip (ESP32 SoC) has been integrated into the SiP module, requiring only an external antenna with LC matching network, decoupling capacitors, and a pull-up resistor for EN signals to function properly.</td>
</tr>
<tr>
<td>LDO</td>
<td>5V-to-3.3V Low dropout voltage regulator (LDO).</td>
</tr>
<tr>
<td>USB-to-UART bridge</td>
<td>CP2102N, single-chip USB-to-UART bridge that offers up to 3 Mbps transfer rates.</td>
</tr>
<tr>
<td>Micro USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board. For details, see the schematic in Related Documents.</td>
</tr>
<tr>
<td>I/O Connector</td>
<td>All the pins on ESP32-PICO-V3 are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc. For details, please see Section Pin Descriptions.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
</tbody>
</table>
Fig. 43: ESP32-PICO-KIT-1 Overview (click to enlarge)
Chapter 1. Get Started

Fig. 44: ESP32-PICO-KIT-1 board layout - front (click to enlarge)

**Start Application Development**  Before powering up your ESP32-PICO-KIT-1, please make sure that the board is in good condition with no obvious signs of damage.

**Required Hardware**

- 1 x ESP32-PICO-KIT-1
- 1 x USB 2.0 A to Micro B cable
- 1 x Computer running Windows, Linux, or macOS

**Software Setup**  Please proceed to *Get Started*, where Section *Installation* will quickly help you set up the development environment.

**Contents and Packaging**

**Retail Orders**  If you order one or several samples of the board, each ESP32-PICO-KIT-1 development board comes in an individual package.


**Wholesale Orders**  If you order in bulk, the boards come in large cardboard boxes.


**Hardware Reference**

**Block Diagram**  The block diagram below shows the main components of ESP32-PICO-KIT-1 and their interconnections.

**Power Supply Options**  There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V/GND header pins
- 3V3/GND header pins
Warning: The power supply must be provided using one and only one of the options above, otherwise the board and/or the power supply source can be damaged.

Pin Descriptions The two tables below provide the Name and Function of I/O header pins on both sides of the board, see Description of Components. The pin numbering and header names are the same as in the schematic given in Related Documents.

**Header J2**

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IO20</td>
<td>I/O</td>
<td>GPIO20</td>
</tr>
<tr>
<td>2</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21, VSPIHD, EMAC_TX_EN</td>
</tr>
<tr>
<td>3</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22, VSPIWP, U0RTS, EMAC_TXD1</td>
</tr>
<tr>
<td>4</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19, VSPIQ, U0CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>5</td>
<td>IO8</td>
<td>I/O</td>
<td>GPIO8, SD_DATA1, HS1_DATA1, U2CTS</td>
</tr>
<tr>
<td>6</td>
<td>IO7</td>
<td>I/O</td>
<td>GPIO7, SD_DATA0, HS1_DATA0, U2RTS</td>
</tr>
<tr>
<td>7</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK</td>
</tr>
<tr>
<td>8</td>
<td>IO10</td>
<td>I/O</td>
<td>GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD</td>
</tr>
<tr>
<td>9</td>
<td>IO9</td>
<td>I/O</td>
<td>GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD</td>
</tr>
<tr>
<td>10</td>
<td>RXD0</td>
<td>I/O</td>
<td>GPIO3, U0RXD (See 1), CLK_OUT2</td>
</tr>
<tr>
<td>11</td>
<td>TXD0</td>
<td>I/O</td>
<td>GPIO1, U0TXD (See 1), CLK_OUT3, EMAC_RXD2</td>
</tr>
<tr>
<td>12</td>
<td>IO35</td>
<td>I</td>
<td>ADC1_CH7, RTC_GPIO5</td>
</tr>
<tr>
<td>13</td>
<td>IO34</td>
<td>I</td>
<td>ADC1_CH6, RTC_GPIO4</td>
</tr>
<tr>
<td>14</td>
<td>IO38</td>
<td>I</td>
<td>GPIO38, ADC1_CH2, RTC_GPIO2</td>
</tr>
<tr>
<td>15</td>
<td>IO37</td>
<td>I</td>
<td>GPIO37, ADC1_CH1, RTC_GPIO1</td>
</tr>
<tr>
<td>16</td>
<td>EN</td>
<td>I</td>
<td>CHIP PU</td>
</tr>
<tr>
<td>17</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>18</td>
<td>VDD33 (3V3)</td>
<td>P</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>
### Header J3

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>SEN-SOR_VP (FSVP)</td>
<td>I</td>
<td>GPIO36, ADC1_CH0, RTC_GPIO0</td>
</tr>
<tr>
<td>3</td>
<td>SEN-SOR_VN (FSVN)</td>
<td>I</td>
<td>GPIO39, ADC1_CH3, RTC_GPIO3</td>
</tr>
<tr>
<td>4</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0</td>
</tr>
<tr>
<td>5</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1</td>
</tr>
<tr>
<td>6</td>
<td>IO32</td>
<td>I/O</td>
<td>32K_XP (See 2a), ADC1_CH4, TOUCH9, RTC_GPIO9</td>
</tr>
<tr>
<td>7</td>
<td>IO33</td>
<td>I/O</td>
<td>32K_XN (See 2b), ADC1_CH5, TOUCH8, RTC_GPIO8</td>
</tr>
<tr>
<td>8</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV</td>
</tr>
<tr>
<td>9</td>
<td>IO14</td>
<td>I/O</td>
<td>ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2</td>
</tr>
<tr>
<td>10</td>
<td>IO12</td>
<td>I/O</td>
<td>ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI (See 3), HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3</td>
</tr>
<tr>
<td>11</td>
<td>IO13</td>
<td>I/O</td>
<td>ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER</td>
</tr>
<tr>
<td>12</td>
<td>IO15</td>
<td>I/O</td>
<td>ADC2_CH3, TOUCH3, RTC_GPIO13, MTD0, HSPICS0, HS2_CMD, SD_CMD, EMAC_RXD3</td>
</tr>
<tr>
<td>13</td>
<td>IO2</td>
<td>I/O</td>
<td>ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0</td>
</tr>
<tr>
<td>14</td>
<td>IO4</td>
<td>I/O</td>
<td>ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER</td>
</tr>
<tr>
<td>15</td>
<td>IO0</td>
<td>I/O</td>
<td>ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK</td>
</tr>
<tr>
<td>16</td>
<td>VDD33 (3V3)</td>
<td>P</td>
<td>3.3V power supply</td>
</tr>
<tr>
<td>17</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>18</td>
<td>EXT_5V (5V)</td>
<td>P</td>
<td>5V power supply</td>
</tr>
</tbody>
</table>

**Note:**

1. This pin is connected to the pin of the USB bridge chip on the board.
2. 32.768 kHz crystal oscillator: a) input b) output
3. The operating voltage of ESP32-PICO-KIT-1’s embedded SPI flash is 3.3 V. Therefore, the strapping pin MTDI should be pulled down during the module power-on reset. If connected, please make sure that this pin is not held up on reset.

**Pin Layout**

**Hardware Revision Details**  No previous versions available.

**Related Documents**

- ESP32-PICO-V3 Datasheet (PDF)
- ESP Product Selector
- ESP32-PICO-KIT-1 Schematic (PDF)
- ESP32-PICO-KIT-1 PCB Layout (PDF)

For other design documentation for the board, please contact us at sales@espressif.com.
**Overview**

ESP32-PICO-DevKitM-2 is an ESP32-based development board produced by Espressif.

The core of this board is ESP32-PICO-MINI-02(02U) module with complete Wi-Fi and Bluetooth functionalities. The development board features a USB-to-UART Bridge circuit which allows developers to connect the board to a computer’s USB port for flashing and debugging.

All the IO signals and system power on ESP32-PICO-MINI-02(02U) are led out to two rows of 18 x 0.1” header pads on both sides of the development board for easy access. For compatibility with Dupont wires, all header pads are populated with two rows of male pin headers.

**Note:** ESP32-PICO-DevKitM-2 comes with male headers by default.

ESP32-PICO-DevKitM-2 provides the users with hardware for development of applications based on the ESP32, making it easier for users to explore ESP32 functionalities.

This guide covers:

- **Getting Started:** Provides an overview of the ESP32-PICO-DevKitM-2 and software setup instructions to get started.
- **Contents and Packaging:** Provides information about packaging and contents for retail and wholesale orders.
- **Hardware Reference:** Provides more detailed information about the ESP32-PICO-DevKitM-2’s hardware.
- **Hardware Revision Details:** Covers revision history, known issues, and links to user guides for previous versions (if any) of the ESP32-PICO-DevKitM-2.
- **Related Documents:** Gives links to related documentation.

**Getting Started**

This section describes how to get started with the ESP32-PICO-DevKitM-2. It begins with a few introductory sections about the ESP32-PICO-DevKitM-2, then Section *Start Application Development* provides instructions on how to flash firmware onto the ESP32-PICO-DevKitM-2.
Fig. 47: ESP32-PICO-DevKitM-2 Overview (click to enlarge)
Description of Components  The following figure and the table below describe the key components, interfaces, and controls of the ESP32-PICO-DevKitM-2 board. We take the board with a ESP32-PICO-MINI-02 module as an example in the following sections.

![Fig. 48: ESP32-PICO-DevKitM-2 board layout - front (click to enlarge)](image)

Below is the description of the items identified in the figure starting from the top left corner and going clockwise.

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-PICO-MINI-02</td>
<td>Standard ESP32-PICO-MINI-02 module soldered to the ESP32-PICO-DevKitM-2 board. The complete ESP32 system on a chip (ESP32 SoC) has been integrated into the module. Users can also select the board with ESP32-PICO-MINI-02U soldered.</td>
</tr>
<tr>
<td>LDO</td>
<td>V-to-3.3V Low dropout voltage regulator (LDO).</td>
</tr>
<tr>
<td>USB-to-UART bridge</td>
<td>CP2102N, single-chip USB-UART bridge that offers up to 3 Mbps transfers rates.</td>
</tr>
<tr>
<td>Micro-B USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the board.</td>
</tr>
<tr>
<td>5V Power On LED</td>
<td>This red LED turns on when power is supplied to the board. For details, see the schematic in Related Documents.</td>
</tr>
<tr>
<td>I/O Connector</td>
<td>All the pins on ESP32-PICO-MINI-02 are broken out to pin headers. You can program ESP32 to enable multiple functions, such as PWM, ADC, DAC, I2C, I2S, SPI, etc. For details, please see Section Pin Descriptions.</td>
</tr>
<tr>
<td>BOOT Button</td>
<td>Download button. Holding down Boot and then pressing EN initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>EN Button</td>
<td>Reset button.</td>
</tr>
</tbody>
</table>

Start Application Development  Before powering up your ESP32-PICO-DevKitM-2, please make sure that the board is in good condition with no obvious signs of damage.

Required Hardware

- 1 x ESP32-PICO-DevKitM-2
- 1 x USB 2.0 A to Micro B cable
- 1 x Computer running Windows, Linux, or macOS
Software Setup  Please proceed to Get Started, where Section Installation will quickly help you set up the development environment.

Contents and Packaging

Retail Orders  If you order one or several samples of the board, each ESP32-PICO-DevKitM-2 development board comes in an individual package.


Wholesale Orders  If you order in bulk, the boards come in large cardboard boxes.

For wholesale orders, please go to https://www.espressif.com/en/contact-us/sales-questions.

Hardware Reference

Block Diagram  The block diagram below shows the main components of ESP32-PICO-DevKitM-2 and their interconnections.

![ESP32-PICO-DevKitM-2 Block Diagram](https://www.espressif.com/en/contact-us/get-samples)

Fig. 49: ESP32-PICO-DevKitM-2 Block Diagram (click to enlarge)

Power Supply Options  There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V/GND header pins
- 3V3/GND header pins

Warning:  The power supply must be provided using one and only one of the options above, otherwise the board and/or the power supply source can be damaged.

Pin Descriptions  The two tables below provide the Name and Function of I/O header pins on both sides of the board, see Description of Components. The pin numbering and header names are the same as in the schematic given in Related Documents.
# Chapter 1. Get Started

## Header J2

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IO20</td>
<td>I/O</td>
<td>GPIO20</td>
</tr>
<tr>
<td>2</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21, VSPHID, EMAC_TX_EN</td>
</tr>
<tr>
<td>3</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22, VSPHWP, U0RTS, EMAC_TXD1</td>
</tr>
<tr>
<td>4</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19, VSPIQ, U0CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>5</td>
<td>IO8</td>
<td>I/O</td>
<td>GPIO8, SD_DATAA1, HS1_DATAA1, U2CTS</td>
</tr>
<tr>
<td>6</td>
<td>IO7</td>
<td>I/O</td>
<td>GPIO7, SD_DATA0, HS1_DATA0, U2RTS</td>
</tr>
<tr>
<td>7</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK</td>
</tr>
<tr>
<td>8</td>
<td>NC</td>
<td>-</td>
<td>NC</td>
</tr>
<tr>
<td>9</td>
<td>NC</td>
<td>-</td>
<td>NC</td>
</tr>
<tr>
<td>10</td>
<td>RXD0</td>
<td>I/O</td>
<td>GPIO3, U0RXD (See 1), CLK_OUT2</td>
</tr>
<tr>
<td>11</td>
<td>TXD0</td>
<td>I/O</td>
<td>GPIO1, U0TXD (See 1), CLK_OUT3, EMAC_RXD2</td>
</tr>
<tr>
<td>12</td>
<td>IO35</td>
<td>I</td>
<td>ADC1.CH7, RTCCGPIO5</td>
</tr>
<tr>
<td>13</td>
<td>IO34</td>
<td>I</td>
<td>ADC1.CH6, RTCCGPIO4</td>
</tr>
<tr>
<td>14</td>
<td>IO38</td>
<td>I</td>
<td>GPIO38, ADC1.CH2, RTCCGPIO2</td>
</tr>
<tr>
<td>15</td>
<td>IO37</td>
<td>I</td>
<td>GPIO37, ADC1.CH1, RTCCGPIO1</td>
</tr>
<tr>
<td>16</td>
<td>EN</td>
<td>I</td>
<td>CHIP_PU</td>
</tr>
<tr>
<td>17</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>18</td>
<td>VDD33 (3V3)</td>
<td>P</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>

## Header J3

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>SEN-SOR_VP (FSVP)</td>
<td>I</td>
<td>GPIO36, ADC1.CH0, RTCCGPIO0</td>
</tr>
<tr>
<td>3</td>
<td>SEN-SOR_VN (FSVN)</td>
<td>I</td>
<td>GPIO39, ADC1.CH3, RTCCGPIO3</td>
</tr>
<tr>
<td>4</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, DAC_.1, ADC2.CH8, RTCCGPIO6, EMAC_RXD0</td>
</tr>
<tr>
<td>5</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, DAC_.2, ADC2.CH9, RTCCGPIO7, EMAC_RXD1</td>
</tr>
<tr>
<td>6</td>
<td>IO32</td>
<td>I/O</td>
<td>32K.XP (See 2a), ADC1.CH4, TOUCH9, RTCCGPIO9</td>
</tr>
<tr>
<td>7</td>
<td>IO33</td>
<td>I/O</td>
<td>32K.XN (See 2b), ADC1.CH5, TOUCH8, RTCCGPIO8</td>
</tr>
<tr>
<td>8</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2.CH7, TOUCH7, RTCCGPIO17, EMAC_RX_DV</td>
</tr>
<tr>
<td>9</td>
<td>IO14</td>
<td>I/O</td>
<td>ADC2.CH6, TOUCH6, RTCCGPIO16, MTMS, HSPICLK, HS2.CLK, SD_CL, EMAC_TXD2</td>
</tr>
<tr>
<td>10</td>
<td>IO12</td>
<td>I/O</td>
<td>ADC2.CH5, TOUCH5, RTCCGPIO15, MTDI (See 3), HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3</td>
</tr>
<tr>
<td>11</td>
<td>IO13</td>
<td>I/O</td>
<td>ADC2.CH4, TOUCH4, RTCCGPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER</td>
</tr>
<tr>
<td>12</td>
<td>IO15</td>
<td>I/O</td>
<td>ADC2.CH3, TOUCH3, RTCCGPIO13, MTDO, HSPICS0, HS2_CMD, SD_CMD, EMAC_RXD3</td>
</tr>
<tr>
<td>13</td>
<td>IO2</td>
<td>I/O</td>
<td>ADC2.CH2, TOUCH2, RTCCGPIO12, HSPIWP, HS2_DATA0, SD_DATA0</td>
</tr>
<tr>
<td>14</td>
<td>IO4</td>
<td>I/O</td>
<td>ADC2.CH0, TOUCH0, RTCCGPIO10, HSPIHID, HS2_DATA1, SD_DATA1, EMAC_TX_ER</td>
</tr>
<tr>
<td>15</td>
<td>IO0</td>
<td>I/O</td>
<td>ADC2.CH1, TOUCH1, RTCCGPIO11, CLK_OUT1, EMAC_TX_CLK</td>
</tr>
<tr>
<td>16</td>
<td>VDD33 (3V3)</td>
<td>P</td>
<td>3.3V power supply</td>
</tr>
<tr>
<td>17</td>
<td>GND</td>
<td>P</td>
<td>Ground</td>
</tr>
<tr>
<td>18</td>
<td>EXT_5V (5V)</td>
<td>P</td>
<td>5V power supply</td>
</tr>
</tbody>
</table>
Note:

1. This pin is connected to the pin of the USB bridge chip on the board.
2. 32.768 kHz crystal oscillator: a) input b) output
3. The operating voltage of ESP32-PICO-DevKitM-2’s embedded SPI flash is 3.3 V. Therefore, the strapping pin MTDI should be pulled down during the module power-on reset. If connected, please make sure that this pin is not held up on reset.

Fig. 50: ESP32-PICO-DevKitM-2 Pin Layout (click to enlarge)

Pin Layout

Hardware Revision Details  No previous versions available.

Related Documents

- ESP32-PICO-MINI-02 & ESP32-PICO-MINI-1U Datasheet (PDF)
- ESP Product Selector
- ESP32-PICO-DevKitM-2 Schematic (PDF)
- ESP32-PICO-DevKitM-2 PCB Layout (PDF)

For other design documentation for the board, please contact us at sales@espressif.com.

ESP32-DevKitM-1

This user guide will help you get started with ESP32-DevKitM-1 and will also provide more in-depth information. ESP32-DevKitM-1 is an ESP32-MINI-1(1U)-based development board produced by Espressif. Most of the I/O pins are broken out to the pin headers on both sides for easy interfacing. Users can either connect peripherals with jumper wires or mount ESP32-DevKitM-1 on a breadboard.
The document consists of the following major sections:

- **Getting started**: Provides an overview of the ESP32-DevKitM-1 and hardware/software setup instructions to get started.
- **Hardware reference**: Provides more detailed information about the ESP32-DevKitM-1’s hardware.
- **Related Documents**: Gives links to related documentation.

**Getting Started** This section describes how to get started with ESP32-DevKitM-1. It begins with a few introductory sections about the ESP32-DevKitM-1, then Section *Start Application Development* provides instructions on how to do the initial hardware setup and then how to flash firmware onto the ESP32-DevKitM-1.

**Overview** This is a small and convenient development board that features:

- ESP32-MINI-1, or ESP32-MINI-1U module
- USB-to-serial programming interface that also provides power supply for the board
- pin headers
- pushbuttons for reset and activation of Firmware Download mode
- a few other components

**Contents and Packaging**

**Retail orders** If you order a few samples, each ESP32-DevKitM-1 comes in an individual package in either antistatic bag or any packaging depending on your retailer.


**Wholesale Orders** If you order in bulk, the boards come in large cardboard boxes.

For wholesale orders, please go to https://www.espressif.com/en/contact-us/sales-questions.

**Description of Components** The following figure and the table below describe the key components, interfaces and controls of the ESP32-DevKitM-1 board. We take the board with a ESP32-MINI-1 module as an example in the following sections.
Chapter 1. Get Started

Fig. 51: ESP32-DevKitM-1 - front

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-board module</td>
<td>ESP32-MINI-1 module or ESP32-MINI-1U module. ESP32-MINI-1 comes with an on-board PCB antenna. ESP32-MINI-1U comes with an external antenna connector. The two modules both have a 4 MB flash in chip package. For details, please see ESP32-MINI-1 &amp; ESP32-MINI-1U Datasheet.</td>
</tr>
<tr>
<td>5 V to 3.3 V LDO</td>
<td>Power regulator converts 5 V to 3.3 V.</td>
</tr>
<tr>
<td>Boot Button</td>
<td>Download button. Holding down <strong>Boot</strong> and then pressing <strong>Reset</strong> initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Reset Button</td>
<td>Reset Button</td>
</tr>
<tr>
<td>Micro-USB Port</td>
<td>USB interface. Power supply for the board as well as the communication interface between a computer and the ESP32 chip.</td>
</tr>
<tr>
<td>USB-to-UART Bridge</td>
<td>Single USB-UART bridge chip provides transfer rates up to 3 Mbps.</td>
</tr>
<tr>
<td>3.3 V Power On LED</td>
<td>Turns on when the USB is connected to the board. For details, please see the schematics in Related Documents.</td>
</tr>
<tr>
<td>I/O Connector</td>
<td>All available GPIO pins (except for the SPI bus for flash) are broken out to the pin headers on the board. Users can program ESP32 chip to enable multiple functions.</td>
</tr>
</tbody>
</table>

**Start Application Development**  Before powering up your ESP32-DevKitM-1, please make sure that it is in good condition with no obvious signs of damage.

**Required Hardware**

- ESP32-DevKitM-1
- USB 2.0 cable (Standard-A to Micro-B)
- Computer running Windows, Linux, or macOS

**Software Setup**  Please proceed to Get Started, where Section Installation will quickly help you set up the development environment and then flash an application example onto your ESP32-DevKitM-1.
Chapter 1. Get Started

Attention: ESP32-DevKitM-1 boards manufactured before December 2, 2021 have a single core module installed. To verify what module you have, please check module marking information in PCN-2021-021. If your board has a single core module installed, please enable single core mode (`CONFIG_FREERTOS_UNICORE`) in `menuconfig` before flashing your applications.

**Hardware Reference**

**Block Diagram**  A block diagram below shows the components of ESP32-DevKitM-1 and their interconnections.

![Block Diagram](image)

Fig. 52: ESP32-DevKitM-1

**Power Source Select**  There are three mutually exclusive ways to provide power to the board:

- Micro USB port, default power supply
- 5V and GND header pins
- 3V3 and GND header pins

**Warning:**

- The power supply must be provided using one and only one of the options above, otherwise the board and/or the power supply source can be damaged.
- Power supply by micro USB port is recommended.

**Pin Descriptions**  The table below provides the Name and Function of pins on both sides of the board. For peripheral pin configurations, please refer to ESP32 Datasheet.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>VCC</td>
<td>Ground</td>
</tr>
<tr>
<td>2</td>
<td>3V3</td>
<td>P</td>
<td>3.3 V power supply</td>
</tr>
</tbody>
</table>

continues on next page
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>I36</td>
<td>I</td>
<td>GPIO36, ADC1_CH0, RTC_GPIO0</td>
</tr>
<tr>
<td>4</td>
<td>I37</td>
<td>I</td>
<td>GPIO37, ADC1_CH1, RTC_GPIO1</td>
</tr>
<tr>
<td>5</td>
<td>I38</td>
<td>I</td>
<td>GPIO38, ADC1_CH2, RTC_GPIO2</td>
</tr>
<tr>
<td>6</td>
<td>I39</td>
<td>I</td>
<td>GPIO39, ADC1_CH3, RTC_GPIO3</td>
</tr>
<tr>
<td>7</td>
<td>RST</td>
<td>I</td>
<td>Reset; High: enable; Low: powers off</td>
</tr>
<tr>
<td>8</td>
<td>I34</td>
<td>I/O</td>
<td>GPIO34, ADC1_CH6, RTC_GPIO4</td>
</tr>
<tr>
<td>9</td>
<td>I35</td>
<td>I</td>
<td>GPIO35, ADC1_CH7, RTC_GPIO5</td>
</tr>
<tr>
<td>10</td>
<td>IO32</td>
<td>I/O</td>
<td>GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9</td>
</tr>
<tr>
<td>11</td>
<td>IO33</td>
<td>I/O</td>
<td>GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8</td>
</tr>
<tr>
<td>12</td>
<td>IO25</td>
<td>I/O</td>
<td>GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0</td>
</tr>
<tr>
<td>13</td>
<td>IO26</td>
<td>I/O</td>
<td>GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1</td>
</tr>
<tr>
<td>14</td>
<td>IO27</td>
<td>I/O</td>
<td>GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX DV</td>
</tr>
<tr>
<td>15</td>
<td>IO14</td>
<td>I/O</td>
<td>GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSICLCLK, HS2_CLK, SD_CLK, EMAC_TXD2</td>
</tr>
<tr>
<td>16</td>
<td>5V</td>
<td>P</td>
<td>5 V power supply</td>
</tr>
<tr>
<td>17</td>
<td>IO12</td>
<td>I/O</td>
<td>GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3</td>
</tr>
<tr>
<td>18</td>
<td>IO13</td>
<td>I/O</td>
<td>GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCR, HSPIQ, HS2_DATA3, SD_DATA3, EMAC_RX_ER</td>
</tr>
<tr>
<td>19</td>
<td>IO15</td>
<td>I/O</td>
<td>GPIO15, ADC2_CH3, TOUCH3, RTC_GPIO13, MTDI, HSPIQ, HS2_CMD, SD_CMD, EMAC_RXD3</td>
</tr>
<tr>
<td>20</td>
<td>IO2</td>
<td>I/O</td>
<td>GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0</td>
</tr>
<tr>
<td>21</td>
<td>IO0</td>
<td>I/O</td>
<td>GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK</td>
</tr>
<tr>
<td>22</td>
<td>IO4</td>
<td>I/O</td>
<td>GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER</td>
</tr>
<tr>
<td>23</td>
<td>IO9</td>
<td>I/O</td>
<td>GPIO9, HS1_DATA2, U1RXD, SD_DATA2</td>
</tr>
<tr>
<td>24</td>
<td>IO10</td>
<td>I/O</td>
<td>GPIO10, HS1_DATA3, U1TXD, SD_DATA3</td>
</tr>
<tr>
<td>25</td>
<td>IO5</td>
<td>I/O</td>
<td>GPIO5, HS1_DATA6, VSPIQ, U1CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>26</td>
<td>IO18</td>
<td>I/O</td>
<td>GPIO18, HS1_DATA7, VSPICLK</td>
</tr>
<tr>
<td>27</td>
<td>IO23</td>
<td>I/O</td>
<td>GPIO23, HS1_STROBE, VSPIQ</td>
</tr>
<tr>
<td>28</td>
<td>IO19</td>
<td>I/O</td>
<td>GPIO19, VSPIQ, U0CTS, EMAC_TXD0</td>
</tr>
<tr>
<td>29</td>
<td>IO22</td>
<td>I/O</td>
<td>GPIO22, VSPIWP, U0RTS, EMAC_TXD1</td>
</tr>
<tr>
<td>30</td>
<td>IO21</td>
<td>I/O</td>
<td>GPIO21, VSPIHD, EMAC_TX EN</td>
</tr>
<tr>
<td>31</td>
<td>TXD0</td>
<td>I/O</td>
<td>GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2</td>
</tr>
<tr>
<td>32</td>
<td>RXD0</td>
<td>I/O</td>
<td>GPIO3, U0RXD, CLK_OUT2</td>
</tr>
</tbody>
</table>

**Pin Layout**

**Hardware Revision Details**  
No previous versions available.

**Related Documents**

- ESP32-MINI-1 & ESP32-MINI-1U Datasheet (PDF)
- ESP32-DevKitM-1 Schematics (PDF)
- ESP32-DevKitM-1 PCB layout (PDF)

1 P: Power supply; I: Input; O: Output.
2 MTDI, GPIO0, GPIO2, MTD0, and GPIO5 are strapping pins. These pins are used to control several chip functions depending on binary voltage values applied to the pins during chip power-up or system reset. For description and application of the strapping pins, please refer to ESP32 Datasheet > Section Strapping Pins.
Fig. 53: ESP32-DevKitM-1 (click to enlarge)

- ESP32-DevKitM-1 layout (DXF) - You can view it with Autodesk Viewer online
- ESP32 Datasheet (PDF)
- ESP Product Selector

For other design documentation for the board, please contact us at sales@espressif.com.

1.2.2 Software

To start using ESP-IDF on ESP32, install the following software:

- **Toolchain** to compile code for ESP32
- **Build tools** - CMake and Ninja to build a full Application for ESP32
- **ESP-IDF** that essentially contains API (software libraries and source code) for ESP32 and scripts to operate the **Toolchain**
1.3 Installation

To install all the required software, we offer some different ways to facilitate this task. Choose from one of the available options.

1.3.1 IDE

Note: We highly recommend installing the ESP-IDF through your favorite IDE.

- Eclipse Plugin
- VSCode Extension

1.3.2 Manual Installation

For the manual procedure, please select according to your operating system.

Standard Setup of Toolchain for Windows

Introduction ESP-IDF requires some prerequisite tools to be installed so you can build firmware for supported chips. The prerequisite tools include Python, Git, cross-compilers, CMake and Ninja build tools.

For this Getting Started we’re going to use the Command Prompt, but after ESP-IDF is installed you can use Eclipse Plugin or another graphical IDE with CMake support instead.

Note: Limitations: - The installation path of ESP-IDF and ESP-IDF Tools must not be longer than 90 characters. Too long installation paths might result in a failed build. - The installation path of Python or ESP-IDF must not contain white spaces or parentheses. - The installation path of Python or ESP-IDF should not contain special characters (non-ASCII) unless the operating system is configured with “Unicode UTF-8” support.

System Administrator can enable the support via Control Panel - Change date, time, or number formats - Administrative tab - Change system locale - check the option “Beta: Use Unicode UTF-8 for worldwide language support” - Ok and reboot the computer.

ESP-IDF Tools Installer The easiest way to install ESP-IDF’s prerequisites is to download one of ESP-IDF Tools Installers.
Chapter 1. Get Started

**What is the use case for Online and Offline Installer**  
Online Installer is very small and allows the installation of all available releases of ESP-IDF. The installer will download only necessary dependencies including Git For Windows during the installation process. The installer stores downloaded files in the cache directory `%userprofile%\espressif`.  

Offline Installer does not require any network connection. The installer contains all required dependencies including Git For Windows.

**Components of the installation**  
The installer deploys the following components:

- Embedded Python
- Cross-compilers
- OpenOCD
- CMake and Ninja build tools
- ESP-IDF

The installer also allows reusing the existing directory with ESP-IDF. The recommended directory is `%userprofile%\Desktop\esp-idf` where `%userprofile%` is your home directory.

**Launching ESP-IDF Environment**  
At the end of the installation process you can check out option Run ESP-IDF PowerShell Environment or Run ESP-IDF Command Prompt (cmd.exe). The installer will launch ESP-IDF environment in selected prompt.

Run ESP-IDF PowerShell Environment:

![Completing the ESP-IDF Tools Setup Wizard](image)

**Fig. 54: Completing the ESP-IDF Tools Setup Wizard with Run ESP-IDF PowerShell Environment**

Run ESP-IDF Command Prompt (cmd.exe):
Chapter 1. Get Started

Fig. 55: ESP-IDF PowerShell

Fig. 56: Completing the ESP-IDF Tools Setup Wizard with Run ESP-IDF Command Prompt (cmd.exe)
Using Python in C:\Users\test\AppData\Local\Programs\Python\Python37\Python 3.7.8
Using Git in C:\Users\test\Git\cmd\git version 2.30.0.windows.1
Setting IDF_PATH: C:\Users\test\esp\esp-idf

Adding ESP-IDF tools to PATH...
   C:\Users\test\esp\esp-idf\tools\xtensa-esp32-elf\esp-2020r3-8.4.0\xtensa-esp32-elf\bin
   C:\Users\test\esp\esp-idf\tools\xtensa-esp32s2-elf\esp-2020r3-8.4.0\xtensa-esp32s2-elf\bin
   C:\Users\test\esp\esp-idf\tools\xtensa-esp32s3-elf\esp-2020r3-8.4.0\xtensa-esp32s3-elf\bin
   C:\Users\test\esp\esp-idf\tools\riscv32-esp-elf\1.24.0.123_64eb9ff-8.4.0\riscv32-esp-elf\bin
   C:\Users\test\esp\esp-idf\tools\esp32ulp-elf\2.28.51-esp-20191205\esp32ulp-elf\f-binutils\bin
   C:\Users\test\esp\esp-idf\tools\esp32ulp-elf\2.28.51-esp-20191205\esp32ulp-elf\p-elf-binutils\bin
   C:\Users\test\esp\esp-idf\tools\cmake\3.16.4\bin
   C:\Users\test\esp\esp-idf\tools\openocd-esp32\v0.10.0-esp32-20200709\openocd-esp32\bin
   C:\Users\test\esp\esp-idf\tools\ninja\1.10.0\n   C:\Users\test\esp\esp-idf\tools\idf-exe\1.0.1\n   C:\Users\test\esp\esp-idf\tools\ccache\3.7\n   C:\Users\test\esp\esp-idf\tools\dfu-util\0.9\dfu-util-0.9-win64
   C:\Users\test\esp\esp-idf\python_env\idf4.3._py9-3.7_env\Scripts
   C:\Users\test\esp\esp-idf\tools

Checking if Python packages are up to date...
Python requirements from C:\Users\test\esp\esp-idf\requirements.txt are satisfied.

Done! You can now compile ESP-IDF projects.
Go to the project directory and run:

idf.py build

C:\Users\test\esp\esp-idf>

Fig. 57: ESP-IDF Command Prompt
Using the Command Prompt  For the remaining Getting Started steps, we’re going to use the Windows Command Prompt.

ESP-IDF Tools Installer also creates a shortcut in the Start menu to launch the ESP-IDF Command Prompt. This shortcut launches the Command Prompt (cmd.exe) and runs export.bat script to set up the environment variables (PATH, IDF_PATH and others). Inside this command prompt, all the installed tools are available.

Note that this shortcut is specific to the ESP-IDF directory selected in the ESP-IDF Tools Installer. If you have multiple ESP-IDF directories on the computer (for example, to work with different versions of ESP-IDF), you have two options to use them:

1. Create a copy of the shortcut created by the ESP-IDF Tools Installer, and change the working directory of the new shortcut to the ESP-IDF directory you wish to use.
2. Alternatively, run cmd.exe, then change to the ESP-IDF directory you wish to use, and run export.bat. Note that unlike the previous option, this way requires Python and Git to be present in PATH. If you get errors related to Python or Git not being found, use the first option.

First Steps on ESP-IDF  Now since all requirements are met, the next topic will guide you on how to start your first project.

This guide will help you on the first steps using ESP-IDF. Follow this guide to start a new project on the ESP32 and build, flash, and monitor the device output.

Note: If you have not yet installed ESP-IDF, please go to Installation and follow the instruction in order to get all the software needed to use this guide.

Start a Project  Now you are ready to prepare your application for ESP32. You can start with get-started/hello_world project from examples directory in ESP-IDF.

Important: The ESP-IDF build system does not support spaces in the paths to either ESP-IDF or to projects.

Copy the project get-started/hello_world to ~/esp directory:

cd %userprofile%\esp
xcopy /e /i %IDF_PATH%\examples\get-started\hello_world hello_world

Note: There is a range of example projects in the examples directory in ESP-IDF. You can copy any project in the same way as presented above and run it. It is also possible to build examples in-place without copying them first.

Connect Your Device  Now connect your ESP32 board to the computer and check under which serial port the board is visible.

Serial port names start with COM in Windows.

If you are not sure how to check the serial port name, please refer to Establish Serial Connection with ESP32 for full details.

Note: Keep the port name handy as you will need it in the next steps.

Configure Your Project  Navigate to your hello_world directory, set ESP32 as the target, and run the project configuration utility menuconfig.
Chapter 1. Get Started

Windows

```bash
cd %userprofile%\esp\hello_world
idf.py set-target esp32
idf.py menuconfig
```

After opening a new project, you should first set the target with `idf.py set-target esp32`. Note that existing builds and configurations in the project, if any, will be cleared and initialized in this process. The target may be saved in the environment variable to skip this step at all. See Select the Target Chip: set-target for additional information.

If the previous steps have been done correctly, the following menu appears:

![Project configuration - Home window](image)

You are using this menu to set up project specific variables, e.g., Wi-Fi network name and password, the processor speed, etc. Setting up the project with menuconfig may be skipped for “hello_world”, since this example runs with default configuration.

**Attention:** If you use ESP32-DevKitC board with the ESP32-SOLO-1 module, or ESP32-DevKitM-1 board with the ESP32-MIN1-1(1U) module, please enable single core mode (`CONFIG_FREERTOS_UNICORE`) in menuconfig before flashing examples.

**Note:** The colors of the menu could be different in your terminal. You can change the appearance with the option `--style`. Please run `idf.py menuconfig --help` for further information.

If you are using one of the supported development boards, you can speed up your development by using Board Support Package. See Additional Tips for more information.

**Build the Project**  
Build the project by running:

```bash
idf.py build
```

This command will compile the application and all ESP-IDF components, then it will generate the bootloader, partition table, and application binaries.
$ idf.py build
Running cmake in directory /path/to/hello_world/build
Executing "cmake -G Ninja --warn-uninitialized /path/to/hello_world"
Warn about uninitialized values.
-- Found Git: /usr/bin/git (found version "2.17.0")
-- Building empty aws_lot component due to configuration
-- Component names: ...
-- Component paths: ...

... (more lines of build system output)

[527/527] Generating hello_world.bin
esptool.py v2.3.1

Project build complete. To flash, run this command:
.../.../components/esptool_py/esptool/esptool.py -p (PORT) -b 921600 write_flash
  --flash_mode dio --flash_size detect --flash_freq 40m 0x10000 build/hello_world.
  -bin build 0x1000 build/bootloader/bootloader.bin 0x8000 build/partition_table/
  -partition-table.bin
or run 'idf.py -p PORT flash'

If there are no errors, the build will finish by generating the firmware binary .bin files.

**Flash onto the Device**  To flash the binaries that you just built for the ESP32 in the previous step, you need to run the following command:

```
idf.py -p PORT flash
```

Replace PORT with your ESP32 board’s USB port name. If the PORT is not defined, the `idf.py` will try to connect automatically using the available USB ports.

For more information on `idf.py` arguments, see `idf.py`.

**Note:** The option `flash` automatically builds and flashes the project, so running `idf.py build` is not necessary.

Encountered Issues While Flashing? See this Flashing Troubleshooting page or Establish Serial Connection with ESP32 for more detailed information.

**Normal Operation**  When flashing, you will see the output log similar to the following:

```
...
esptool.py --chip esp32 -p /dev/ttyUSB0 -b 460800 --before=default_reset --
--after-hard_reset write_flash --flash_mode dio --flash_freq 40m --flash_size 2MB--
  0x8000 partition_table/partition-table.bin 0x10000 bootloader/bootloader.bin--
  0x10000 hello_world.bin
esptool.py v3.0-dev
Serial port /dev/ttyUSB0
Connecting...........
Chip is ESP32DWDQ6 (revision 0)
Features: WiFi, BT, Dual Core, Coding Scheme None
Crystal is 40MHz
MAC: 24:0a:c4:05:b9:14
Uploading stub...
Running stub...
Stub running...
Changing baud rate to 460800
Changed.
Configuring flash size...
Compressed 3072 bytes to 103...
```

(continues on next page)
If there are no issues by the end of the flash process, the board will reboot and start up the “hello_world” application.

If you’d like to use the Eclipse or VS Code IDE instead of running idf.py, check out Eclipse Plugin, VSCode Extension.

**Monitor the Output** To check if “hello_world” is indeed running, type idf.py -p PORT monitor (Do not forget to replace PORT with your serial port name).

This command launches the **IDF Monitor** application:

```
$ idf.py -p <PORT> monitor
Running idf_monitor in directory [...]/esp/hello_world/build
Executing "python [...]/esp-idf/tools/idf_monitor.py -b 115200 [...]/esp/hello_world/build/hello_world.elf"
--- idf_monitor on <PORT> 115200 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---
ets Jun 8 2016 00:22:57
rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
ets Jun 8 2016 00:22:57
...```

After startup and diagnostic logs scroll up, you should see “Hello world!” printed out by the application.

```
...  
   Hello world!
  Restarting in 10 seconds...
  This is esp32 chip with 2 CPU core(s), WiFi/BT/BLE, silicon revision 1, 2 MB...
  Minimum free heap size: 298968 bytes
  Restarting in 9 seconds...
  Restarting in 8 seconds...
  Restarting in 7 seconds...
```

To exit IDF monitor use the shortcut Ctrl+].

If IDF monitor fails shortly after the upload, or, if instead of the messages above, you see random garbage similar to what is given below, your board is likely using a 26 MHz crystal. Most development board designs use 40 MHz, so ESP-IDF uses this frequency as a default value.
Chapter 1. Get Started

If you have such a problem, do the following:

1. Exit the monitor.
2. Go back to menuconfig.
3. Go to Component config -> Hardware Settings -> Main XTAL Config -> Main XTAL frequency, then change CONFIG_XTAL_FREQ_SEL to 26 MHz.
4. After that, build and flash the application again.

In the current version of ESP-IDF, main XTAL frequencies supported by ESP32 are as follows:

- 26 MHz
- 40 MHz

**Note:** You can combine building, flashing and monitoring into one step by running:

```
idf.py -p PORT flash monitor
```

See also:

- **IDF Monitor** for handy shortcuts and more details on using IDF monitor.
- **idf.py** for a full reference of idf.py commands and options.

**That’s all that you need to get started with ESP32!**

Now you are ready to try some other examples, or go straight to developing your own applications.

**Important:** Some of examples do not support ESP32 because required hardware is not included in ESP32 so it cannot be supported.

If building an example, please check the README file for the Supported Targets table. If this is present including ESP32 target, or the table does not exist at all, the example will work on ESP32.

**Additional Tips**

**Permission issues /dev/ttyUSB0**  With some Linux distributions, you may get the Failed to open port /dev/ttyUSB0 error message when flashing the ESP32. *This can be solved by adding the current user to the dialout group.*

**Python compatibility**  ESP-IDF supports Python 3.7 or newer. It is recommended to upgrade your operating system to a recent version satisfying this requirement. Other options include the installation of Python from sources or the use of a Python version management system such as *pyenv*.

**Start with Board Support Package**  To speed up prototyping on some development boards, you can use Board Support Packages (BSPs), which makes initialization of a particular board as easy as few function calls.

A BSP typically supports all of the hardware components provided on development board. Apart from the pinout definition and initialization functions, a BSP ships with drivers for the external components such as sensors, displays, audio codecs etc.

The BSPs are distributed via *IDF Component Manager*, so they can be found in IDF Component Registry.
Chapter 1. Get Started

Here’s an example of how to add ESP-WROVER-KIT BSP to your project:

```bash
idf.py add-dependency esp_wrover_kit
```

More examples of BSP usage can be found in BSP examples folder.

**Flash Erase**  Erasing the flash is also possible. To erase the entire flash memory you can run the following command:

```bash
idf.py -p PORT erase-flash
```

For erasing the OTA data, if present, you can run this command:

```bash
idf.py -p PORT erase-otadata
```

The flash erase command can take a while to be done. Do not disconnect your device while the flash erasing is in progress.

**Related Documents**  For advanced users who want to customize the install process:

- Updating ESP-IDF tools on Windows
- Establish Serial Connection with ESP32
- Eclipse Plugin
- VSCode Extension
- IDF Monitor

### Updating ESP-IDF tools on Windows

**Install ESP-IDF tools using a script**  From the Windows Command Prompt, change to the directory where ESP-IDF is installed. Then run:

```bash
install.bat
```

For Powershell, change to the directory where ESP-IDF is installed. Then run:

```bash
install.ps1
```

This will download and install the tools necessary to use ESP-IDF. If the specific version of the tool is already installed, no action will be taken. The tools are downloaded and installed into a directory specified during ESP-IDF Tools Installer process. By default, this is `C:\Users\username\.espressif`.

**Add ESP-IDF tools to PATH using an export script**  ESP-IDF tools installer creates a Start menu shortcut for “ESP-IDF Command Prompt”. This shortcut opens a Command Prompt window where all the tools are already available.

In some cases, you may want to work with ESP-IDF in a Command Prompt window which wasn’t started using that shortcut. If this is the case, follow the instructions below to add ESP-IDF tools to PATH.

In the command prompt where you need to use ESP-IDF, change to the directory where ESP-IDF is installed, then execute `export.bat`:

```bash
cd %userprofile%\esp\esp-idf
export.bat
```

Alternatively in the Powershell where you need to use ESP-IDF, change to the directory where ESP-IDF is installed, then execute `export.ps1`:

```bash
cd ~/esp/esp-idf
export.ps1
```
When this is done, the tools will be available in this command prompt.

**Establish Serial Connection with ESP32**

Establishing a serial connection with the ESP32 target device could be done using a USB-to-UART bridge.

Some development boards have the USB-to-UART bridge installed. If a board does not have a bridge then an external bridge may be used.

**USB-to-UART Bridge on Development Board** For boards with an installed USB-to-UART bridge, the connection between the personal computer and the bridge is USB and between the bridge and ESP32 is UART.

![Diagram: Development Board with USB-to-UART Bridge](image)

**External USB-to-UART Bridge** Sometimes the USB-to-UART bridge is external. This is often used in small development boards or finished products when space and costs are crucial.

![Diagram: External USB-to-UART Bridge](image)

**Flash using UART** This section provides guidance on how to establish a serial connection between ESP32 and PC using USB-to-UART Bridge, either installed on the development board or external.

**Connect ESP32 to PC** Connect the ESP32 board to the PC using the USB cable. If device driver does not install automatically, identify USB-to-UART bridge on your ESP32 board (or external converter dongle), search for drivers in internet and install them.

Below is the list of USB to serial converter chips installed on most of the ESP32 boards produced by Espressif together with links to the drivers:
• CP210x: CP210x USB to UART Bridge VCP Drivers
• FTDI: FTDI Virtual COM Port Drivers

Please check the board user guide for specific USB-to-UART bridge chip used. The drivers above are primarily for reference. Under normal circumstances, the drivers should be bundled with an operating system and automatically installed upon connecting the board to the PC.

For devices downloaded using a USB-to-UART bridge, you can run the following command including the optional argument to define the baud rate.

```sh
idf.py -p PORT (-b BAUD) flash
```

You can change the flasher baud rate by replacing `BAUD` with the baud rate you need. The default baud rate is 460800.

**Note:** If the device does not support the auto download mode, you need to get into the download mode manually. To do so, press and hold the **BOOT** button and then press the **RESET** button once. After that release the **BOOT** button.

**Check port on Windows**  Check the list of identified COM ports in the Windows Device Manager. Disconnect ESP32 and connect it back, to verify which port disappears from the list and then shows back again.

Figures below show serial port for ESP32 DevKitC and ESP32 WROVER KIT

![Device Manager](image)

Fig. 61: USB to UART bridge of ESP32-DevKitC in Windows Device Manager

**Check port on Linux and macOS**  To check the device name for the serial port of your ESP32 board (or external converter dongle), run this command two times, first with the board / dongle unplugged, then with plugged in. The port which appears the second time is the one you need:
Fig. 62: Two USB Serial Ports of ESP-WROVER-KIT in Windows Device Manager
## Chapter 1. Get Started

### Linux

```
ls /dev/tty*
```

### macOS

```
ls /dev/cu.*
```

**Note:** macOS users: if you don’t see the serial port then check you have the USB/serial drivers installed. See Section *Connect ESP32 to PC* for links to drivers. For macOS High Sierra (10.13), you may also have to explicitly allow the drivers to load. Open System Preferences -> Security & Privacy -> General and check if there is a message shown here about “System Software from developer …” where the developer name is Silicon Labs or FTDI.

---

### Adding user to dialout on Linux

The currently logged user should have read and write access to the serial port over USB. On most Linux distributions, this is done by adding the user to *dialout* group with the following command:

```
sudo usermod -a -G dialout $USER
```

On Arch Linux this is done by adding the user to *uucp* group with the following command:

```
sudo usermod -a -G uucp $USER
```

Make sure you re-login to enable read and write permissions for the serial port.

### Verify serial connection

Now verify that the serial connection is operational. You can do this using a serial terminal program by checking if you get any output on the terminal after resetting ESP32.

The default console baud rate on ESP32 is 115200.

### Windows and Linux

In this example we will use PuTTY SSH Client that is available for both Windows and Linux. You can use other serial programs and set communication parameters like below.

Run terminal and set identified serial port. Baud rate = 115200 (if needed, change this to the default baud rate of the chip in use), data bits = 8, stop bits = 1, and parity = N. Below are example screenshots of setting the port and such transmission parameters (in short described as 115200-8-1-N) on Windows and Linux. Remember to select exactly the same serial port you have identified in steps above.

Then open serial port in terminal and check, if you see any log printed out by ESP32. The log contents will depend on application loaded to ESP32, see *Example Output*.

**Note:** Close the serial terminal after verification that communication is working. If you keep the terminal session open, the serial port will be inaccessible for uploading firmware later.

### macOS

To spare you the trouble of installing a serial terminal program, macOS offers the *screen* command.

- As discussed in *Check port on Linux and macOS*, run:
  ```
  ls /dev/cu.*
  ```

- You should see similar output:
  ```
  /dev/cu.Bluetooth-Incoming-Port /dev/cu.SLAB_USBtoUART /dev/cu.SLAB_USBtoUART7
  ```

- The output will vary depending on the type and the number of boards connected to your PC. Then pick the device name of your board and run (if needed, change “115200” to the default baud rate of the chip in use):
Fig. 63: Setting Serial Communication in PuTTY on Windows
Fig. 64: Setting Serial Communication in PuTTY on Linux
Chapter 1. Get Started

Screen/Dev/cu.device_name 115200

Replace device_name with the name found running `ls /dev/cu.*`.

- What you are looking for is some log displayed by the `screen`. The log contents will depend on application loaded to ESP32, see Example Output. To exit the `screen` session type Ctrl-A + \.

**Note:** Do not forget to **exit the screen session** after verifying that the communication is working. If you fail to do it and just close the terminal window, the serial port will be inaccessible for uploading firmware later.

**Example Output** An example log is shown below. Reset the board if you do not see anything.

```
est Jun 8 2016 00:22:57
rst:0x5 (DEEPSLEEP_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
est Jun 8 2016 00:22:57
rst:0x7 (TGOWDT_SYS_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configspi: 0, SPIWP:0x00
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0008,len:8
load:0x3fff0010,len:3464
load:0x40078000,len:7828
load:0x40080000,len:252
entry 0x40080034
I (44) boot: ESP-IDF v2.0-rc1-401-gf9fba35 2nd stage bootloader
I (45) boot: compile time 18:48:10
...
```

If you can see readable log output, it means serial connection is working and you are ready to proceed with installation and finally upload an application to ESP32.

**Note:** For some serial port wiring configurations, the serial RTS & DTR pins need to be disabled in the terminal program before the ESP32 will boot and produce serial output. This depends on the hardware itself, most development boards (including all Espressif boards) do not have this issue. The issue is present if RTS & DTR are wired directly to the EN & GPIO0 pins. See the esptool documentation for more details.

If you got here from Step 5. First Steps on ESP-IDF when installing s/w for ESP32 development, then you can continue with Step 5. First Steps on ESP-IDF.

**Flashing Troubleshooting**

**Failed to Connect** If you run the given command and see errors such as “Failed to connect”, there might be several reasons for this. One of the reasons might be issues encountered by `esptool.py`, the utility that is called by the build system to reset the chip, interact with the ROM bootloader, and flash firmware. One simple solution to try is to manually reset as described below. If it does not help, you can find more details about possible issues in the esptool troubleshooting page.

`esptool.py` resets ESP32 automatically by asserting DTR and RTS control lines of the USB-to-UART bridge, i.e., FTDI or CP210x (for more information, see Establish Serial Connection with ESP32). The DTR and RTS control lines are in turn connected to GPIO0 and CHIP_PU (EN) pins of ESP32, thus changes in the voltage levels of DTR and RTS will boot ESP32 into Firmware Download mode. As an example, check the schematic for the ESP32 DevKitC development board.

In general, you should have no problems with the **official esp-idf development boards**. However, `esptool.py` is not able to reset your hardware automatically in the following cases:

-----

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Release v5.1.2

Espressif Systems 107
• Your hardware does not have the DTR and RTS lines connected to GPIO0 and CHIP_PU.
• The DTR and RTS lines are configured differently.
• There are no such serial control lines at all.

Depending on the kind of hardware you have, it may also be possible to manually put your ESP32 board into Firmware Download mode (reset).

• For development boards produced by Espressif, this information can be found in the respective getting started guides or user guides. For example, to manually reset an ESP-IDF development board, hold down the Boot button (GPIO0) and press the EN button (CHIP_PU).
• For other types of hardware, try pulling GPIO0 down.

**IDF Monitor**

IDF Monitor uses the esp-idf-monitor package as a serial terminal program which relays serial data to and from the target device’s serial port. It also provides some IDF-specific features.

IDF Monitor can be launched from an IDF project by running `idf.py monitor`.

**Keyboard Shortcuts**  For easy interaction with IDF Monitor, use the keyboard shortcuts given in the table.
<table>
<thead>
<tr>
<th>Keyboard Shortcut</th>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ctrl+]</td>
<td>Exit the program</td>
<td>Press and follow it by one of the keys given below.</td>
</tr>
<tr>
<td>Ctrl+T</td>
<td>Menu escape key</td>
<td>Press and follow it by one of the keys given below.</td>
</tr>
<tr>
<td>• Ctrl+T</td>
<td>Send the menu character itself to remote</td>
<td></td>
</tr>
<tr>
<td>• Ctrl+]</td>
<td>Send the exit character itself to remote</td>
<td></td>
</tr>
<tr>
<td>• Ctrl+P</td>
<td>Reset target into bootloader to pause app via RTS line</td>
<td>Resets the target, into bootloader via the RTS line (if connected), so that the board runs nothing. Useful when you need to wait for another device to startup.</td>
</tr>
<tr>
<td>• Ctrl+R</td>
<td>Reset target board via RTS</td>
<td>Resets the target board and re-starts the application via the RTS line (if connected).</td>
</tr>
<tr>
<td>• Ctrl+F</td>
<td>Build and flash the project</td>
<td>Pauses idf_monitor to run the project flash target, then resumes idf_monitor. Any changed source files are recompiled and then re-flashed. Target encrypted-flash is run if idf_monitor was started with argument -E.</td>
</tr>
<tr>
<td>• Ctrl+A (or A)</td>
<td>Build and flash the app only</td>
<td>Pauses idf_monitor to run the app-flash target, then resumes idf_monitor. Similar to the flash target, but only the main app is built and re-flashed. Target encrypted-app-flash is run if idf_monitor was started with argument -E.</td>
</tr>
<tr>
<td>• Ctrl+Y</td>
<td>Stop/resume log output printing on screen</td>
<td>Discards all incoming serial data while activated. Allows to quickly pause and examine log output without quitting the monitor.</td>
</tr>
<tr>
<td>• Ctrl+L</td>
<td>Stop/resume log output saved to file</td>
<td>Creates a file in the project directory and the output is written to that file until this is disabled with the same keyboard shortcut (or IDF Monitor exits).</td>
</tr>
<tr>
<td>• Ctrl+I (or I)</td>
<td>Stop/resume printing timestamps</td>
<td>IDF Monitor can print a timestamp in the beginning of each line. The timestamp format can be changed by the --timestamp-format command line argument.</td>
</tr>
<tr>
<td>• Ctrl+H (or H)</td>
<td>Display all keyboard shortcuts</td>
<td></td>
</tr>
<tr>
<td>• Ctrl+X (or X)</td>
<td>Exit the program</td>
<td></td>
</tr>
<tr>
<td>Ctrl+C</td>
<td>Interrupt running application</td>
<td>Pauses IDF Monitor and runs GDB project debugger to debug the application at runtime. This requires :ref:<code>CONFIG_ESP_SYSTEM_GDBSTUB_RUNTIME</code> option to be enabled.</td>
</tr>
</tbody>
</table>

Any keys pressed, other than Ctrl-] and Ctrl-T, will be sent through the serial port.

**IDF-specific features**

**Automatic Address Decoding**  Whenever the chip outputs a hexadecimal address that points to executable code, IDF monitor looks up the location in the source code (file name and line number) and prints the location on the next line in yellow.

If an ESP-IDF app crashes and panics, a register dump and backtrace are produced, such as the following:
Chapter 1. Get Started

Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.

Register dump:
PC   : 0x400f360d  PS  : 0x00060330  A0   : 0x800dbf56  A1   : ...
→0x3ffb7e00
A2   : 0x3ffb136c  A3   : 0x00000005  A4   : 0x00000000  A5   : ...
→0x00000000
A6   : 0x00000000  A7   : 0x00000080  A8   : 0x00000000  A9   : ...
→0x3ffb7dd0
A10  : 0x00000003  A11  : 0x00060f23  A12  : 0x00060f20  A13  : ...
→0x3ffba6d0
A14  : 0x00000047  A15  : 0x000000f  SAR  : 0x00000019  EXCCAUSE:...
→0x0000001d
EXCVADDR: 0x00000000  LBEG : 0x4000c46c  LEND : 0x4000c477  LCOUNT : ...
→0x00000000

Backtrace: 0x400f360d:0x3ffb7e00 0x400dbf56:0x3ffb7e20 0x400dbf5e:0x3ffb7e40...
→0x400dbf82:0x3ffb7e60 0x400d071d:0x3ffb7e90

IDF Monitor adds more details to the dump:

Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.

Register dump:
PC   : 0x400f360d  PS  : 0x00060330  A0   : 0x800dbf56  A1   : ...
→0x3ffb7e00
0x400f360d: do_something_to_crash at /home/gus/esp/32/idf/examples/get-started/
→hello_world/main/../hello_world_main.c:57
(inlined by) inner_dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_
→world/main/../hello_world_main.c:52
A2   : 0x3ffb136c  A3   : 0x00000005  A4   : 0x00000000  A5   : ...
→0x00000000
A6   : 0x00000000  A7   : 0x00000080  A8   : 0x00000000  A9   : ...
→0x3ffb7dd0
A10  : 0x00000003  A11  : 0x00060f23  A12  : 0x00060f20  A13  : ...
→0x3ffba6d0
A14  : 0x00000047  A15  : 0x0000000f  SAR  : 0x00000019  EXCCAUSE:...
→0x0000001d
EXCVADDR: 0x00000000  LBEG : 0x4000c46c  LEND : 0x4000c477  LCOUNT : ...
→0x00000000

Backtrace: 0x400f360d:0x3ffb7e00 0x400dbf56:0x3ffb7e20 0x400dbf5e:0x3ffb7e40...
→0x400dbf82:0x3ffb7e60 0x400d071d:0x3ffb7e90
0x400f360d: do_something_to_crash at /home/gus/esp/32/idf/examples/get-started/
→hello_world/main/../hello_world_main.c:57
(inlined by) inner_dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_
→world/main/../hello_world_main.c:52
0x400dbf56: still_dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_
→world/main/../hello_world_main.c:52
0x400dbf5e: dont_crash at /home/gus/esp/32/idf/examples/get-started/hello_world/
→main/../hello_world_main.c:42
0x400dbf82: app_main at /home/gus/esp/32/idf/examples/get-started/hello_world/main/
→. ./hello_world_main.c:33
0x400d071d: main_task at /home/gus/esp/32/idf/components/esp32/. ./cpu_start.c:254

To decode each address, IDF Monitor runs the following command in the background:

```
xtensa-esp32-elf-addr2line -pfiaC -e build/PROJECT.elf ADDRESS
```

If an address is not matched in the app source code, IDF monitor also checks the ROM code. Instead of printing the source file name and line number, only the function name followed by in ROM is displayed:
Chapter 1. Get Started

The ROM ELF file is automatically loaded from a location based on the IDF_PATH and ESP_ROM_ELF_DIR environment variables. This can be overridden by calling esp_idf_monitor and providing a path to a specific ROM ELF file: python -m esp_idf_monitor --rom-elf-file [path to ROM ELF file].

Note: Set environment variable ESP_MONITOR_DECODE to 0 or call esp_idf_monitor with specific command line option: python -m esp_idf_monitor --disable-address-decoding to disable address decoding.

Target Reset on Connection  By default, IDF Monitor will reset the target when connecting to it. The reset of the target chip is performed using the DTR and RTS serial lines. To prevent IDF Monitor from automatically resetting the target on connection, call IDF Monitor with the --no-reset option (e.g., idf.py monitor --no-reset).

Note: The --no-reset option applies the same behavior even when connecting IDF Monitor to a particular port (e.g., idf.py monitor --no-reset -p [PORT]).

Launching GDB with GDBstub  GDBstub is a useful runtime debugging feature that runs on the target and connects to the host over the serial port to receive debugging commands. GDBstub supports commands such as reading memory and variables, examining call stack frames etc. Although GDBstub is less versatile than JTAG debugging, it does not require any special hardware (such as a JTAG to USB bridge) as communication is done entirely over the serial port.

A target can be configured to run GDBstub in the background by setting the CONFIG_ESP_SYSTEM_PANIC to GDBstub on runtime. GDBstub will run in the background until a Ctrl+C message is sent over the serial port and causes the GDBstub to break (i.e., stop the execution of) the program, thus allowing GDBstub to handle debugging commands.

Furthermore, the panic handler can be configured to run GDBstub on a crash by setting the CONFIG_ESP_SYSTEM_PANIC to GDBstub on panic. When a crash occurs, GDBstub will output a special string pattern over the serial port to indicate that it is running.

In both cases (i.e., sending the Ctrl+C message, or receiving the special string pattern), IDF Monitor will automatically launch GDB in order to allow the user to send debugging commands. After GDB exits, the target is reset via the RTS serial line. If this line is not connected, users can reset their target (by pressing the board’s Reset button).

Note: In the background, IDF Monitor runs the following command to launch GDB:
xtensa-esp32-elf-gdb -ex "set serial baud BAUD" -ex "target remote PORT" -ex...

→ interrupt build/PROJECT.elf :idf_target:`Hello NAME chip`

Output Filtering  IDF monitor can be invoked as `idf.py monitor --print-filter="xyz"`, where

`--print-filter` is the parameter for output filtering. The default value is an empty string, which means that everything is printed.

Restrictions on what to print can be specified as a series of `<tag>:`<log_level>` items where `<tag>` is the tag string and `<log_level>` is a character from the set `{N, E, W, I, D, V, *}` referring to a level for logging.

For example, `PRINT_FILTER="tag1:W"` matches and prints only the outputs written with `ESP_LOGW("tag1", ...) or at lower verbosity level, i.e. ESP_LOGE("tag1", ...)`. Not specifying a `<log_level>` or using * defaults to Verbose level.

Note: Use primary logging to disable at compilation the outputs you do not need through the `logging library`. Output filtering with IDF monitor is a secondary solution which can be useful for adjusting the filtering options without recompiling the application.

Your app tags must not contain spaces, asterisks *, or colons : to be compatible with the output filtering feature.

If the last line of the output in your app is not followed by a carriage return, the output filtering might get confused, i.e., the monitor starts to print the line and later finds out that the line should not have been written. This is a known issue and can be avoided by always adding a carriage return (especially when no output follows immediately afterwards).

Examples of Filtering Rules:

- * can be used to match any tags. However, the string `PRINT_FILTER="*:I tag1:E"` with regards to `tag1` prints errors only, because the rule for `tag1` has a higher priority over the rule for *.
- The default (empty) rule is equivalent to `*:V` because matching every tag at the Verbose level or lower means matching everything.
- "*:N" suppresses not only the outputs from logging functions, but also the prints made by `printf`, etc. To avoid this, use `*:E` or a higher verbosity level.
- Rules "tag1:V", "tag1:V", "tag1:", "tag1:*", and "tag1" are equivalent.
- Rule "tag1:W tag1:E" is equivalent to "tag1:E" because any consequent occurrence of the same tag name overwrites the previous one.
- Rule "tag1:I tag2:W" only prints `tag1` at the Info verbosity level or lower and `tag2` at the Warning verbosity level or lower.
- Rule "tag1:I tag2:W tag3:N" is essentially equivalent to the previous one because `tag3:N` specifies that `tag3` should not be printed.
- `tag3:N in the rule "tag1:I tag2:W tag3:N *:V" is more meaningful because without `tag3:N` the `tag3` messages could have been printed; the errors for `tag1` and `tag2` will be printed at the specified (or lower) verbosity level and everything else will be printed by default.

A More Complex Filtering Example  The following log snippet was acquired without any filtering options:

```
load:0x40078000,len:13564
entry 0x40078d4c
E (31) esp_image: image at 0x30000 has invalid magic byte
W (31) esp_image: image at 0x30000 has invalid SPI mode 255
E (39) boot: Factory app partition is not bootable
I (568) cpu_start: Factory cpu up.
I (569) heap_init: Initializing. RAM available for dynamic allocation:
I (603) cpu_start: Pro cpu start user code
D (309) light_driver: [light_init, 74]:status: 1, mode: 2
```
Chapter 1. Get Started

(continued from previous page)

D (318) vfs: esp_vfs_register_fd_range is successful for range <54; 64) and VFS ID_
→1
I (328) wifi: wifi driver task: 3ffdbf84, prio:23, stack:4096, core=0

The captured output for the filtering options PRINT_FILTER="wifi esp_image:E light_driver:I"
is given below:

E (31) esp_image: image at 0x30000 has invalid magic byte
I (328) wifi: wifi driver task: 3ffdbf84, prio:23, stack:4096, core=0

The options `PRINT_FILTER="light_driver:D esp_image:N boot:N cpu_start:N
vfs:N wifi:N *:V"` show the following output:

load:0x40078000,len:13564
entry 0x40078d4c
I (569) heap_init: Initializing. RAM available for dynamic allocation:
D (309) light_driver: [light_init, 74]:status: 1, mode: 2

Known Issues with IDF Monitor

Issues Observed on Windows

- Arrow keys, as well as some other keys, do not work in GDB due to Windows Console limitations.
- Occasionally, when “idf.py” exits, it might stall for up to 30 seconds before IDF Monitor resumes.
- When “gdb” is run, it might stall for a short time before it begins communicating with the GDBStub.

Standard Toolchain Setup for Linux and macOS

Installation Step by Step  This is a detailed roadmap to walk you through the installation process.

Setting up Development Environment  These are the steps for setting up the ESP-IDF for your ESP32.

- Step 1. Install Prerequisites
- Step 2. Get ESP-IDF
- Step 3. Set up the tools
- Step 4. Set up the environment variables
- Step 5. First Steps on ESP-IDF

Step 1. Install Prerequisites  In order to use ESP-IDF with the ESP32, you need to install some software packages based on your Operating System. This setup guide will help you on getting everything installed on Linux and macOS based systems.

For Linux Users  To compile using ESP-IDF you will need to get the following packages. The command to run depends on which distribution of Linux you are using:

- Ubuntu and Debian:

  ```
  sudo apt-get install git wget flex bison gperf python3 python3-pip python3-
  →venv cmake ninja-build ccache libffi-dev libssl-dev dfu-util libusb-1.0-0
  ```

- CentOS 7 & 8:
Chapter 1. Get Started

```
sudo yum -y update & & sudo yum install git wget flex bison gperf python3 cmake
--ninja-build ccache dfu-util libusbx
```

CentOS 7 is still supported but CentOS version 8 is recommended for a better user experience.

- Arch:
  ```
sudo pacman -S --needed gcc git make flex bison gperf python cmake ninja
--ccache dfu-util libusb
```

Note:
- CMake version 3.16 or newer is required for use with ESP-IDF. Run “tools/idf_tools.py install cmake” to install a suitable version if your OS versions doesn’t have one.
- If you do not see your Linux distribution in the above list then please check its documentation to find out which command to use for package installation.

For macOS Users  ESP-IDF will use the version of Python installed by default on macOS.

- Install CMake & Ninja build:
  - If you have HomeBrew, you can run:
    ```
brew install cmake ninja dfu-util
```
  - If you have MacPorts, you can run:
    ```
sudo port install cmake ninja dfu-util
```
  - Otherwise, consult the CMake and Ninja home pages for macOS installation downloads.
- It is strongly recommended to also install ccache for faster builds. If you have HomeBrew, this can be done via brew install ccache or sudo port install ccache on MacPorts.

Note: If an error like this is shown during any step:

```
```

Then you will need to install the XCode command line tools to continue. You can install these by running xcode-select --install.

Apple M1 Users  If you use Apple M1 platform and see an error like this:

```
WARNING: directory for tool xtensa-esp32-elf version esp-2021r2-patch3-8.4.0 is not present, but tool was not found.
ERROR: tool xtensa-esp32-elf has no installed versions. Please run 'install.sh' to install it.
```

or:

```
zsh: bad CPU type in executable: ~/.espressif/tools/xtensa-esp32-elf/esp-2021r2-patch3-8.4.0/xtensa-esp32-elf/bin/xtensa-esp32-elf-gcc
```

Then you will need to install Apple Rosetta 2 by running

```
/usr/sbin/softwareupdate --install-rosetta --agree-to-license
```
Chapter 1. Get Started

Installing Python 3

Based on macOS Catalina 10.15 release notes, use of Python 2.7 is not recommended and Python 2.7 will not be included by default in future versions of macOS. Check what Python you currently have:

```
python --version
```

If the output is like Python 2.7.17, your default interpreter is Python 2.7. If so, also check if Python 3 isn’t already installed on your computer:

```
python3 --version
```

If the above command returns an error, it means Python 3 is not installed.

Below is an overview of the steps to install Python 3.

- Installing with HomeBrew can be done as follows:
  
  ```
brew install python3
  ```

- If you have MacPorts, you can run:
  
  ```
sudo port install python38
  ```

Step 2. Get ESP-IDF

To build applications for the ESP32, you need the software libraries provided by Espressif in ESP-IDF repository.

To get ESP-IDF, navigate to your installation directory and clone the repository with `git clone`, following instructions below specific to your operating system.

Open Terminal, and run the following commands:

```
mkdir -p ~/esp
cd ~/esp
git clone -b v5.1.2 --recursive https://github.com/espressif/esp-idf.git
```

ESP-IDF will be downloaded into ~/esp/esp-idf.

Consult ESP-IDF Versions for information about which ESP-IDF version to use in a given situation.

Step 3. Set up the tools

Aside from the ESP-IDF, you also need to install the tools used by ESP-IDF, such as the compiler, debugger, Python packages, etc, for projects supporting ESP32.

```
cd ~/esp/esp-idf
./install.sh esp32
```

or with Fish shell

```
cd ~/esp/esp-idf
./install.fish esp32
```

The above commands install tools for ESP32 only. If you intend to develop projects for more chip targets then you should list all of them and run for example:

```
cd ~/esp/esp-idf
./install.sh esp32,esp32s2
```

or with Fish shell

```
cd ~/esp/esp-idf
./install.fish esp32,esp32s2
```

In order to install tools for all supported targets please run the following command:
Chapter 1. Get Started

```bash
cd ~/esp/esp-idf
./install.sh all
```

or with Fish shell

```bash
cd ~/esp/esp-idf
./install.fish all
```

**Note:** For macOS users, if an error like this is shown during any step:

```python
<urlopen error [SSL: CERTIFICATE_VERIFY_FAILED] certificate verify failed: unable...
→ to get local issuer certificate (_ssl.c:xxx)
```

You may run `Install Certificates.command` in the Python folder of your computer to install certificates. For details, see Download Error While Installing ESP-IDF Tools.

**Alternative File Downloads**  The tools installer downloads a number of files attached to GitHub Releases. If accessing GitHub is slow then it is possible to set an environment variable to prefer Espressif’s download server for GitHub asset downloads.

**Note:** This setting only controls individual tools downloaded from GitHub releases, it doesn’t change the URLs used to access any Git repositories.

To prefer the Espressif download server when installing tools, use the following sequence of commands when running `install.sh`:

```bash
cd ~/esp/esp-idf
export IDF_GITHUB_ASSETS="dl.espressif.com/github_assets"
./install.sh
```

**Customizing the tools installation path**  The scripts introduced in this step install compilation tools required by ESP-IDF inside the user home directory: `$HOME/.espressif` on Linux. If you wish to install the tools into a different directory, set the environment variable `IDF_TOOLS_PATH` before running the installation scripts. Make sure that your user account has sufficient permissions to read and write this path.

If changing the `IDF_TOOLS_PATH`, make sure it is set to the same value every time the Install script (install.bat, install.ps1 or install.sh) and an Export script (export.bat, export.ps1 or export.sh) are executed.

**Step 4. Set up the environment variables**  The installed tools are not yet added to the PATH environment variable. To make the tools usable from the command line, some environment variables must be set. ESP-IDF provides another script which does that.

In the terminal where you are going to use ESP-IDF, run:

```bash
. $HOME/esp/esp-idf/export.sh
```

or for fish (supported only since fish version 3.0.0):

```bash
. $HOME/esp/esp-idf/export.fish
```

Note the space between the leading dot and the path!

If you plan to use esp-idf frequently, you can create an alias for executing export.sh:

1. Copy and paste the following command to your shell’s profile (.profile, .bashrc, .zprofile, etc.)
Chapter 1. Get Started

```
alias get_idf='.

2. Refresh the configuration by restarting the terminal session or by running `source [path to profile]`, for example, `source ~/.bashrc`.

Now you can run `get_idf` to set up or refresh the esp-idf environment in any terminal session.

Technically, you can add `export.sh` to your shell’s profile directly; however, it is not recommended. Doing so activates IDF virtual environment in every terminal session (including those where IDF is not needed), defeating the purpose of the virtual environment and likely affecting other software.

Step 5. First Steps on ESP-IDF  Now since all requirements are met, the next topic will guide you on how to start your first project.

This guide will help you on the first steps using ESP-IDF. Follow this guide to start a new project on the ESP32 and build, flash, and monitor the device output.

Note: If you have not yet installed ESP-IDF, please go to Installation and follow the instruction in order to get all the software needed to use this guide.

Start a Project  Now you are ready to prepare your application for ESP32. You can start with `get-started/hello_world` project from `examples` directory in ESP-IDF.

Important: The ESP-IDF build system does not support spaces in the paths to either ESP-IDF or to projects.

Copy the project `get-started/hello_world` to `~/esp` directory:

```
cd ~/esp
cp -r $IDF_PATH/examples/get-started/hello_world
```

Note: There is a range of example projects in the `examples` directory in ESP-IDF. You can copy any project in the same way as presented above and run it. It is also possible to build examples in-place without copying them first.

Connect Your Device  Now connect your ESP32 board to the computer and check under which serial port the board is visible.

Serial ports have the following naming patterns:

- **Linux**: starting with `/dev/tty`
- **macOS**: starting with `/dev/cu`

If you are not sure how to check the serial port name, please refer to Establish Serial Connection with ESP32 for full details.

Note: Keep the port name handy as you will need it in the next steps.

Configure Your Project  Navigate to your `hello_world` directory, set ESP32 as the target, and run the project configuration utility `menuconfig`.

```
cd ~/esp/hello_world
idf.py set-target esp32
idf.py menuconfig
```
Chapter 1. Get Started

After opening a new project, you should first set the target with `idf.py set-target esp32`. Note that existing builds and configurations in the project, if any, will be cleared and initialized in this process. The target may be saved in the environment variable to skip this step at all. See `Select the Target Chip: set-target` for additional information.

If the previous steps have been done correctly, the following menu appears:

![Project configuration - Home window](image)

**Fig. 65: Project configuration - Home window**

You are using this menu to set up project specific variables, e.g., Wi-Fi network name and password, the processor speed, etc. Setting up the project with menuconfig may be skipped for “hello_world”, since this example runs with default configuration.

**Attention:** If you use ESP32-DevKitC board with the ESP32-SOLO-1 module, or ESP32-DevKitM-1 board with the ESP32-MIN1-1(1U) module, please enable single core mode (`CONFIG_FREERTOS_UNICORE`) in menuconfig before flashing examples.

**Note:** The colors of the menu could be different in your terminal. You can change the appearance with the option `--style`. Please run `idf.py menuconfig --help` for further information.

If you are using one of the supported development boards, you can speed up your development by using Board Support Package. See `Additional Tips` for more information.

**Build the Project** Build the project by running:

```shell
idf.py build
```

This command will compile the application and all ESP-IDF components, then it will generate the bootloader, partition table, and application binaries.

```
$ idf.py build
Running cmake in directory /path/to/hello_world/build
Executing "cmake -G Ninja --warn-uninitialized /path/to/hello_world"...
Warn about uninitialized values.
-- Found Git: /usr/bin/git (found version "2.17.0")
-- Building empty aws_iot component due to configuration
-- Component names: ...
```

(continues on next page)
Chapter 1. Get Started

--- Component paths: ...
... (more lines of build system output)

[527/527] Generating hello_world.bin
esptool.py v2.3.1

Project build complete. To flash, run this command:

```bash
..//..//components/esptool_py/esptool/esptool.py -p (PORT) -b 921600 write_flash -
--flash_mode dio --flash_size detect --flash_freq 40m 0x10000 build/hello_world.
--bin build 0x1000 build/bootloader/bootloader.bin 0x8000 build/partition_table/
--partition-table.bin
or run 'idf.py -p PORT flash'
```

If there are no errors, the build will finish by generating the firmware binary `.bin` files.

**Flash onto the Device**  To flash the binaries that you just built for the ESP32 in the previous step, you need to run the following command:

```bash
idf.py -p PORT flash
```

Replace `PORT` with your ESP32 board’s USB port name. If the `PORT` is not defined, the `idf.py` will try to connect automatically using the available USB ports.

For more information on `idf.py` arguments, see `idf.py`.

**Note:** The option `flash` automatically builds and flashes the project, so running `idf.py build` is not necessary.

Encountered Issues While Flashing? See this Flashing Troubleshooting page or Establish Serial Connection with ESP32 for more detailed information.

**Normal Operation**  When flashing, you will see the output log similar to the following:

```bash
...
esptool.py --chip esp32 -p /dev/ttyUSB0 -b 460800 --before=default_reset --
--after=hard_reset write_flash --flash_mode dio --flash_freq 40m --flash_size 2MB.
--0x8000 partition_table/partition-table.bin 0x1000 bootloader/bootloader.bin--
--0x10000 hello_world.bin
esptool.py v3.0-dev
Serial port /dev/ttyUSB0
Connecting..........
Chip is ESP32DWDQ6 (revision 0)
Features: WiFi, BT, Dual Core, Coding Scheme None
Crystal is 40MHz
MAC: 24:0a:c4:05:b9:14
Uploading stub...
Running stub...
Stub running...
Changing baud rate to 460800
Changed.
Configuring flash size...
Compressed 3072 bytes to 103...
Writing at 0x00008000... (100 %)
Wrote 3072 bytes (103 compressed) at 0x000008000 in 0.0 seconds (effective 5962.8...--kbit/s)...
Hash of data verified.
Compressed 26096 bytes to 15408...
Writing at 0x00001000... (100 %)
```

(continues on next page)
Chapter 1. Get Started

Wrote 26096 bytes (15408 compressed) at 0x00001000 in 0.4 seconds (effective 546.7—kbit/s)... Hash of data verified.
Compressed 147104 bytes to 77364...
Writing at 0x00001000... (20 %)
Writing at 0x00014000... (40 %)
Writing at 0x00018000... (60 %)
Writing at 0x0001c000... (80 %)
Writing at 0x00020000... (100 %)
Wrote 147104 bytes (77364 compressed) at 0x000010000 in 1.9 seconds (effective 615. —5 kbit/s)... Hash of data verified.

Leaving...
Hard resetting via RTS pin...
Done

If there are no issues by the end of the flash process, the board will reboot and start up the “hello_world” application.

If you’d like to use the Eclipse or VS Code IDE instead of running idf.py, check out Eclipse Plugin, VSCode Extension.

Monitor the Output To check if “hello_world” is indeed running, type idf.py -p PORT monitor (Do not forget to replace PORT with your serial port name).

This command launches the IDF Monitor application:

```
$ idf.py -p <PORT> monitor
Running idf_monitor in directory [...]/esp/hello_world/build
Executing "python [...]/esp-idf/tools,idf_monitor.py -b 115200 [...]/esp/hello_
-world/build/hello_world.elf"...
--- idf_monitor on <PORT> 115200 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+H followed by Ctrl+H ---
ets Jun 8 2016 00:22:57
rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
ets Jun 8 2016 00:22:57
...`

After startup and diagnostic logs scroll up, you should see “Hello world!” printed out by the application.

```
...  
Hello world! 
Restarting in 10 seconds...  
This is esp32 chip with 2 CPU core(s), WiFi/BT/BLE, silicon revision 1, 2 MB...  
Minimum free heap size: 298968 bytes  
Restarting in 8 seconds...  
Restarting in 7 seconds...
```

To exit IDF monitor use the shortcut Ctrl+].

If IDF monitor fails shortly after the upload, or, if instead of the messages above, you see random garbage similar to what is given below, your board is likely using a 26 MHz crystal. Most development board designs use 40 MHz, so ESP-IDF uses this frequency as a default value.

```
^C
```

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Chapter 1. Get Started

If you have such a problem, do the following:

1. Exit the monitor.
2. Go back to `menuconfig`.
3. Go to `Component config -> Hardware Settings -> Main XTAL Config -> Main XTAL frequency`, then change `CONFIG_XTAL_FREQ_SEL` to 26 MHz.
4. After that, build and flash the application again.

In the current version of ESP-IDF, main XTAL frequencies supported by ESP32 are as follows:

- 26 MHz
- 40 MHz

**Note:** You can combine building, flashing and monitoring into one step by running:

```
idf.py -p PORT flash monitor
```

See also:

- `IDF Monitor` for handy shortcuts and more details on using IDF monitor.
- `idf.py` for a full reference of `idf.py` commands and options.

That’s all that you need to get started with ESP32!

Now you are ready to try some other examples, or go straight to developing your own applications.

**Important:** Some of examples do not support ESP32 because required hardware is not included in ESP32 so it cannot be supported.

If building an example, please check the README file for the **Supported Targets** table. If this is present including ESP32 target, or the table does not exist at all, the example will work on ESP32.

**Additional Tips**

**Permission issues /dev/ttyUSB0**  With some Linux distributions, you may get the **Failed to open port /dev/ttyUSB0** error message when flashing the ESP32. This can be solved by adding the current user to the dialout group.

**Python compatibility**  ESP-IDF supports Python 3.7 or newer. It is recommended to upgrade your operating system to a recent version satisfying this requirement. Other options include the installation of Python from sources or the use of a Python version management system such as **pyenv**.

**Start with Board Support Package**  To speed up prototyping on some development boards, you can use **Board Support Packages (BSPs)**, which makes initialization of a particular board as easy as few function calls.

A BSP typically supports all of the hardware components provided on development board. Apart from the pinout definition and initialization functions, a BSP ships with drivers for the external components such as sensors, displays, audio codecs etc.

The BSPs are distributed via **IDF Component Manager**, so they can be found in **IDF Component Registry**.

**Here’s an example of how to add ESP-WROVER-KIT BSP to your project:**

```
idf.py add-dependency esp_wrover_kit
```

More examples of BSP usage can be found in **BSP examples folder**.
Flash Erase  Erasing the flash is also possible. To erase the entire flash memory you can run the following command:

```
idf.py -p PORT erase-flash
```

For erasing the OTA data, if present, you can run this command:

```
idf.py -p PORT erase-otadata
```

The flash erase command can take a while to be done. Do not disconnect your device while the flash erasing is in progress.

Tip: Updating ESP-IDF  It is recommended to update ESP-IDF from time to time, as newer versions fix bugs and/or provide new features. Please note that each ESP-IDF major and minor release version has an associated support period, and when one release branch is approaching end of life (EOL), all users are encouraged to upgrade their projects to more recent ESP-IDF releases, to find out more about support periods, see ESP-IDF Versions.

The simplest way to do the update is to delete the existing esp-idf folder and clone it again, as if performing the initial installation described in Step 2. Get ESP-IDF.

Another solution is to update only what has changed. *The update procedure depends on the version of ESP-IDF you are using.*

After updating ESP-IDF, execute the Install script again, in case the new ESP-IDF version requires different versions of tools. See instructions at Step 3. Set up the tools.

Once the new tools are installed, update the environment using the Export script. See instructions at Step 4. Set up the environment variables.

Related Documents

- Establish Serial Connection with ESP32
- Eclipse Plugin
- VSCode Extension
- IDF Monitor

1.4  Build Your First Project

If you already have the ESP-IDF installed and not using IDE, you can build your first project from the command line following the Start a Project on Windows or Start a Project on Linux and macOS.

1.5  Uninstall ESP-IDF

If you want to remove ESP-IDF, please follow Uninstall ESP-IDF.
Chapter 2

API Reference

2.1 API Conventions

This document describes conventions and assumptions common to ESP-IDF Application Programming Interfaces (APIs).

ESP-IDF provides several kinds of programming interfaces:

- C functions, structures, enums, type definitions, and preprocessor macros declared in public header files of ESP-IDF components. Various pages in the API Reference section of the programming guide contain descriptions of these functions, structures, and types.
- Build system functions, predefined variables, and options. These are documented in the ESP-IDF CMake Build System API.
- Kconfig options can be used in code and in the build system (CMakeLists.txt) files.
- Host tools and their command line parameters are also part of the ESP-IDF interfaces.

ESP-IDF is made up of multiple components where these components either contain code specifically written for ESP chips, or contain a third-party library (i.e., a third-party component). In some cases, third-party components will contain an “ESP-IDF specific” wrapper in order to provide an interface that is either simpler or better integrated with the rest of ESP-IDF’s features. In other cases, third-party components will present the original API of the underlying library directly.

The following sections explain some of the aspects of ESP-IDF APIs and their usage.

2.1.1 Error Handling

Most ESP-IDF APIs return error codes defined with the `esp_err_t` type. See Error Handling section for more information about error handling approaches. Error Codes Reference contains the list of error codes returned by ESP-IDF components.

2.1.2 Configuration Structures

### Important:
Correct initialization of configuration structures is an important part of making the application compatible with future versions of ESP-IDF.
Chapter 2. API Reference

Most initialization, configuration, and installation functions in ESP-IDF (typically named \_\_init(), \_\_config(), and \_\_install()) take a configuration structure pointer as an argument. For example:

```c
const esp_timer_create_args_t my_timer_args = {
    .callback = &my_timer_callback,
    .arg = callback_arg,
    .name = "my_timer"
};
esp_timer_handle_t my_timer;
esp_err_t err = esp_timer_create(&my_timer_args, &my_timer);
```

These functions never store the pointer to the configuration structure, so it is safe to allocate the structure on the stack. The application must initialize all fields of the structure. The following is incorrect:

```c
esp_timer_create_args_t my_timer_args;
my_timer_args.callback = &my_timer_callback;
/* Incorrect! Fields .arg and .name are not initialized */
esp_timer_create(&my_timer_args, &my_timer);
```

Most ESP-IDF examples use C99 designated initializers for structure initialization since they provide a concise way of setting a subset of fields, and zero-initializing the remaining fields:

```c
const esp_timer_create_args_t my_timer_args = {
    .callback = &my_timer_callback,
    /* Correct, fields .arg and .name are zero-initialized */
};
```

The C++ language supports designated initializer syntax, too, but the initializers must be in the order of declaration. When using ESP-IDF APIs in C++ code, you may consider using the following pattern:

```cpp
/* Correct, fields .dispatch_method, .name and .skip_unhandled_events are zero-
->initialized */
const esp_timer_create_args_t my_timer_args = {
    .callback = &my_timer_callback,
    /* Correct, fields .arg and .name are zero-initialized */
};
```

For more information on designated initializers, see Designated Initializers. Note that C++ language versions older than C++20, which are not the default in the current version of ESP-IDF, do not support designated initializers. If you have to compile code with an older C++ standard than C++20, you may use GCC extensions to produce the following pattern:

```c
esp_timer_create_args_t my_timer_args = {};
/* All the fields are zero-initialized */
my_timer_args.callback = &my_timer_callback;
```

**Default Initializers**

For some configuration structures, ESP-IDF provides macros for setting default values of fields:

```c
httpd_config_t config = HTTPD_DEFAULT_CONFIG();
/* HTTPD_DEFAULT_CONFIG expands to a designated initializer. Now all fields are-
set to the default values, and any field can still be modified: */
config.server_port = 8081;
```

(continues on next page)
httpd_handle_t server;
esp_err_t err = httpd_start(&server, &config);

It is recommended to use default initializer macros whenever they are provided for a particular configuration structure.

### 2.1.3 Private APIs

Certain header files in ESP-IDF contain APIs intended to be used only in ESP-IDF source code rather than by the applications. Such header files often contain `private` or `esp_private` in their name or path. Certain components, such as `hal` only contain private APIs.

Private APIs may be removed or changed in an incompatible way between minor or patch releases.

### 2.1.4 Components in Example Projects

ESP-IDF examples contain a variety of projects demonstrating the usage of ESP-IDF APIs. In order to reduce code duplication in the examples, a few common helpers are defined inside components that are used by multiple examples. This includes components located in `common_components` directory, as well as some of the components located in the examples themselves. These components are not considered to be part of the ESP-IDF API.

It is not recommended to reference these components directly in custom projects (via `EXTRA_COMPONENT_DIRS` build system variable), as they may change significantly between ESP-IDF versions. When starting a new project based on an ESP-IDF example, copy both the project and the common components it depends on out of ESP-IDF, and treat the common components as part of the project. Note that the common components are written with examples in mind, and might not include all the error handling required for production applications. Before using, take time to read the code and understand if it is applicable to your use case.

### 2.1.5 API Stability

ESP-IDF uses Semantic Versioning as explained in the Versioning Scheme.

Minor and bugfix releases of ESP-IDF guarantee compatibility with previous releases. The sections below explain different aspects and limitations to compatibility.

#### Source-level Compatibility

ESP-IDF guarantees source-level compatibility of C functions, structures, enums, type definitions, and preprocessor macros declared in public header files of ESP-IDF components. Source-level compatibility implies that the application source code can be recompiled with the newer version of ESP-IDF without changes.

The following changes are allowed between minor versions and do not break source-level compatibility:

- Deprecating functions (using the `deprecated` attribute) and header files (using a preprocessor `#warning`). Deprecations are listed in ESP-IDF release notes. It is recommended to update the source code to use the newer functions or files that replace the deprecated ones, however, this is not mandatory. Deprecated functions and files can be removed from major versions of ESP-IDF.
- Renaming components, moving source and header files between components—provided that the build system ensures that correct files are still found.
- Renaming Kconfig options. Kconfig system’s `backward compatibility` ensures that the original Kconfig option names can still be used by the application in `sdkconfig` file, CMake files, and source code.
Lack of Binary Compatibility

ESP-IDF does not guarantee binary compatibility between releases. This means that if a precompiled library is built with one ESP-IDF version, it is not guaranteed to work the same way with the next minor or bugfix release. The following are the possible changes that keep source-level compatibility but not binary compatibility:

- Changing numerical values for C enum members.
- Adding new structure members or changing the order of members. See Configuration Structures for tips that help ensure compatibility.
- Replacing an `extern` function with a `static inline` one with the same signature, or vice versa.
- Replacing a function-like macro with a compatible C function.

Other Exceptions from Compatibility

While we try to make upgrading to a new ESP-IDF version easy, there are parts of ESP-IDF that may change between minor versions in an incompatible way. We appreciate issuing reports about any unintended breaking changes that don’t fall into the categories below.

- **Private APIs**.
- **Components in Example Projects**.
- Features clearly marked as “beta”, “preview”, or “experimental”.
- Changes made to mitigate security issues or to replace insecure default behaviors with secure ones.
- Features that were never functional. For example, if it was never possible to use a certain function or an enumeration value, it may get renamed (as part of fixing it) or removed. This includes software features that depend on non-functional chip hardware features.
- Unexpected or undefined behavior that is not documented explicitly may be fixed/changed, such as due to missing validation of argument ranges.
- Location of `Kconfig` options in menuconfig.
- Location and names of example projects.

### 2.2 Application Protocols

#### 2.2.1 ASIO port

Asio is a cross-platform C++ library, see [https://think-async.com/Asio/](https://think-async.com/Asio/). It provides a consistent asynchronous model using a modern C++ approach.

The ESP-IDF component ASIO has been moved from ESP-IDF since version v5.0 to a separate repository:

- ASIO component on GitHub

To add ASIO component in your project, please run `idf.py add-dependency espressif/asio`

#### Hosted Documentation

The documentation can be found on the link below:

- ASIO documentation (English)

#### 2.2.2 ESP-Modbus

The Espressif ESP-Modbus Library (esp-modbus) supports Modbus communication in the networks based on RS485, Wi-Fi, Ethernet interfaces. The ESP-IDF component `freemodbus` has been moved from ESP-IDF since version v5.0 to a separate repository:
Chapter 2. API Reference

- ESP-Modbus component on GitHub

Hosted Documentation

The documentation can be found on the link below:

- ESP-Modbus documentation (English)

Application Example

The examples below demonstrate the ESP-Modbus library of serial, TCP ports for slave and master implementations accordingly.

- protocols/modbus/serial/mb_slave
- protocols/modbus/serial/mb_master
- protocols/modbus/tcp/mb_tcp_slave
- protocols/modbus/tcp/mb_tcp_master

Please refer to the specific example README.md for details.

Protocol References


2.2.3 ESP-MQTT

Overview

ESP-MQTT is an implementation of MQTT protocol client, which is a lightweight publish/subscribe messaging protocol. Now ESP-MQTT supports MQTT v5.0.

Features

- Support MQTT over TCP, SSL with Mbed TLS, MQTT over WebSocket, and MQTT over WebSocket Secure
- Easy to setup with URI
- Multiple instances (multiple clients in one application)
- Support subscribing, publishing, authentication, last will messages, keep alive pings, and all 3 Quality of Service (QoS) levels (it should be a fully functional client)

Application Examples

- protocols/mqtt/tcp: MQTT over TCP, default port 1883
- protocols/mqtt/tls: MQTT over TLS, default port 8883
- protocols/mqtt/tls_ds: MQTT over TLS using digital signature peripheral for authentication, default port 8883
- protocols/mqtt/tls_mutual_auth: MQTT over TLS using certificates for authentication, default port 8883
- protocols/mqtt/tls_psk: MQTT over TLS using pre-shared keys for authentication, default port 8883
- protocols/mqtt/ws: MQTT over WebSocket, default port 80
- protocols/mqtt/wss: MQTT over WebSocket Secure, default port 443
- protocols/mqtt5: Uses ESP-MQTT library to connect to broker with MQTT v5.0
MQTT Message Retransmission

A new MQTT message is created by calling `esp_mqtt_client_publish` or its non blocking counterpart `esp_mqtt_client_enqueue`.

Messages with QoS 0 will be sent only once. QoS 1 and 2 have different behaviors since the protocol requires extra steps to complete the process.

The ESP-MQTT library opts to always retransmit unacknowledged QoS 1 and 2 publish messages to avoid losses in faulty connections, even though the MQTT specification requires the re-transmission only on reconnect with Clean Session flag been set to 0 (set `disable_clean_session` to true for this behavior).

QoS 1 and 2 messages that may need retransmission are always enqueued, but first transmission try occurs immediately if `esp_mqtt_client_publish` is used. A transmission retry for unacknowledged messages will occur after `message_retransmit_timeout`. After `CONFIG_MQTT_OUTBOX_EXPIRED_TIMEOUT_MS` messages will expire and be deleted. If `CONFIG_MQTT_REPORT_DELETED_MESSAGES` is set, an event will be sent to notify the user.

Configuration

The configuration is made by setting fields in `esp_mqtt_client_config_t` struct. The configuration struct has the following sub structs to configure different aspects of the client operation.

- `esp_mqtt_client_config_t::broker_t` - Allow to set address and security verification.
- `esp_mqtt_client_config_t::credentials_t` - Client credentials for authentication.
- `esp_mqtt_client_config_t::session_t` - Configuration for MQTT session aspects.
- `esp_mqtt_client_config_t::network_t` - Networking related configuration.
- `esp_mqtt_client_config_t::task_t` - Allow to configure FreeRTOS task.
- `esp_mqtt_client_config_t::buffer_t` - Buffer size for input and output.

In the following sections, the most common aspects are detailed.

Broker

Address

Broker address can be set by usage of `address` struct. The configuration can be made by usage of `uri` field or the combination of `hostname`, `transport` and `port`. Optionally, `path` could be set, this field is useful in WebSocket connections.

The `uri` field is used in the format `scheme://hostname:port/path`.

- Currently support `mqtt`, `mqtts`, `ws`, `wss` schemes
- MQTT over TCP samples:
  - `mqtt://mqtt.eclipseprojects.io`: MQTT over TCP, default port 1883
  - `mqtt://mqtt.eclipseprojects.io:1884`: MQTT over TCP, port 1884
  - `mqtt://username:password@mqtt.eclipseprojects.io:1884`: MQTT over TCP, port 1884, with username and password
- MQTT over SSL samples:
  - `mqtts://mqtt.eclipseprojects.io`: MQTT over SSL, port 8883
  - `mqtts://mqtt.eclipseprojects.io:8884`: MQTT over SSL, port 8884
- MQTT over WebSocket samples:
  - `ws://mqtt.eclipseprojects.io:80/mqtt`
  - `ws://mqtt.eclipseprojects.io:443/mqtt`
- Minimal configurations:

```c
const esp_mqtt_client_config_t mqtt_cfg = {
  .broker.address.uri = "mqtt://mqtt.eclipseprojects.io",
};
esp_mqtt_client_handle_t client = esp_mqtt_client_init(&mqtt_cfg);
```

(continues on next page)
esp_mqtt_client_register_event(client, ESP_EVENT_ANY_ID, mqtt_event_handler, client);
esp_mqtt_client_start(client);

**Note:** By default MQTT client uses event loop library to post related MQTT events (connected, subscribed, published, etc.).

**Verification**  
For secure connections with TLS used, and to guarantee Broker’s identity, the verification struct must be set. The broker certificate may be set in PEM or DER format. To select DER, the equivalent certificate_len field must be set. Otherwise, a null-terminated string in PEM format should be provided to certificate field.

- Get certificate from server, example: mqtt.eclipseprojects.io
  ```bash
  openssl s_client -showcerts -connect mqtt.eclipseprojects.io:8883 < /dev/null 2> /dev/null | openssl x509 -outform PEM > mqtt_eclipse_org.pem
  ```

- Check the sample application: protocols/mqtt/ssl

- Configuration:
  ```c
  const esp_mqtt_client_config_t mqtt_cfg = {
    .broker = {
      .address.uri = "mqtts://mqtt.eclipseprojects.io:8883",
      .verification.certificate = (const char *)mqtt_eclipse_org_pem_start,
    },
  };
  ```

For details about other fields, please check the [API Reference](https://docs.espressif.com) and [TLS Server verification](https://docs.espressif.com).

**Client Credentials**  
All client related credentials are under the credentials field.

- **username**: pointer to the username used for connecting to the broker, can also be set by URI
- **client_id**: pointer to the client ID, defaults to ESP32_%CHIPID% where %CHIPID% are the last 3 bytes of MAC address in hex format

**Authentication**  
It’s possible to set authentication parameters through the authentication field. The client supports the following authentication methods:

- **password**: use a password by setting
- **certificate** and **key**: mutual authentication with TLS, and both can be provided in PEM or DER format
- **use_secure_element**: use secure element available in ESP32-WROOM-32SE
- **ds_data**: use Digital Signature Peripheral available in some Espressif devices

**Session**  
For MQTT session related configurations, **session** fields should be used.

**Last Will and Testament**  
MQTT allows for a last will and testament (LWT) message to notify other clients when a client ungracefully disconnects. This is configured by the following fields in the last_will struct.

- **topic**: pointer to the LWT message topic
- **msg**: pointer to the LWT message
- **msg_len**: length of the LWT message, required if msg is not null-terminated
- **qos**: quality of service for the LWT message
- **retain**: specifies the retain flag of the LWT message
Change Settings in Project Configuration Menu

The settings for MQTT can be found using `idf.py menu-config`, under Component config > ESP-MQTT Configuration.

The following settings are available:

- `CONFIG_MQTT_PROTOCOL_311`: enable 3.1.1 version of MQTT protocol
- `CONFIG_MQTT_TRANSPORT_SSL` and `CONFIG_MQTT_TRANSPORT_WEBSOCKET`: enable specific MQTT transport layer, such as SSL, WEBSOCKET, and WEBSOCKET_SECURE
- `CONFIG_MQTT_CUSTOM_OUTBOX`: disable default implementation of mqtt_outbox, so a specific implementation can be supplied

Events

The following events may be posted by the MQTT client:

- `MQTT_EVENT_BEFORE_CONNECT`: The client is initialized and about to start connecting to the broker.
- `MQTT_EVENT_CONNECTED`: The client has successfully established a connection to the broker. The client is now ready to send and receive data.
- `MQTT_EVENT_DISCONNECTED`: The client has aborted the connection due to being unable to read or write data, e.g. because the server is unavailable.
- `MQTT_EVENT_SUBSCRIBED`: The broker has acknowledged the client’s subscribe request. The event data will contain the message ID of the subscribe message.
- `MQTT_EVENT_UNSUBSCRIBED`: The broker has acknowledged the client’s unsubscribe request. The event data will contain the message ID of the unsubscribe message.
- `MQTT_EVENT_PUBLISHED`: The broker has acknowledged the client’s publish message. This will only be posted for QoS level 1 and 2, as level 0 does not use acknowledgements. The event data will contain the message ID of the publish message.
- `MQTT_EVENT_DATA`: The client has received a publish message. The event data contains: message ID, name of the topic it was published to, received data and its length. For data that exceeds the internal buffer, multiple `MQTT_EVENT_DATA` will be posted and `current_data_offset` and `total_data_len` from event data updated to keep track of the fragmented message.
- `MQTT_EVENT_ERROR`: The client has encountered an error. The field `error_handle` in the event data contains `error_type` that can be used to identify the error. The type of error will determine which parts of the `error_handle` struct is filled.

API Reference

Header File

- components/mqtt/esp-mqtt/include/mqtt_client.h

Functions

`esp_mqtt_client_handle_t esp_mqtt_client_init(const esp_mqtt_client_config_t *config)`

Creates MQTT client handle based on the configuration.

Parameters

- `config` - MQTT configuration structure

Returns

- `mqtt_client_handle` if successfully created, `NULL` on error

`esp_err_t esp_mqtt_client_set_uri(esp_mqtt_client_handle_t client, const char *uri)`

Sets MQTT connection URI. This API is usually used to overrides the URI configured in `esp_mqtt_client_init`

Parameters

- `client` - MQTT client handle
- `uri` - URI

Returns

- `ESP_FAIL` if URI parse error, `ESP_OK` on success

`esp_err_t esp_mqtt_client_start(esp_mqtt_client_handle_t client)`

Starts MQTT client with already created client handle.

Parameters

- `client` - MQTT client handle
Returns ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL on other error

.esp_err_t esp_mqtt_client_reconnect (esp_mqtt_client_handle_t client)

This api is typically used to force reconnection upon a specific event.

Parameters client –MQTT client handle
Returns ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL if
client is in invalid state

.esp_err_t esp_mqtt_client_disconnect (esp_mqtt_client_handle_t client)

This api is typically used to force disconnection from the broker.

Parameters client –MQTT client handle
Returns ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization

.esp_err_t esp_mqtt_client_stop (esp_mqtt_client_handle_t client)

Stops MQTT client tasks.

• Notes:
  • Cannot be called from the MQTT event handler

Parameters client –MQTT client handle
Returns ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL if
client is in invalid state

int esp_mqtt_client_subscribe_single (esp_mqtt_client_handle_t client, const char *topic, int qos)

Subscribe the client to defined topic with defined qos.

Notes:
• Client must be connected to send subscribe message
• This API is could be executed from a user task or from a MQTT event callback i.e. internal MQTT task
  (API is protected by internal mutex, so it might block if a longer data receive operation is in progress.
• esp_mqtt_client_subscribe could be used to call this function.

Parameters
• client –MQTT client handle
• topic –topic filter to subscribe
• qos –Max qos level of the subscription
Returns message_id of the subscribe message on success -1 on failure -2 in case of full outbox.

int esp_mqtt_client_subscribe_multiple (esp_mqtt_client_handle_t client, const esp_mqtt_topic_t *topic_list, int size)

Subscribe the client to a list of defined topics with defined qos.

Notes:
• Client must be connected to send subscribe message
• This API is could be executed from a user task or from a MQTT event callback i.e. internal MQTT task
  (API is protected by internal mutex, so it might block if a longer data receive operation is in progress.
• esp_mqtt_client_subscribe could be used to call this function.

Parameters
• client –MQTT client handle
• topic_list -List of topics to subscribe
• size –size of topic_list
Returns message_id of the subscribe message on success -1 on failure -2 in case of full outbox.
int esp_mqtt_client_unsubscribe (esp_mqtt_client_handle_t client, const char *topic)
    Unsubscribe the client from defined topic.

    Notes:
    • Client must be connected to send unsubscribe message
    • It is thread safe, please refer to esp_mqtt_client_subscribe_single for details

    Parameters
    • client - MQTT client handle
    • topic -

    Returns message_id of the subscribe message on success -1 on failure

int esp_mqtt_client_publish (esp_mqtt_client_handle_t client, const char *topic, const char *data, int len, int qos, int retain)
    Client to send a publish message to the broker.

    Notes:
    • This API might block for several seconds, either due to network timeout (10s) or if publishing payloads longer than internal buffer (due to message fragmentation)
    • Client doesn’t have to be connected for this API to work, enqueueing the messages with qos>1 (returning -1 for all the qos=0 messages if disconnected). If MQTT_SKIP_PUBLISH_IF_DISCONNECTED is enabled, this API will not attempt to publish when the client is not connected and will always return -1.
    • It is thread safe, please refer to esp_mqtt_client_subscribe for details

    Parameters
    • client - MQTT client handle
    • topic - topic string
    • data - payload string (set to NULL, sending empty payload message
    • len - data length, if set to 0, length is calculated from payload string
    • qos - QoS of publish message
    • retain - retain flag

    Returns message_id of the publish message (for qos 0 message_id will always be zero) on success.
    -1 on failure, -2 in case of full outbox.

int esp_mqtt_client_enqueue (esp_mqtt_client_handle_t client, const char *topic, const char *data, int len, int qos, int retain, bool store)
    Enqueue a message to the outbox, to be sent later. Typically used for messages with qos>0, but could be also used for qos=0 messages if store=true.

    This API generates and stores the publish message into the internal outbox and the actual sending to the network is performed in the mqtt-task context (in contrast to the esp_mqtt_client_publish() which sends the publish message immediately in the user task’s context). Thus, it could be used as a non blocking version of esp_mqtt_client_publish().

    Parameters
    • client - MQTT client handle
    • topic - topic string
    • data - payload string (set to NULL, sending empty payload message
    • len - data length, if set to 0, length is calculated from payload string
    • qos - QoS of publish message
    • retain - retain flag
    • store - if true, all messages are enqueued; otherwise only QoS 1 and QoS 2 are enqueued

    Returns message_id if queued successfully, -1 on failure, -2 in case of full outbox.

esp_err_t esp_mqtt_client_destroy (esp_mqtt_client_handle_t client)
    Destroys the client handle.

    Notes:
    • Cannot be called from the MQTT event handler
Chapter 2. API Reference

Parameters client - MQTT client handle
Returns ESP_OK ESP_ERR_INVALID_ARG on wrong initialization

```
esp_err_t esp_mqtt_set_config(esp_mqtt_client_handle_t client, const esp_mqtt_client_config_t *config)
```
Set configuration structure, typically used when updating the config (i.e. on “before_connect” event.

Parameters
- client - MQTT client handle
- config - MQTT configuration structure
Returns ESP_ERR_NO_MEM if failed to allocate ESP_ERR_INVALID_ARG if conflicts on transport configuration. ESP_OK on success

```
esp_err_t esp_mqtt_client_register_event(esp_mqtt_client_handle_t client, esp_mqtt_event_id_t event, esp_event_handler_t event_handler, void *event_handler_arg)
```
Registers MQTT event.

Parameters
- client - MQTT client handle
- event - event type
- event_handler - handler callback
- event_handler_arg - handlers context
Returns ESP_ERR_NO_MEM if failed to allocate ESP_ERR_INVALID_ARG on wrong initialization ESP_OK on success

```
esp_err_t esp_mqtt_client_unregister_event(esp_mqtt_client_handle_t client, esp_mqtt_event_id_t event, esp_event_handler_t event_handler)
```
Unregisters mqtt event.

Parameters
- client - mqtt client handle
- event - event ID
- event_handler - handler to unregister
Returns ESP_ERR_NO_MEM if failed to allocate ESP_ERR_INVALID_ARG on invalid event ID ESP_OK on success

```
int esp_mqtt_client_get_outbox_size(esp_mqtt_client_handle_t client)
```
Get outbox size.

Parameters client - MQTT client handle
Returns outbox size 0 on wrong initialization

```
esp_err_t esp_mqtt_dispatch_custom_event(esp_mqtt_client_handle_t client, esp_mqtt_event_t *event)
```
Dispatch user event to the mqtt internal event loop.

Parameters
- client - MQTT client handle
- event - MQTT event handle structure
Returns ESP_OK on success ESP_ERR_TIMEOUT if the event couldn’t be queued (ref also CONFIG_MQTT_EVENT_QUEUE_SIZE)

Structures

```
struct esp_mqtt_error_codes
MQTT error code structure to be passed as a contextual information into ERROR event
```
Important: This structure extends esp_tls_last_error error structure and is backward compatible with it (so might be down-casted and treated as esp_tls_last_error error, but recommended to update applications if used this way previously)

Use this structure directly checking error_type first and then appropriate error code depending on the source of the error:
Chapter 2. API Reference

| error_type | related member variables | note | | MQTT_ERROR_TYPE_TCP_TRANSPORT | esp_tls_last_esp_err, esp_tls_stack_err, esp_tls_cert_verify_flags, sock_errno | Error reported from tcp_transport/esp-tls |
| MQTT_ERROR_TYPE_CONNECTION_REFUSED | connect_return_code | Internal error reported from MQTT broker on connection |

**Public Members**

```
esp_err_t esp_tls_last_esp_err
    last esp_err code reported from esp-tls component

int esp_tls_stack_err
    tls specific error code reported from underlying tls stack

int esp_tls_cert_verify_flags
    tls flags reported from underlying tls stack during certificate verification

esp_mqtt_error_type_t error_type
    error type referring to the source of the error

esp_mqtt_connect_return_code_t connect_return_code
    connection refused error code reported from MQTT* broker on connection

int esp_transport_sock_errno
    errno from the underlying socket

struct esp_mqtt_event_t
    MQTT event configuration structure
```

**Public Members**

```
esp_mqtt_event_id_t event_id
    MQTT event type

esp_mqtt_client_handle_t client
    MQTT client handle for this event

char *data
    Data associated with this event

int data_len
    Length of the data for this event

int total_data_len
    Total length of the data (longer data are supplied with multiple events)

int current_data_offset
    Actual offset for the data associated with this event
char *topic
    Topic associated with this event

int topic_len
    Length of the topic for this event associated with this event

int msg_id
    MQTT message id of message

int session_present
    MQTT session_present flag for connection event

esp_mqtt_error_codes_t *error_handle
    esp-mqtt error handle including esp-tls errors as well as internal MQTT errors

bool retain
    Retained flag of the message associated with this event

int qos
    QoS of the messages associated with this event

bool dup
    dup flag of the message associated with this event

esp_mqtt_protocol_ver_t protocol_ver
    MQTT protocol version used for connection, defaults to value from menuconfig

struct esp_mqtt_client_config_t
    MQTT client configuration structure

    • Default values can be set via menuconfig
    • All certificates and key data could be passed in PEM or DER format. PEM format must have a terminating NULL character and the related len field set to 0. DER format requires a related len field set to the correct length.

Public Members

struct esp_mqtt_client_config_t::broker_t broker
    Broker address and security verification

struct esp_mqtt_client_config_t::credentials_t credentials
    User credentials for broker

struct esp_mqtt_client_config_t::session_t session
    MQTT session configuration.

struct esp_mqtt_client_config_t::network_t network
    Network configuration
struct esp_mqtt_client_config_t::task_t task
    FreeRTOS task configuration.

struct esp_mqtt_client_config_t::buffer_t buffer
    Buffer size configuration.

struct esp_mqtt_client_config_t::outbox_config_t outbox
    Outbox configuration.

struct broker_t
    Broker related configuration

Public Members

struct esp_mqtt_client_config_t::broker_t::address_t address
    Broker address configuration

struct esp_mqtt_client_config_t::broker_t::verification_t verification
    Security verification of the broker

struct address_t
    Broker address

    • uri have precedence over other fields
    • If 'uri isn’t set at least hostname, transport and port should.

Public Members

const char *uri
    Complete MQTT broker URI

const char *hostname
    Hostname, to set ipv4 pass it as string

    esp_mqtt_transport_t transport
    Selects transport

const char *path
    Path in the URI

uint32_t port
    MQTT server port

struct verification_t
    Broker identity verification

    If fields are not set broker’s identity isn’t verified. it’s recommended to set the options in this
struct for security reasons.
Public Members

bool use_global_ca_store
    Use a global ca_store, look esp-tls documentation for details.

esp_err_t (*crt_bundle_attach)(void *conf)
    Pointer to ESP x509 Certificate Bundle attach function for the usage of certificate bundles.

const char *certificate
    Certificate data, default is NULL, not required to verify the server.

size_t certificate_len
    Length of the buffer pointed to by certificate.

const struct psk_key_hint *psk_hint_key
    Pointer to PSK struct defined in esp_tls.h to enable PSK authentication (as alternative to certificate verification). PSK is enabled only if there are no other ways to verify broker.

bool skip_cert_common_name_check
    Skip any validation of server certificate CN field, this reduces the security of TLS and makes the MQTT client susceptible to MITM attacks

const char **alpn_protos
    NULL-terminated list of supported application protocols to be used for ALPN

const char *common_name
    Pointer to the string containing server certificate common name. If non-NULL, server certificate CN must match this name. If NULL, server certificate CN must match hostname. This is ignored if skip_cert_common_name_check=true.

struct buffer_t
    Client buffer size configuration
    Client have two buffers for input and output respectively.

Public Members

int size
    size of MQTT send/receive buffer

int out_size
    size of MQTT output buffer. If not defined, defaults to the size defined by buffer_size

struct credentials_t
    Client related credentials for authentication.

Public Members
const char *username

MQTT username

const char *client_id

Set MQTT client identifier. Ignored if set_null_client_id == true. If NULL set the default client id. Default client id is ESP32_CHIPID% where CHIPID% are last 3 bytes of MAC address in hex format.

bool set_null_client_id

Selects a NULL client id

struct esp_mqtt_client_config_t::credentials_t::authentication_t authentication

Client authentication

struct authentication_t

Client authentication

Fields related to client authentication by broker

For mutual authentication using TLS, user could select certificate and key, secure element or digital signature peripheral if available.

Public Members

const char *password

MQTT password

const char *certificate

Certificate for ssl mutual authentication, not required if mutual authentication is not needed. Must be provided with key.

size_t certificate_len

Length of the buffer pointed to by certificate.

const char *key

Private key for SSL mutual authentication, not required if mutual authentication is not needed. If it is not NULL, also certificate has to be provided.

size_t key_len

Length of the buffer pointed to by key.

const char *key_password

Client key decryption password, not PEM nor DER, if provided key_password_len must be correctly set.

int key_password_len

Length of the password pointed to by key_password

bool use_secure_element

Enable secure element, available in ESP32-ROOM-32SE, for SSL connection
void *ds_data
Carrier of handle for digital signature parameters, digital signature peripheral is available in some Espressif devices.

struct network_t
Network related configuration

Public Members

int reconnect_timeout_ms
Reconnect to the broker after this value in milliseconds if auto reconnect is not disabled (defaults to 10s)

int timeout_ms
Abort network operation if it is not completed after this value, in milliseconds (defaults to 10s).

int refresh_connection_after_ms
Refresh connection after this value (in milliseconds)

bool disable_auto_reconnect
Client will reconnect to server (when errors/disconnect). Set disable_auto_reconnect=true to disable

esp_transport_handle_t transport
Custom transport handle to use. Warning: The transport should be valid during the client lifetime and is destroyed when esp_mqtt_client_destroy is called.

struct ifreq *if_name
The name of interface for data to go through. Use the default interface without setting

struct outbox_config_t
Client outbox configuration options.

Public Members

uint64_t limit
Size limit for the outbox in bytes.

struct session_t
MQTT Session related configuration

Public Members

struct esp_mqtt_client_config_t::session_t::last_will_t last_will
Last will configuration
bool disabled_clean_session

MQTT clean session, default clean_session is true

int keepalive

MQTT keepalive, default is 120 seconds When configuring this value, keep in mind that the client attempts to communicate with the broker at half the interval that is actually set. This conservative approach allows for more attempts before the broker’s timeout occurs

bool disable_keepalive

Set disable_keepalive=true to turn off keep-alive mechanism, keepalive is active by default. Note: setting the config value keepalive to 0 doesn’t disable keepalive feature, but uses a default keepalive period

esp_mqtt_protocol_ver_t protocol_ver

MQTT protocol version used for connection.

int message_retransmit_timeout

timeout for retransmitting of failed packet

struct last_will_t

Last Will and Testament message configuration.

Public Members

cnst char *topic

LWT (Last Will and Testament) message topic

cnst char *msg

LWT message, may be NULL terminated

int msg_len

LWT message length, if msg isn’t NULL terminated must have the correct length

int qos

LWT message QoS

int retain

LWT retained message flag

struct task_t

Client task configuration

Public Members

int priority

MQTT task priority
int stack_size

MQTT task stack size

struct topic_t
    Topic definition struct

Public Members

const char *filter
    Topic filter to subscribe

int qos
    Max QoS level of the subscription

Macros

MQTT_ERROR_TYPE_ESP_TLS
    MQTT_ERROR_TYPE_TCP_TRANSPORT error type hold all sorts of transport layer errors, including ESP-TLS error, but in the past only the errors from MQTT_ERROR_TYPE_ESP_TLS layer were reported, so the ESP-TLS error type is re-defined here for backward compatibility

esp_mqtt_client_subscribe(client_handle, topic_type, qos_or_size)
    Convenience macro to select subscribe function to use.

Notes:
• Usage of esp_mqtt_client_subscribe_single is the same as previous esp_mqtt_client_subscribe, refer to it for details.

Parameters
• client_handle – MQTT client handle
• topic_type – Needs to be char* for single subscription or esp_mqtt_topic_t for multiple topics
• qos_or_size – It’s either a qos when subscribing to a single topic or the size of the subscription array when subscribing to multiple topics.

Returns message_id of the subscribe message on success -1 on failure -2 in case of full outbox.

Type Definitions

typedef struct esp_mqtt_client *esp_mqtt_client_handle_t

typedef enum esp_mqtt_event_id_t esp_mqtt_event_id_t
    MQTT event types,
    User event handler receives context data in esp_mqtt_event_t structure with
    • client - MQTT client handle
    • various other data depending on event type

typedef enum esp_mqtt_connect_return_code_t esp_mqtt_connect_return_code_t
    MQTT connection error codes propagated via ERROR event

typedef enum esp_mqtt_error_type_t esp_mqtt_error_type_t
    MQTT connection error codes propagated via ERROR event
typedef enum esp_mqtt_transport_t esp_mqtt_transport_t

typedef enum esp_mqtt_protocol_ver_t esp_mqtt_protocol_ver_t
    MQTT protocol version used for connection

typedef struct esp_mqtt_error_codes esp_mqtt_error_codes_t
    MQTT error code structure to be passed as a contextual information into ERROR event
    Important: This structure extends esp_tls_last_error error structure and is backward compatible with
    it (so might be down-casted and treated as esp_tls_last_error error, but recommended to update
    applications if used this way previously)
    Use this structure directly checking error_type first and then appropriate error code depending on the source
    of the error:
        | error_type   | related member variables | note                | | MQTT_ERROR_TYPE_TCP_TRANSPORT | esp_tls_last_esp_err, esp_tls_stack_err, esp_tls_cert_verify_flags, sock_errno | Error reported from
        |              |                         |                    | tcp_transport/esp-tls | MQTT_ERROR_TYPE_CONNECTION_REFUSED | connect_return_code | Internal
        |              |                         |                    |               | error reported from MQTT broker on connection |

typedef struct esp_mqtt_event_t esp_mqtt_event_t
    MQTT event configuration structure

typedef esp_mqtt_event_t *esp_mqtt_event_handle_t

typedef struct esp_mqtt_client_config_t esp_mqtt_client_config_t
    MQTT client configuration structure
    • Default values can be set via menuconfig
    • All certificates and key data could be passed in PEM or DER format. PEM format must have a terminating
      NULL character and the related len field set to 0. DER format requires a related len field set to the correct
      length.

typedef struct topic_t esp_mqtt_topic_t
    Topic definition struct

Enumeration
enum esp_mqtt_event_id_t
    MQTT event types.
    User event handler receives context data in esp_mqtt_event_t structure with
        • client - MQTT client handle
        • various other data depending on event type
    Values:

    enumerator MQTT_EVENT_ANY
    enumerator MQTT_EVENT_ERROR
        on error event, additional context: connection return code, error handle from esp_tls (if supported)
Chapter 2. API Reference

enumerator MQTT_EVENT_CONNECTED
    connected event, additional context: session_present flag

enumerator MQTT_EVENT_DISCONNECTED
    disconnected event

enumerator MQTT_EVENT_SUBSCRIBED
    subscribed event, additional context:
    • msg_id message id
    • error_handle error_type in case subscribing failed
    • data pointer to broker response, check for errors.
    • data_len length of the data for this event

enumerator MQTT_EVENT_UNSUBSCRIBED
    unsubscribed event, additional context: msg_id

enumerator MQTT_EVENT_PUBLISHED
    published event, additional context: msg_id

enumerator MQTT_EVENT_DATA
    data event, additional context:
    • msg_id message id
    • topic pointer to the received topic
    • topic_len length of the topic
    • data pointer to the received data
    • data_len length of the data for this event
    • current_data_offset offset of the current data for this event
    • total_data_len total length of the data received
    • retain retain flag of the message
    • qos QoS level of the message
    • dup dup flag of the message Note: Multiple MQTT_EVENT_DATA could be fired for one message, if it is longer than internal buffer. In that case only first event contains topic pointer and length, other contain data only with current data length and current data offset updating.

enumerator MQTT_EVENT_BEFORE_CONNECT
    The event occurs before connecting

enumerator MQTT_EVENT_DELETED
    Notification on delete of one message from the internal outbox, if the message couldn’t have been sent and acknowledged before expiring defined in OUTBOX_EXPIRED_TIMEOUT_MS. (events are not posted upon deletion of successfully acknowledged messages)
    • This event id is posted only if MQTT_REPORT_DELETED_MESSAGES==1
    • Additional context: msg_id (id of the deleted message).

enumerator MQTT_USER_EVENT
    Custom event used to queue tasks into mqtt event handler All fields from the esp_mqtt_event_t type could be used to pass an additional context data to the handler.

enum esp_mqtt_connect_return_code_t
    MQTT connection error codes propagated via ERROR event

Values:
Chapter 2. API Reference

enumerator **MQTT_CONNECTION_ACCEPTED**
Connection accepted

enumerator **MQTT_CONNECTION_REFUSE_PROTOCOL**
MQTT connection refused reason: Wrong protocol

enumerator **MQTT_CONNECTION_REFUSE_ID_REJECTED**
MQTT connection refused reason: ID rejected

enumerator **MQTT_CONNECTION_REFUSE_SERVER_UNAVAILABLE**
MQTT connection refused reason: Server unavailable

enumerator **MQTT_CONNECTION_REFUSE_BAD_USERNAME**
MQTT connection refused reason: Wrong user

enumerator **MQTT_CONNECTION_REFUSE_NOT_AUTHORIZED**
MQTT connection refused reason: Wrong username or password

enum **esp_mqtt_error_type_t**
MQTT connection error codes propagated via ERROR event

Values:

enumerator **MQTT_ERROR_TYPE_NONE**

enumerator **MQTT_ERROR_TYPE_TCP_TRANSPORT**

enumerator **MQTT_ERROR_TYPE_CONNECTION_REFUSED**

enumerator **MQTT_ERROR_TYPE_SUBSCRIBE_FAILED**

enum **esp_mqtt_transport_t**

Values:

enumerator **MQTT_TRANSPORT_UNKNOWN**

enumerator **MQTT_TRANSPORT_OVER_TCP**
MQTT over TCP, using scheme: MQTT

enumerator **MQTT_TRANSPORT_OVER_SSL**
MQTT over SSL, using scheme: MQTTs

enumerator **MQTT_TRANSPORT_OVER_WS**
MQTT over Websocket, using scheme: ws

enumerator **MQTT_TRANSPORT_OVER_WSS**
MQTT over Websocket Secure, using scheme: wss
enum esp_mqtt_protocol_ver_t

MQTT protocol version used for connection

Values:

enumerator MQTT_PROTOCOL_UNDEFINED
enumerator MQTT_PROTOCOL_V_3_1
enumerator MQTT_PROTOCOL_V_3_1_1
enumerator MQTT_PROTOCOL_V_5

2.2.4 ESP-TLS

Overview

The ESP-TLS component provides a simplified API interface for accessing the commonly used TLS functionality. It supports common scenarios like CA certification validation, SNI, ALPN negotiation, non-blocking connection among others. All the configuration can be specified in the esp_tls_cfg_t data structure. Once done, TLS communication can be conducted using the following APIs:

- esp_tls_init(): for initializing the TLS connection handle.
- esp_tls_conn_new_sync(): for opening a new blocking TLS connection.
- esp_tls_conn_new_async(): for opening a new non-blocking TLS connection.
- esp_tls_conn_read(): for reading from the connection.
- esp_tls_conn_write(): for writing into the connection.
- esp_tls_conn_destroy(): for freeing up the connection.

Any application layer protocol like HTTP1, HTTP2 etc can be executed on top of this layer.

Application Example

Simple HTTPS example that uses ESP-TLS to establish a secure socket connection: protocols/https_request.

Tree structure for ESP-TLS component

```
├── esp_tls.c
├── esp_tls.h
├── esp_tls_mbedtls.c
├── esp_tls_wolfssl.c
└── private_include
    ├── esp_tls_mbedtls.h
    └── esp_tls_wolfssl.h
```

The ESP-TLS component has a file esp-tls/esp_tls.h which contain the public API headers for the component. Internally ESP-TLS component uses one of the two SSL/TLS Libraries between mbedtls and wolfssl for its operation. API specific to mbedtls are present in esp-tls/private_include/esp_tls_mbedtls.h and API specific to wolfssl are present in esp-tls/private_include/esp_tls_wolfssl.h.
TLS Server verification

The ESP-TLS provides multiple options for TLS server verification on the client side. The ESP-TLS client can verify the server by validating the peer’s server certificate or with the help of pre-shared keys. The user should select only one of the following options in the esp_tls_cfg_t structure for TLS server verification. If no option is selected then client will return a fatal error by default at the time of the TLS connection setup.

- **cacert_buf** and **cacert_bytes**: The CA certificate can be provided in a buffer to the esp_tls_cfg_t structure. The ESP-TLS will use the CA certificate present in the buffer to verify the server. The following variables in esp_tls_cfg_t structure must be set.
  - cacert_buf - pointer to the buffer which contains the CA cert.
  - cacert_bytes - size of the CA certificate in bytes.

- **use_global_ca_store**: The global_ca_store can be initialized and set at once. Then it can be used to verify the server for all the ESP-TLS connections which have set use_global_ca_store = true in their respective esp_tls_cfg_t structure. See API Reference section below on information regarding different API used for initializing and setting up the global_ca_store.

- **crt_bundle_attach**: The ESP x509 Certificate Bundle API provides an easy way to include a bundle of custom x509 root certificates for TLS server verification. More details can be found at ESP x509 Certificate Bundle.

- **psk_hint_key**: To use pre-shared keys for server verification, CONFIG_ESP_TLS_PSK_VERIFICATION should be enabled in the ESP-TLS menuconfig. Then the pointer to PSK hint and key should be provided to the esp_tls_cfg_t structure. The ESP-TLS will use the PSK for server verification only when no other option regarding the server verification is selected.

- **skip server verification**: This is an insecure option provided in the ESP-TLS for testing purpose. The option can be set by enabling CONFIG_ESP_TLS_INSECURE and CONFIG_ESP_TLS_SKIP_SERVER_CERT_VERIFY in the ESP-TLS menuconfig. When this option is enabled the ESP-TLS will skip server verification by default when no other options for server verification are selected in the esp_tls_cfg_t structure. WARNING:Enabling this option comes with a potential risk of establishing a TLS connection with a server which has a fake identity, provided that the server certificate is not provided either through API or other mechanism like ca_store etc.

ESP-TLS Server cert selection hook

The ESP-TLS component provides an option to set the server cert selection hook when using the mbedTLS stack. This provides an ability to configure and use a certificate selection callback during server handshake, to select a certificate to present to the client based on the TLS extensions supplied in the client hello (alpn, sni, etc). To enable this feature, please enable CONFIG_ESP_TLS_SERVER_CERT_SELECT_HOOK in the ESP-TLS menuconfig. The certificate selection callback can be configured in the esp_tls_cfg_t structure as follows:

```c
int cert_selection_callback(mbedtls_ssl_context *ssl)
{
    /* Code that the callback should execute */
    return 0;
}

esp_tls_cfg_t cfg = {
    cert_select_cb = cert_section_callback,
};
```

Underlying SSL/TLS Library Options

The ESP-TLS component has an option to use mbedtls or wolfssl as their underlying SSL/TLS library. By default only mbedtls is available and is used, wolfssl SSL/TLS library is available publicly at https://github.com/espressif/esp-wolfssl. The repository provides wolfssl component in binary format, it also provides few examples which are useful for understanding the API. Please refer the repository README.md for information on licensing and other options. Please see below option for using wolfssl in your project.
How to use wolfssl with ESP-IDF

There are two ways to use wolfssl in your project

1) Directly add wolfssl as a component in your project with following three commands:

```
(First change directory (cd) to your project directory)
mkdir components
cd components
git clone https://github.com/espressif/esp-wolfssl.git
```

2) Add wolfssl as an extra component in your project.

- Download wolfssl with:

  ```
git clone https://github.com/espressif/esp-wolfssl.git
  ```

- Include esp-wolfssl in ESP-IDF with setting EXTRA_COMPONENT_DIRS in CMakeLists.txt of your project as done in wolfssl/examples. For reference see Optional Project variables in build-system.

After above steps, you will have option to choose wolfssl as underlying SSL/TLS library in configuration menu of your project as follows:

```
idf.py menuconfig -> ESP-TLS -> choose SSL/TLS Library -> mbedtls/wolfssl
```

Comparison between mbedtls and wolfssl

The following table shows a typical comparison between wolfssl and mbedtls when protocols/https_request example (which has server authentication) was run with both SSL/TLS libraries and with all respective configurations set to default. (mbedtls IN_CONTENT length and OUT_CONTENT length were set to 16384 bytes and 4096 bytes respectively)

<table>
<thead>
<tr>
<th>Property</th>
<th>Wolfssl</th>
<th>Mbedtls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Heap Consumed</td>
<td>~19 Kb</td>
<td>~37 Kb</td>
</tr>
<tr>
<td>Task Stack Used</td>
<td>~2.2 Kb</td>
<td>~3.6 Kb</td>
</tr>
<tr>
<td>Bin size</td>
<td>~858 Kb</td>
<td>~736 Kb</td>
</tr>
</tbody>
</table>

Note: These values are subject to change with change in configuration options and version of respective libraries.

ATECC608A (Secure Element) with ESP-TLS

ESP-TLS provides support for using ATECC608A cryptoauth chip with ESP32-WROOM-32SE. Use of ATECC608A is supported only when ESP-TLS is used with mbedtls as its underlying SSL/TLS stack. ESP-TLS uses mbedtls as its underlying TLS/SSL stack by default unless changed manually.

Note: ATECC608A chip on ESP32-WROOM-32SE must be already configured and provisioned, for details refer esp_cryptoauth_utility

To enable the secure element support, and use it in your project for TLS connection, you will have to follow below steps
1) Add esp-cryptoauthlib in your project, for details please refer esp-cryptoauthlib with ESP_IDF
2) Enable following menuconfig option:

```
menuconfig->Component config->ESP-TLS->Use Secure Element (ATECC608A) with ESP-TLS
```

3) Select type of ATECC608A chip with following option:

```
menuconfig->Component config->esp-cryptoauthlib->Choose Type of ATECC608A chip
```

4) Enable use of ATECC608A in ESP-TLS by providing following config option in `esp_tls_cfg_t`

```
esp_tls_cfg_t cfg = {
    /* other configurations options */
    .use_secure_element = true,
};
```

### API Reference

#### Header File

- components/esp-tls/esp_tls.h

#### Functions

- `esp_tls_t *esp_tls_init (void)`
  
  Create TLS connection.

  This function allocates and initializes esp-tls structure handle.

  **Returns**
  
  Tls Pointer to esp-tls as esp-tls handle if successfully initialized, NULL if allocation error

- `esp_tls_t *esp_tls_conn_http_new (const char *url, const esp_tls_cfg_t *cfg)`

  Create a new blocking TLS/SSL connection with a given “HTTP” url.

  **Parameters**

  - **url** - [in] url of host.
  - **cfg** - [in] TLS configuration as esp_tls_cfg_t. If you wish to open non-TLS connection, keep this NULL. For TLS connection, a pass pointer to `esp_tls_cfg_t`. At a minimum, this structure should be zero-initialized.

  **Returns**

  Pointer to esp_tls_t, or NULL if connection couldn’t be opened.

- `int esp_tls_conn_new_sync (const char *hostname, int hostlen, int port, const esp_tls_cfg_t *cfg, esp_tls_t *tls)`

  Create a new blocking TLS/SSL connection.

  This function establishes a TLS/SSL connection with the specified host in blocking manner.

  **Parameters**

  - **hostname** - [in] Hostname of the host.
  - **hostlen** - [in] Length of hostname.
  - **port** - [in] Port number of the host.
  - **cfg** - [in] TLS configuration as esp_tls_cfg_t. If you wish to open non-TLS connection, keep this NULL. For TLS connection, a pass pointer to esp_tls_cfg_t. At a minimum, this structure should be zero-initialized.

  **Returns**

  Pointer to esp-tls as esp-tls handle.
• -1 If connection establishment fails.
• 1 If connection establishment is successful.
• 0 If connection state is in progress.

int esp_tls_conn_http_new_sync (const char *url, const esp_tls_cfg_t *cfg, esp_tls_t *tls)
Create a new blocking TLS/SSL connection with a given “HTTP” url.

The behaviour is same as esp_tls_conn_new_sync() API. However this API accepts host’s url.

Parameters
• url –[in] url of host.
• cfg –[in] TLS configuration as esp_tls_cfg_t. If you wish to open non-TLS connection, keep this NULL. For TLS connection, a pass pointer to ‘esp_tls_cfg_t’ . At a minimum, this structure should be zero-initialized.
• tls –[in] Pointer to esp-tls as esp-tls handle.

Returns
• -1 If connection establishment fails.
• 1 If connection establishment is successful.
• 0 If connection state is in progress.

int esp_tls_conn_new_async (const char *hostname, int hostlen, int port, const esp_tls_cfg_t *cfg, esp_tls_t *tls)
Create a new non-blocking TLS/SSL connection.

This function initiates a non-blocking TLS/SSL connection with the specified host, but due to its non-blocking nature, it doesn’t wait for the connection to get established.

Parameters
• hostname –[in] Hostname of the host.
• hostlen –[in] Length of hostname.
• port –[in] Port number of the host.
• cfg –[in] TLS configuration as esp_tls_cfg_t. non_block member of this structure should be set to be true.
• tls –[in] pointer to esp-tls as esp-tls handle.

Returns
• -1 If connection establishment fails.
• 0 If connection establishment is in progress.
• 1 If connection establishment is successful.

int esp_tls_conn_http_new_async (const char *url, const esp_tls_cfg_t *cfg, esp_tls_t *tls)
Create a new non-blocking TLS/SSL connection with a given “HTTP” url.

The behaviour is same as esp_tls_conn_new_async() API. However this API accepts host’s url.

Parameters
• url –[in] url of host.
• cfg –[in] TLS configuration as esp_tls_cfg_t.
• tls –[in] pointer to esp-tls as esp-tls handle.

Returns
• -1 If connection establishment fails.
• 0 If connection establishment is in progress.
• 1 If connection establishment is successful.

ssize_t esp_tls_conn_write (esp_tls_t *tls, const void *data, size_t datalen)
Write from buffer ‘data’ into specified tls connection.

Parameters
• tls –[in] pointer to esp-tls as esp-tls handle.
• data –[in] Buffer from which data will be written.
• datalen –[in] Length of data buffer.

Returns
• >=0 if write operation was successful, the return value is the number of bytes actually written to the TLS/SSL connection.
Chapter 2. API Reference

- <0 if write operation was not successful, because either an error occurred or an action must be taken by the calling process.
- ESP_TLS_ERR_SSL_WANT_READ/ ESP_TLS_ERR_SSL_WANT_WRITE. If the handshake is incomplete and waiting for data to be available for reading. In this case this functions needs to be called again when the underlying transport is ready for operation.

\[
\text{ssize_t esp_tls_conn_read}(\text{esp_tls_t } *\text{tls}, \text{void } *\text{data}, \text{size_t } \text{datalen})
\]
Read from specified tls connection into the buffer ‘data’.

**Parameters**

- **tls** – [in] pointer to esp-tls as esp-tls handle.
- **data** – [in] Buffer to hold read data.
- **datalen** – [in] Length of data buffer.

**Returns**

- >0 if read operation was successful, the return value is the number of bytes actually read from the TLS/SSL connection.
- 0 if read operation was not successful. The underlying connection was closed.
- <0 if read operation was not successful, because either an error occurred or an action must be taken by the calling process.

\[
\text{int esp_tls_conn_destroy}(\text{esp_tls_t } *\text{tls})
\]
Close the TLS/SSL connection and free any allocated resources.

This function should be called to close each tls connection opened with esp_tls_conn_new_sync() (or esp_tls_conn_http_new_sync()) and esp_tls_conn_new_async() (or esp_tls_conn_http_new_async()) APIs.

**Parameters**

- **tls** – [in] pointer to esp-tls as esp-tls handle.

**Returns**

- 0 on success
- -1 if socket error or an invalid argument

\[
\text{ssize_t esp_tls_get_bytes_avail}(\text{esp_tls_t } *\text{tls})
\]
Return the number of application data bytes remaining to be read from the current record.

This API is a wrapper over mbedtls’s mbedtls_ssl_get_bytes_avail() API.

**Parameters**

- **tls** – [in] pointer to esp-tls as esp-tls handle.

**Returns**

- -1 in case of invalid arg
- bytes available in the application data record read buffer

\[
\text{esp_err_t esp_tls_get_conn_sockfd}(\text{esp_tls_t } *\text{tls}, \text{int } \text{sockfd})
\]
Returns the connection socket file descriptor from esp_tls session.

**Parameters**

- **tls** – [in] handle to esp_tls context
- **sockfd** – [out] int pointer to sockfd value.

**Returns**

- ESP_OK on success and value of sockfd will be updated with socket file descriptor for connection
- ESP_ERR_INVALID_ARG if (tls == NULL || sockfd == NULL)

\[
\text{esp_err_t esp_tls_set_conn_sockfd}(\text{esp_tls_t } *\text{tls}, \text{int } \text{sockfd})
\]
Sets the connection socket file descriptor for the esp_tls session.

**Parameters**

- **tls** – [in] handle to esp_tls context
- **sockfd** – [in] sockfd value to set.

**Returns**

- ESP_OK on success and value of sockfd for the tls connection shall updated with the provided value
- ESP_ERR_INVALID_ARG if (tls == NULL || sockfd < 0)

\[
\text{esp_err_t esp_tls_get_conn_state}(\text{esp_tls_t } *\text{tls}, \text{esp_tls_conn_state_t } *\text{conn_state})
\]
Gets the connection state for the esp_tls session.

**Parameters**
tls – [in] handle to esp_tls context
conn_state – [out] pointer to the connection state value.

Returns
- ESP_OK on success and value of sockfd for the tls connection shall updated with the provided value
- ESP_ERR_INVALID_ARG (Invalid arguments)

esp_err_t esp_tls_set_conn_state (esp_tls_t *tls, esp_tls_conn_state_t conn_state)
Sets the connection state for the esp_tls session.

Parameters
- tls – [in] handle to esp_tls context

Returns
- ESP_OK on success and value of sockfd for the tls connection shall updated with the provided value
- ESP_ERR_INVALID_ARG (Invalid arguments)

esp_err_t esp_tls_set_global_ca_store (void)
Create a global CA store, initially empty.

This function should be called if the application wants to use the same CA store for multiple connections. This function initialises the global CA store which can be then set by calling esp_tls_set_global_ca_store(). To be effective, this function must be called before any call to esp_tls_set_global_ca_store().

Returns
- ESP_OK if creating global CA store was successful.
- ESP_ERR_NO_MEM if an error occurred when allocating the mbedTLS resources.

esp_err_t esp_tls_set_global_ca_store (const unsigned char *cacert_pem_buf, const unsigned int cacert_pem_bytes)
Set the global CA store with the buffer provided in pem format.

This function should be called if the application wants to set the global CA store for multiple connections i.e. to add the certificates in the provided buffer to the certificate chain. This function implicitly calls esp_tls_init_global_ca_store() if it has not already been called. The application must call this function before calling esp_tls_conn_new().

Parameters
- cacert_pem_buf – [in] Buffer which has certificates in pem format. This buffer is used for creating a global CA store, which can be used by other tls connections.

Returns
- ESP_OK if adding certificates was successful.
- Other if an error occurred or an action must be taken by the calling process.

void esp_tls_free_global_ca_store (void)
Free the global CA store currently being used.

The memory being used by the global CA store to store all the parsed certificates is freed up. The application can call this API if it no longer needs the global CA store.

esp_err_t esp_tls_get_and_clear_last_error (esp_tls_error_handle_t h, int *esp_tls_code, int *esp_tls_flags)
Returns last error in esp_tls with detailed mbedtls related error codes. The error information is cleared internally upon return.

Parameters
**esp_tls_code** - [out] last error code returned from mbedtls api (set to zero if none)

This pointer could be NULL if caller does not care about esp_tls_code

**esp_tls_flags** - [out] last certification verification flags (set to zero if none) This pointer could be NULL if caller does not care about esp_tls_code

**Returns**

- ESP_ERR_INVALID_STATE if invalid parameters
- ESP_OK (0) if no error occurred
- specific error code (based on ESP_ERR_ESP_TLS_BASE) otherwise

```c
esp_err_t esp_tls_get_and_clear_error_type(esp_tls_error_handle_t h, esp_tls_error_type_t err_type, int *error_code)
```

Returns the last error captured in esp_tls of a specific type. The error information is cleared internally upon return.

**Parameters**

- **h** - [in] esp-tls error handle.
- **err_type** - [in] specific error type
- **error_code** - [out] last error code returned from mbedtls api (set to zero if none) This pointer could be NULL if caller does not care about esp_tls_code

**Returns**

- ESP_ERR_INVALID_STATE if invalid parameters
- ESP_OK if a valid error returned and was cleared

```c
esp_err_t esp_tls_get_error_handle(esp_tls_t *tls, esp_tls_error_handle_t *error_handle)
```

Returns the ESP-TLS error handle.

**Parameters**

- **tls** - [in] handle to esp_tls context
- **error_handle** - [out] pointer to the error handle.

**Returns**

- ESP_OK on success and error_handle will be updated with the ESP-TLS error handle.
- ESP_ERR_INVALID_ARG if (tls == NULL || error_handle == NULL)

```c
mbedtls_x509_crt *esp_tls_get_global_ca_store(void)
```

Get the pointer to the global CA store currently being used.

The application must first call esp_tls_set_global_ca_store(). Then the same CA store could be used by the application for APIs other than esp_tls.

**Note:** Modifying the pointer might cause a failure in verifying the certificates.

**Returns**

- Pointer to the global CA store currently being used if successful.
- NULL if there is no global CA store set.

```c
esp_err_t esp_tls_plain_tcp_connect(const char *host, int hostlen, int port, const esp_tls_cfg_t *cfg, esp_tls_error_handle_t *error_handle, int *sockfd)
```

Creates a plain TCP connection, returning a valid socket fd on success or an error handle.

**Parameters**

- **host** - [in] Hostname of the host.
- **hostlen** - [in] Length of hostname.
- **port** - [in] Port number of the host.
- **cfg** - [in] ESP-TLS configuration as esp_tls_cfg_t.
- **error_handle** - [out] ESP-TLS error handle holding potential errors occurred during connection
- **sockfd** - [out] Socket descriptor if successfully connected on TCP layer

**Returns**

- ESP_OK on success ESP_ERR_INVALID_ARG if invalid output parameters ESP-TLS based error codes on failure
Structures

struct **psk_key_hint**

ESP-TLS preshared key and hint structure.

**Public Members**

const uint8_t * **key**

key in PSK authentication mode in binary format

const size_t **key_size**

length of the key

const char * **hint**

hint in PSK authentication mode in string format

struct **tls_keep_alive_cfg**

esp-tls client session ticket ctx

Keep alive parameters structure

**Public Members**

bool **keep_alive_enable**

Enable keep-alive timeout

int **keep_alive_idle**

Keep-alive idle time (second)

int **keep_alive_interval**

Keep-alive interval time (second)

int **keep_alive_count**

Keep-alive packet retry send count

struct **esp_tls_cfg**

ESP-TLS configuration parameters.

**Note:** Note about format of certificates:

- This structure includes certificates of a Certificate Authority, of client or server as well as private keys, which may be of PEM or DER format. In case of PEM format, the buffer must be NULL terminated (with NULL character included in certificate size).
- Certificate Authority’s certificate may be a chain of certificates in case of PEM format, but could be only one certificate in case of DER format.
- Variables names of certificates and private key buffers and sizes are defined as unions providing backward compatibility for legacy *_pem_buf and *_pem_bytes names which suggested only PEM format was supported. It is encouraged to use generic names such as cacert_buf and cacert_bytes.
Public Members

const char **_{alpn_protos}_

Application protocols required for HTTP2. If HTTP2/ALPN support is required, a list of protocols that should be negotiated. The format is length followed by protocol name. For the most common cases the following is ok: const char **_{alpn_protos} = { "h2", NULL };

- where ‘h2’ is the protocol name

const unsigned char *_{cacert_buf}_

Certificate Authority’s certificate in a buffer. Format may be PEM or DER, depending on mbedtlssupport. This buffer should be NULL terminated in case of PEM

const unsigned char *_{cacert_pem_buf}_

CA certificate buffer legacy name

unsigned int _{cacert_bytes}_

Size of Certificate Authority certificate pointed to by cacert_buf (including NULL-terminator in case of PEM format)

unsigned int _{cacert_pem_bytes}_

Size of Certificate Authority certificate legacy name

const unsigned char *_{clientcert_buf}_

Client certificate in a buffer. Format may be PEM or DER, depending on mbedtlssupport. This buffer should be NULL terminated in case of PEM

const unsigned char *_{clientcert_pem_buf}_

Client certificate legacy name

unsigned int _{clientcert_bytes}_

Size of client certificate pointed to by clientcert_pem_buf (including NULL-terminator in case of PEM format)

unsigned int _{clientcert_pem_bytes}_

Size of client certificate legacy name

const unsigned char *_{clientkey_buf}_

Client key in a buffer. Format may be PEM or DER, depending on mbedtlssupport. This buffer should be NULL terminated in case of PEM

const unsigned char *_{clientkey_pem_buf}_

Client key legacy name

unsigned int _{clientkey_bytes}_

Size of client key pointed to by clientkey_pem_buf (including NULL-terminator in case of PEM format)

unsigned int _{clientkey_pem_bytes}_

Size of client key legacy name
const unsigned char *clientkey_password
Client key decryption password string

unsigned int clientkey_password_len
String length of the password pointed to by clientkey_password

bool non_block
Configure non-blocking mode. If set to true the underneath socket will be configured in non blocking mode after tls session is established

bool use_secure_element
Enable this option to use secure element or atecc608a chip (Integrated with ESP32-WROOM-32SE)

int timeout_ms
Network timeout in milliseconds. Note: If this value is not set, by default the timeout is set to 10 seconds.
If you wish that the session should wait indefinitely then please use a larger value e.g., INT32_MAX

bool use_global_ca_store
Use a global ca_store for all the connections in which this bool is set.

const char *common_name
If non-NULL, server certificate CN must match this name. If NULL, server certificate CN must match hostname.

bool skip_common_name
Skip any validation of server certificate CN field

tls_keep_alive_cfg_t *keep_alive_cfg
Enable TCP keep-alive timeout for SSL connection

const psk_hint_key_t *psk_hint_key
Pointer to PSK hint and key. if not NULL (and certificates are NULL) then PSK authentication is enabled with configured setup. Important note: the pointer must be valid for connection

esp_err_t (*crt_bundle_attach)(void *conf)
Function pointer to esp_crt_bundle_attach. Enables the use of certification bundle for server verification, must be enabled in menuconfig

void *ds_data
Pointer for digital signature peripheral context

bool is_plain_tcp
Use non-TLS connection: When set to true, the esp-tls uses plain TCP transport rather then TLS/SSL connection. Note, that it is possible to connect using a plain tcp transport directly with esp_tls_plain_tcp_connect() API

struct ifreq *if_name
The name of interface for data to go through. Use the default interface without setting

esp_tls_addr_family_t addr_family
The address family to use when connecting to a host.
Chapter 2. API Reference

**Type Definitions**

typedef enum \texttt{esp\_tls\_conn\_state} \texttt{esp\_tls\_conn\_state\_t}
ESP-TLS Connection State.

typedef enum \texttt{esp\_tls\_role} \texttt{esp\_tls\_role\_t}

typedef struct \texttt{psk\_key\_hint} \texttt{psk\_hint\_key\_t}
ESP-TLS preshared key and hint structure.

typedef struct \texttt{tls\_keep\_alive\_cfg} \texttt{tls\_keep\_alive\_cfg\_t}
esp-tls client session ticket ctx
Keep alive parameters structure

typedef enum \texttt{esp\_tls\_addr\_family} \texttt{esp\_tls\_addr\_family\_t}

typedef struct \texttt{esp\_tls\_cfg} \texttt{esp\_tls\_cfg\_t}
ESP-TLS configuration parameters.

**Note:** Note about format of certificates:

- This structure includes certificates of a Certificate Authority, of client or server as well as private keys, which may be of PEM or DER format. In case of PEM format, the buffer must be NULL terminated (with NULL character included in certificate size).
- Certificate Authority’s certificate may be a chain of certificates in case of PEM format, but could be only one certificate in case of DER format.
- Variables names of certificates and private key buffers and sizes are defined as unions providing backward compatibility for legacy *\_pem\_buf and *\_pem\_bytes names which suggested only PEM format was supported. It is encouraged to use generic names such as cacert\_buf and cacert\_bytes.

typedef struct \texttt{esp\_tls} \texttt{esp\_tls\_t}

**Enumerations**

typedef enum \texttt{esp\_tls\_conn\_state} \texttt{esp\_tls\_conn\_state\_t}
ESP-TLS Connection State.

\textbf{Values:}

- enumerator \texttt{ESP\_TLS\_INIT}

- enumerator \texttt{ESP\_TLS\_CONNECTING}

- enumerator \texttt{ESP\_TLS\_HANDSHAKE}

- enumerator \texttt{ESP\_TLS\_FAIL}

- enumerator \texttt{ESP\_TLS\_DONE}

typedef enum \texttt{esp\_tls\_role} \texttt{esp\_tls\_role\_t}

\textbf{Values:}
enumerator ESP_TLS_CLIENT

enumerator ESP_TLS_SERVER

enum esp_tls_addr_family

Values:

enumerator ESP_TLS_AF_UNSPEC

Unspecified address family.

enumerator ESP_TLS_AF_INET

IPv4 address family.

enumerator ESP_TLS_AF_INET6

IPv6 address family.

Header File

• components/esp-tls/esp_tls_errors.h

Structures

struct esp_tls_last_error

Error structure containing relevant errors in case tls error occurred.

Public Members

esp_err_t last_error

error code (based on ESP_ERR_ESP_TLS_BASE) of the last occurred error

int esp_tls_error_code

esp_tls error code from last esp_tls failed api

int esp_tls_flags

last certification verification flags

Macros

ESP_ERR_ESP_TLS_BASE

Starting number of ESP-TLS error codes

ESP_ERR_ESP_TLS_CANNOT_RESOLVE_HOSTNAME

Error if hostname couldn’t be resolved upon tls connection

ESP_ERR_ESP_TLS_CANNOT_CREATE_SOCKET

Failed to create socket

ESP_ERR_ESP_TLS_UNSUPPORTED_PROTOCOL_FAMILY

Unsupported protocol family
ESP_ERR_ESP_TLS_FAILED_CONNECT_TO_HOST
   Failed to connect to host

ESP_ERR_ESP_TLS_SOCKET_SETOPT_FAILED
   failed to set/get socket option

ESP_ERR_ESP_TLS_CONNECTION_TIMEOUT
   new connection in esp_tls_low_level_conn connection timeouted

ESP_ERR_ESP_TLS_SE_FAILED

ESP_ERR_ESP_TLS_TCP_CLOSED_FIN

ESP_ERR_MBEDTLS_CERT_PARTLY_OK
   mbedtls parse certificates was partly successful

ESP_ERR_MBEDTLS_CTR_DRBG_SEED_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_SET_HOSTNAME_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_CONFIG_DEFAULTS_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_CONF_ALPN_PROTOCOLS_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_X509_CRT_PARSE_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_CONF_own_cert_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_SETUP_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_SSL_WRITE_FAILED
   mbedtls api returned error

ESP_ERR_MBEDTLS_PK_PARSE_KEY_FAILED
   mbedtls api returned failed

ESP_ERR_MBEDTLS_SSL_HANSHAKE_FAILED
   mbedtls api returned failed

ESP_ERR_MBEDTLS_SSL_CONF_PSK_FAILED
   mbedtls api returned failed
Chapter 2. API Reference

ESP_ERR_MBEDTLS_SSL_TICKET_SETUP_FAILED
  mbedtls api returned failed

ESP_ERR_WOLFSSL_SSL_SET_HOSTNAME_FAILED
  wolfSSL api returned error

ESP_ERR_WOLFSSL_SSL_CONF_ALPN_PROTOCOLS_FAILED
  wolfSSL api returned error

ESP_ERR_WOLFSSL_CERT_VERIFY_SETUP_FAILED
  wolfSSL api returned error

ESP_ERR_WOLFSSL_KEY_VERIFY_SETUP_FAILED
  wolfSSL api returned error

ESP_ERR_WOLFSSL_SSL_HANDSHAKE_FAILED
  wolfSSL api returned failed

ESP_ERR_WOLFSSL_CTX_SETUP_FAILED
  wolfSSL api returned failed

ESP_ERR_WOLFSSL_SSL_SETUP_FAILED
  wolfSSL api returned failed

ESP_ERR_WOLFSSL_SSL_WRITE_FAILED
  wolfSSL api returned failed

ESP_TLS_ERR_SSL_WANT_READ
  Definition of errors reported from IO API (potentially non-blocking) in case of error:
  • esp_tls_conn_read()
  • esp_tls_conn_write()

ESP_TLS_ERR_SSL_WANT_WRITE

ESP_TLS_ERR_SSL_TIMEOUT

Type Definitions

typedef struct esp_tls_last_error *esp_tls_error_handle_t

typedef struct esp_tls_last_error esp_tls_last_error_t
  Error structure containing relevant errors in case tls error occurred.

Enumerations

tenum esp_tls_error_type_t
  Definition of different types/sources of error codes reported from different components
  Values:
2.2.5 ESP HTTP Client

Overview

The esp_http_client component provides a set of APIs for making HTTP/S requests from ESP-IDF applications. The steps to use these APIs are as follows:

- `esp_http_client_init()`: Creates a `esp_http_client_handle_t` instance, i.e., an HTTP client handle based on the given `esp_http_client_config_t` configuration. This function must be the first to be called; default values will be assumed for the configuration values that are not explicitly defined by the user.
- `esp_http_client_perform()`: Performs all operations of the `esp_http_client` - opening the connection, exchanging data, and closing the connection (as required), while blocking the current task before its completion. All related events will be invoked through the event handler (as specified in `esp_http_client_config_t`).
- `esp_http_client_cleanup()`: Closes the connection (if any) and frees up all the memory allocated to the HTTP client instance. This must be the last function to be called after the completion of operations.

Application Example

Simple example that uses ESP HTTP Client to make HTTP/S requests can be found at protocols/esp_http_client.

Basic HTTP Request

Check out the example functions `http_rest_with_url` and `http_rest_with_hostname_path` in the application example for implementation details.
Persistent Connections

Persistent connection means that the HTTP client can re-use the same connection for several exchanges. If the server does not request to close the connection with the `Connection: close` header, the connection is not dropped but is instead kept open and used for further requests.

To allow ESP HTTP client to take full advantage of persistent connections, one should make as many requests as possible using the same handle instance. Check out the example functions `http_rest_with_url` and `http_rest_with_hostname_path` in the application example. Here, once the connection is created, multiple requests (GET, POST, PUT, etc.) are made before the connection is closed.

Use Secure Element (ATECC608) for TLS

A secure element (ATECC608) can be also used for the underlying TLS connection in the HTTP client connection. Please refer to the ATECC608A (Secure Element) with ESP-TLS section in the ESP-TLS documentation for more details. The secure element support has to be first enabled in menu config through `CONFIG_ESP_TLS_USE_SECURE_ELEMENT`. Then the HTTP client can be configured to use secure element as follows:

```c
esp_http_client_config_t cfg = {
    /* other configurations options */
    .use_secure_element = true,
};
```

HTTPS Request

ESP HTTP client supports SSL connections using mbedTLS, with the `url` configuration starting with `https` scheme or `transport_type` set to `HTTP_TRANSPORT_OVER_SSL`. HTTPS support can be configured via `CONFIG_ESP_HTTP_CLIENT_ENABLE_HTTPS` (enabled by default).

**Note:** While making HTTPS requests, if server verification is needed, an additional root certificate (in PEM format) needs to be provided to the `cert_pem` member in the `esp_http_client_config_t` configuration. Users can also use the ESP x509 Certificate Bundle for server verification using the `crt_bundle_attach` member of the `esp_http_client_config_t` configuration.

Check out the example functions `https_with_url` and `https_with_hostname_path` in the application example for implementation details of the above note.

HTTP Stream

Some applications need to open the connection and control the exchange of data actively (data streaming). In such cases, the application flow is different from regular requests. Example flow is given below:

- `esp_http_client_init()`: Create a HTTP client handle.
- `esp_http_client_set_*` or `esp_http_client_delete_*`: Modify the HTTP connection parameters (optional).
- `esp_http_client_open()`: Open the HTTP connection with `write_len` parameter (content length that needs to be written to server), set `write_len=0` for read-only connection.
- `esp_http_client_write()`: Write data to server with a maximum length equal to `write_len` of `esp_http_client_open()` function; no need to call this function for `write_len=0`.
- `esp_http_client_fetch_headers()`: Read the HTTP Server response headers, after sending the request headers and server data (if any). Returns the content-length from the server and can be succeeded by `esp_http_client_get_status_code()` for getting the HTTP status of the connection.
- `esp_http_client_read()`: Read the HTTP stream.
- `esp_http_client_close()`: Close the connection.
- `esp_http_client_cleanup()`: Release allocated resources.

Check out the example function `http_perform_as_stream_reader` in the application example for implementation details.
HTTP Authentication

ESP HTTP client supports both Basic and Digest Authentication.

- Users can provide the username and password in the url or the username and password members of the esp_http_client_config_t configuration. For auth_type = HTTP_AUTH_TYPE_BASIC, the HTTP client takes only one perform operation to pass the authentication process.
- If auth_type = HTTP_AUTH_TYPE_NONE, but the username and password fields are present in the configuration, the HTTP client takes two perform operations. The client will receive the 401 Unauthorized header in its first attempt to connect to the server. Based on this information, it decides which authentication method to choose and performs it in the second operation.
- Check out the example functions http_auth_basic, http_auth_basic_redirect (for Basic authentication) and http_auth_digest (for Digest authentication) in the application example for implementation details.

Examples of Authentication Configuration

- Authentication with URI

```c
esp_http_client_config_t config = {
    .url = "http://user:passwd@httpbin.org/basic-auth/user/passwd",
    .auth_type = HTTP_AUTH_TYPE_BASIC,
};
```

- Authentication with username and password entry

```c
esp_http_client_config_t config = {
    .url = "http://httpbin.org/basic-auth/user/passwd",
    .username = "user",
    .password = "passwd",
    .auth_type = HTTP_AUTH_TYPE_BASIC,
};
```

Event Handling

ESP HTTP Client supports event handling by triggering an event handler corresponding to the event which takes place. esp_http_client_event_id_t contains all the events which could occur while performing an HTTP request using the ESP HTTP Client.

To enable event handling, you just need to set a callback function using the esp_http_client_config_t::event_handler member.

ESP HTTP Client Diagnostic Information

Diagnostic information could be helpful to gain insights into a problem. In the case of ESP HTTP Client, the diagnostic information can be collected by registering an event handler with the Event Loop library. This feature has been added by keeping in mind the ESP Insights framework which collects the diagnostic information. However, this feature can also be used without any dependency on the ESP Insights framework for the diagnostic purpose. Event handler can be registered to the event loop using the esp_event_handler_register() function.

Expected data types for different HTTP Client events in the event loop are as follows:

- HTTP_EVENT_ERROR: esp_http_client_handle_t
- HTTP_EVENT_ON_CONNECTED: esp_http_client_handle_t
- HTTP_EVENT_HEADERS_SENT: esp_http_client_handle_t
- HTTP_EVENT_ON_HEADER: esp_http_client_handle_t
- HTTP_EVENT_ON_DATA: esp_http_client_on_data_t
- HTTP_EVENT_ON_FINISH: esp_http_client_handle_t
- HTTP_EVENT_DISCONNECTED: esp_http_client_handle_t
• **HTTP_EVENT_REDIRECT**: `esp_http_client_redirect_event_data_t`

The `esp_http_client_handle_t` received along with the event data will be valid until `HTTP_EVENT_DISCONNECTED` is not received. This handle has been sent primarily to differentiate between different client connections and must not be used for any other purpose, as it may change based on client connection state.

### API Reference

#### Header File

- `components/esp_http_client/include/esp_http_client.h`

#### Functions

**`esp_http_client_handle_t esp_http_client_init(const esp_http_client_config_t *config)`**

Start a HTTP session. This function must be the first function to call, and it returns an `esp_http_client_handle_t` that you must use as input to other functions in the interface. This call MUST have a corresponding call to `esp_http_client_cleanup` when the operation is complete.

**Parameters**

- `config` – [in] The configurations, see `http_client_config_t`

**Returns**

- `esp_http_client_handle_t`
- NULL if any errors

**`esp_err_t esp_http_client_perform(esp_http_client_handle_t client)`**

Invoke this function after `esp_http_client_init` and all the options calls are made, and will perform the transfer as described in the options. It must be called with the same `esp_http_client_handle_t` as input as the `esp_http_client_init` call returned. `esp_http_client_perform` performs the entire request in either blocking or non-blocking manner. By default, the `esp_http_client_perform` returns in a blocking manner and returns when done, or if it failed, and in non-blocking manner, it returns if EAGAIN/EWOULDBLOCK or EINPROGRESS is encountered, or if it failed. And in case of non-blocking request, the user may call this API multiple times unless request & response is complete or there is a failure. To enable non-blocking `esp_http_client_perform()`, `is_async` member of `esp_http_client_config_t` must be set while making a call to `esp_http_client_init()` API. You can do any amount of calls to `esp_http_client_perform` while using the same `esp_http_client_handle_t`. The underlying connection may be kept open if the server allows it. If you intend to transfer more than one file, you are even encouraged to do so. `esp_http_client` will then attempt to re-use the same connection for the following transfers, thus making the operations faster, less CPU intense and using less network resources. Just note that you will have to use `esp_http_client_set_**` between the invoke to set options for the following `esp_http_client_perform`.

**Note:** You must never call this function simultaneously from two places using the same client handle. Let the function return first before invoking it another time. If you want parallel transfers, you must use several `esp_http_client_handle_t`. This function include `esp_http_client_open` -> `esp_http_client_write` -> `esp_http_client_fetch_headers` -> `esp_http_client_read` (and option) `esp_http_client_close`.

**Parameters**

- `client` – The `esp_http_client_handle`

**Returns**

- ESP_OK on successful
- ESP_FAIL on error

**`esp_err_t esp_http_client_cancel_request(esp_http_client_handle_t client)`**

Cancel an ongoing HTTP request. This API closes the current socket and opens a new socket with the same `esp_http_client` context.

**Parameters**

- `client` – The `esp_http_client_handle`

**Returns**

- ESP_OK on successful
- ESP_FAIL on error
• ESP_OK on successful
• ESP_FAIL on error
• ESP_ERR_INVALID_ARG
• ESP_ERR_INVALID_STATE

`esp_err_t esp_http_client_set_url (esp_http_client_handle_t client, const char *url)`
Set URL for client, when performing this behavior, the options in the URL will replace the old ones.

**Parameters**
- `client` - [in] The esp_http_client handle
- `url` - [in] The url

**Returns**
- ESP_OK
- ESP_FAIL

`esp_err_t esp_http_client_set_post_field (esp_http_client_handle_t client, const char *data, int len)`
Set post data, this function must be called before `esp_http_client_perform`. Note: The data parameter passed to this function is a pointer and this function will not copy the data.

**Parameters**
- `client` - [in] The esp_http_client handle
- `data` - [in] post data pointer
- `len` - [in] post length

**Returns**
- ESP_OK
- ESP_FAIL

`int esp_http_client_get_post_field (esp_http_client_handle_t client, char **data)`
Get current post field information.

**Parameters**
- `client` - [in] The client
- `data` - [out] Point to post data pointer

**Returns**
- Size of post data

`esp_err_t esp_http_client_set_header (esp_http_client_handle_t client, const char *key, const char *value)`
Set http request header, this function must be called after `esp_http_client_init` and before any perform function.

**Parameters**
- `client` - [in] The esp_http_client handle
- `key` - [in] The header key
- `value` - [in] The header value

**Returns**
- ESP_OK
- ESP_FAIL

`esp_err_t esp_http_client_get_header (esp_http_client_handle_t client, const char *key, char **value)`
Get http request header. The value parameter will be set to NULL if there is no header which is same as the key specified, otherwise the address of header value will be assigned to value parameter. This function must be called after `esp_http_client_init`.

**Parameters**
- `client` - [in] The esp_http_client handle
- `key` - [in] The header key
- `value` - [out] The header value

**Returns**
- ESP_OK
- ESP_FAIL
**esp_err_t esp_http_client_get_username (esp_http_client_handle_t client, char **value)**

Get http request username. The address of username buffer will be assigned to value parameter. This function must be called after `esp_http_client_init`.

**Parameters**
- `client` [in] The esp_http_client handle
- `value` [out] The username value

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG

**esp_err_t esp_http_client_set_username (esp_http_client_handle_t client, const char *username)**

Set http request username. The value of username parameter will be assigned to username buffer. If the username parameter is NULL then username buffer will be freed.

**Parameters**
- `client` [in] The esp_http_client handle
- `username` [in] The username value

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG

**esp_err_t esp_http_client_get_password (esp_http_client_handle_t client, char **value)**

Get http request password. The address of password buffer will be assigned to value parameter. This function must be called after `esp_http_client_init`.

**Parameters**
- `client` [in] The esp_http_client handle
- `value` [out] The password value

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG

**esp_err_t esp_http_client_set_password (esp_http_client_handle_t client, const char *password)**

Set http request password. The value of password parameter will be assigned to password buffer. If the password parameter is NULL then password buffer will be freed.

**Parameters**
- `client` [in] The esp_http_client handle
- `password` [in] The password value

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG

**esp_err_t esp_http_client_set_auth_type (esp_http_client_handle_t client, esp_http_client_auth_type_t auth_type)**

Set http request auth_type.

**Parameters**
- `client` [in] The esp_http_client handle
- `auth_type` [in] The esp_http_client auth type

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG

**esp_err_t esp_http_client_get_user_data (esp_http_client_handle_t client, void **data)**

Get http request user_data. The value stored from the `esp_http_client_config_t` will be written to the address passed into data.

**Parameters**
- `client` [in] The esp_http_client handle
- `data` [out] A pointer to the pointer that will be set to user_data.
Chapter 2. API Reference

Returns
- ESP_OK
- ESP_ERR_INVALID_ARG

`esp_err_t esp_http_client_set_user_data(esp_http_client_handle_t client, void *data)`
Set http request user_data. The value passed in `data` will be available during event callbacks. No memory management will be performed on the user’s behalf.

Parameters
- `client` [in] The esp_http_client handle
- `data` [in] The pointer to the user data

Returns
- ESP_OK
- ESP_ERR_INVALID_ARG

`int esp_http_client_get_errno(esp_http_client_handle_t client)`
Get HTTP client session errno.

Parameters `client` [in] The esp_http_client handle

Returns
- (-1) if invalid argument
- errno

`esp_err_t esp_http_client_set_method(esp_http_client_handle_t client, esp_http_client_method_t method)`
Set http request method.

Parameters
- `client` [in] The esp_http_client handle
- `method` [in] The method

Returns
- ESP_OK
- ESP_ERR_INVALID_ARG

`esp_err_t esp_http_client_set_timeout_ms(esp_http_client_handle_t client, int timeout_ms)`
Set http request timeout.

Parameters
- `client` [in] The esp_http_client handle
- `timeout_ms` [in] The timeout value

Returns
- ESP_OK
- ESP_ERR_INVALID_ARG

`esp_err_t esp_http_client_delete_header(esp_http_client_handle_t client, const char *key)`
Delete http request header.

Parameters
- `client` [in] The esp_http_client handle
- `key` [in] The key

Returns
- ESP_OK
- ESP_FAIL

`esp_err_t esp_http_client_open(esp_http_client_handle_t client, int write_len)`
This function will be open the connection, write all header strings and return.

Parameters
- `client` [in] The esp_http_client handle
- `write_len` [in] HTTP Content length need to write to the server

Returns
- ESP_OK
- ESP_FAIL
int esp_http_client_write(esp_http_client_handle_t client, const char *buffer, int len)

This function will write data to the HTTP connection previously opened by esp_http_client_open()

Parameters
• client - [in] The esp_http_client handle
• buffer - The buffer
• len - [in] This value must not be larger than the write_len parameter provided to esp_http_client_open()

Returns
• (-1) if any errors
• Length of data written

int64_t esp_http_client_fetch_headers(esp_http_client_handle_t client)

This function need to call after esp_http_client_open, it will read from http stream, process all receive headers.

Parameters client - [in] The esp_http_client handle

Returns
• (0) if stream doesn’t contain content-length header, or chunked encoding (checked by esp_http_client_is_chunked_response)
• (-1: ESP_FAIL) if any errors
• (-ESP_ERR_HTTP_EAGAIN = -0x7007) if call is timed-out before any data was ready
• Download data length defined by content-length header

bool esp_http_client_is_chunked_response(esp_http_client_handle_t client)

Check response data is chunked.

Parameters client - [in] The esp_http_client handle

Returns true or false

int esp_http_client_read(esp_http_client_handle_t client, char *buffer, int len)

Read data from http stream.

Note: (-ESP_ERR_HTTP_EAGAIN = -0x7007) is returned when call is timed-out before any data was ready

Parameters
• client - [in] The esp_http_client handle
• buffer - The buffer
• len - [in] The length

Returns
• (-1) if any errors
• Length of data was read

int esp_http_client_get_status_code(esp_http_client_handle_t client)

Get http response status code, the valid value if this function invoke after esp_http_client_perform

Parameters client - [in] The esp_http_client handle

Returns Status code

int64_t esp_http_client_get_content_length(esp_http_client_handle_t client)

Get http response content length (from header Content-Length) the valid value if this function invoke after esp_http_client_perform

Parameters client - [in] The esp_http_client handle

Returns
• (-1) Chunked transfer
• Content-Length value as bytes

esp_err_t esp_http_client_close(esp_http_client_handle_t client)

Close http connection, still kept all http request resources.

Parameters client - [in] The esp_http_client handle
Returns
- ESP_OK
- ESP_FAIL

```c
esp_err_t esp_http_client_cleanup (esp_http_client_handle_t client)
```

This function must be the last function to call for an session. It is the opposite of the esp_http_client_init function and must be called with the same handle as input that a esp_http_client_init call returned. This might close all connections this handle has used and possibly has kept open until now. Don’t call this function if you intend to transfer more files, re-using handles is a key to good performance with esp_http_client.

**Parameters**
- `client` [in] The esp_http_client handle

**Returns**
- ESP_OK
- ESP_FAIL

```c
esp_http_client_transport_t esp_http_client_get_transport_type (esp_http_client_handle_t client)
```

Get transport type.

**Parameters**
- `client` [in] The esp_http_client handle

**Returns**
- HTTP_TRANSPORT_UNKNOWN
- HTTP_TRANSPORT_OVER_TCP
- HTTP_TRANSPORT_OVER_SSL

```c
esp_err_t esp_http_client_set_redirection (esp_http_client_handle_t client)
```

Set redirection URL. When received the 30x code from the server, the client stores the redirect URL provided by the server. This function will set the current URL to redirect to enable client to execute the redirection request. When `disable_auto_redirect` is set, the client will not call this function but the event HTTP_EVENT_REDIRECT will be dispatched giving the user control over the redirection event.

**Parameters**
- `client` [in] The esp_http_client handle

**Returns**
- ESP_OK
- ESP_FAIL

```c
void esp_http_client_add_auth (esp_http_client_handle_t client)
```

On receiving HTTP Status code 401, this API can be invoked to add authorization information.

**Note:** There is a possibility of receiving body message with redirection status codes, thus make sure to flush off body data after calling this API.

**Parameters**
- `client` [in] The esp_http_client handle

```c
bool esp_http_client_is_complete_data_received (esp_http_client_handle_t client)
```

Checks if entire data in the response has been read without any error.

**Parameters**
- `client` [in] The esp_http_client handle

**Returns**
- true
- false

```c
int esp_http_client_read_response (esp_http_client_handle_t client, char *buffer, int len)
```

Helper API to read larger data chunks This is a helper API which internally calls esp_http_client_read multiple times till the end of data is reached or till the buffer gets full.

**Parameters**
- `client` [in] The esp_http_client handle
- `buffer` The buffer
- `len` [in] The buffer length

**Returns**
• Length of data was read

```c
esp_err_t esp_http_client_flush_response (esp_http_client_handle_t client, int* len)
```
Process all remaining response data. This uses an internal buffer to repeatedly receive, parse, and discard response data until complete data is processed. As no additional user-supplied buffer is required, this may be preferable to `esp_http_client_read_response` in situations where the content of the response may be ignored.

**Parameters**
- **client** - [in] The esp_http_client handle
- **len** - Length of data discarded

**Returns**
- ESP_OK If successful, len will have discarded length
- ESP_FAIL If failed to read response
- ESP_ERR_INVALID_ARG If the client is NULL

```c
esp_err_t esp_http_client_get_url (esp_http_client_handle_t client, char* url, const int len)
```
Get URL from client.

**Parameters**
- **client** - [in] The esp_http_client handle
- **url** - [inout] The buffer to store URL
- **len** - [in] The buffer length

**Returns**
- ESP_OK
- ESP_FAIL

```c
esp_err_t esp_http_client_get_chunk_length (esp_http_client_handle_t client, int* len)
```
Get Chunk-Length from client.

**Parameters**
- **client** - [in] The esp_http_client handle
- **len** - [out] Variable to store length

**Returns**
- ESP_OK If successful, len will have length of current chunk
- ESP_FAIL If the server is not a chunked server
- ESP_ERR_INVALID_ARG If the client or len are NULL

**Structures**

```c
define esp_http_client_event
HTTPClient events data.
```

**Public Members**

```c
esp_http_client_event_id_t event_id
```
event_id, to know the cause of the event

```c
esp_http_client_handle_t client
```
esp_http_client_handle_t context

```c
void* data
```
data of the event

```c
int data_len
```
data length of data
void *user_data
user_data context, from esp_http_client_config_t user_data

char *header_key
For HTTP_EVENT_ON_HEADER event_id, it’s store current http header key

char *header_value
For HTTP_EVENT_ON_HEADER event_id, it’s store current http header value

struct esp_http_client_on_data
Argument structure for HTTP_EVENT_ON_DATA event.

Public Members

esp_http_client_handle_t client
Client handle

int64_t data_process
Total data processed

struct esp_http_client_redirect_event_data
Argument structure for HTTP_EVENT_REDIRECT event.

Public Members

esp_http_client_handle_t client
Client handle

int status_code
Status Code

struct esp_http_client_config_t
HTTP configuration.

Public Members

const char *url
HTTP URL, the information on the URL is most important, it overrides the other fields below, if any

const char *host
Domain or IP as string

int port
Port to connect, default depend on esp_http_client_transport_t (80 or 443)

const char *username
Using for Http authentication
const char *password
   Using for Http authentication

*esp_http_client_auth_type_t* auth_type
   Http authentication type, see esp_http_client_auth_type_t

const char *path
   HTTP Path, if not set, default is /

const char *query
   HTTP query

const char *cert_pem
   SSL server certification, PEM format as string, if the client requires to verify server

size_t cert_len
   Length of the buffer pointed to by cert_pem. May be 0 for null-terminated pem

const char *client_cert_pem
   SSL client certification, PEM format as string, if the server requires to verify client

size_t client_cert_len
   Length of the buffer pointed to by client_cert_pem. May be 0 for null-terminated pem

const char *client_key_pem
   SSL client key, PEM format as string, if the server requires to verify client

size_t client_key_len
   Length of the buffer pointed to by client_key_pem. May be 0 for null-terminated pem

const char *client_key_password
   Client key decryption password string

size_t client_key_password_len
   String length of the password pointed to by client_key_password

const char *user_agent
   The User Agent string to send with HTTP requests

*esp_http_client_method_t* method
   HTTP Method

int timeout_ms
   Network timeout in milliseconds

bool disable_auto_redirect
   Disable HTTP automatic redirects
int `max_redirection_count`
Max number of redirections on receiving HTTP redirect status code, using default value if zero

int `max_authorization_retries`
Max connection retries on receiving HTTP unauthorized status code, using default value if zero. Disables authorization retry if -1

`http_event_handle_cb event_handler`
HTTP Event Handle

`esp_http_client_transport_t transport_type`
HTTP transport type, see `esp_http_client_transport_t`

int `buffer_size`
HTTP receive buffer size

int `buffer_size_tx`
HTTP transmit buffer size

void *`user_data`
HTTP user_data context

bool `is_async`
Set asynchronous mode, only supported with HTTPS for now

bool `use_global_ca_store`
Use a global ca_store for all the connections in which this bool is set.

bool `skip_cert_common_name_check`
Skip any validation of server certificate CN field

const char *`common_name`
Pointer to the string containing server certificate common name. If non-NULL, server certificate CN must match this name. If NULL, server certificate CN must match hostname.

`esp_err_t (*crt_bundle_attach)(void *conf)`
Function pointer to esp_crt_bundle_attach. Enables the use of certification bundle for server verification, must be enabled in menuconfig

bool `keep_alive_enable`
Enable keep-alive timeout

int `keep_alive_idle`
Keep-alive idle time. Default is 5 (second)

int `keep_alive_interval`
Keep-alive interval time. Default is 5 (second)
int keep_alive_count
    Keep-alive packet retry send count. Default is 3 counts

struct ifreq *if_name
    The name of interface for data to go through. Use the default interface without setting

**Macros**

**DEFAULT_HTTP_BUF_SIZE**

**ESP_ERR_HTTP_BASE**
    Starting number of HTTP error codes

**ESP_ERR_HTTP_MAX_REDIRECT**
    The error exceeds the number of HTTP redirects

**ESP_ERR_HTTP_CONNECT**
    Error open the HTTP connection

**ESP_ERR_HTTP_WRITE_DATA**
    Error write HTTP data

**ESP_ERR_HTTP_FETCH_HEADER**
    Error read HTTP header from server

**ESP_ERR_HTTP_INVALID_TRANSPORT**
    There are no transport support for the input scheme

**ESP_ERR_HTTP_CONNECTING**
    HTTP connection hasn’t been established yet

**ESP_ERR_HTTP_EAGAIN**
    Mapping of errno EAGAIN to esp_err_t

**ESP_ERR_HTTP_CONNECTION_CLOSED**
    Read FIN from peer and the connection closed

**Type Definitions**

typedef struct esp_http_client *esp_http_client_handle_t

typedef struct esp_http_client_event *esp_http_client_event_handle_t

typedef struct esp_http_client_event esp_http_client_event_t
    HTTP Client events data.

typedef struct esp_http_client_on_data esp_http_client_on_data_t
    Argument structure for HTTP_EVENT_ON_DATA event.
typedef struct esp_http_client_redirect_event_data esp_http_client_redirect_event_data_t
    Argument structure for HTTP_EVENT_REDIRECT event.

typedef esp_err_t (*http_event_handle_cb)(esp_http_client_event_t *evt)

Enumerations
enum esp_http_client_event_id_t
    HTTP Client events id.
    Values:
    enumerator HTTP_EVENT_ERROR
        This event occurs when there are any errors during execution
    enumerator HTTP_EVENT_ON_CONNECTED
        Once the HTTP has been connected to the server, no data exchange has been performed
    enumerator HTTP_EVENT_HEADERS_SENT
        After sending all the headers to the server
    enumerator HTTP_EVENT_HEADER_SENT
        This header has been kept for backward compatability and will be deprecated in future versions esp-idf
    enumerator HTTP_EVENT_ON_HEADER
        Occurs when receiving each header sent from the server
    enumerator HTTP_EVENT_ON_DATA
        Occurs when receiving data from the server, possibly multiple portions of the packet
    enumerator HTTP_EVENT_ON_FINISH
        Occurs when finish a HTTP session
    enumerator HTTP_EVENT_DISCONNECTED
        The connection has been disconnected
    enumerator HTTP_EVENT_REDIRECT
        Intercepting HTTP redirects to handle them manually

enum esp_http_client_transport_t
    HTTP Client transport.
    Values:
    enumerator HTTP_TRANSPORT_UNKNOWN
        Unknown
    enumerator HTTP_TRANSPORT_OVER_TCP
        Transport over tcp
enumerator **HTTP_TRANSPORT_OVER_SSL**
Transport over ssl

enum **esp_http_client_method_t**
HTTP method.

*Values:*

enumerator **HTTP_METHOD_GET**
HTTP GET Method

enumerator **HTTP_METHOD_POST**
HTTP POST Method

enumerator **HTTP_METHOD_PUT**
HTTP PUT Method

enumerator **HTTP_METHOD_PATCH**
HTTP PATCH Method

enumerator **HTTP_METHOD_DELETE**
HTTP DELETE Method

enumerator **HTTP_METHOD_HEAD**
HTTP HEAD Method

enumerator **HTTP_METHOD_NOTIFY**
HTTP NOTIFY Method

enumerator **HTTP_METHOD_SUBSCRIBE**
HTTP SUBSCRIBE Method

enumerator **HTTP_METHOD_UNsubscribe**
HTTP UNSUBSCRIBE Method

enumerator **HTTP_METHOD_OPTIONS**
HTTP OPTIONS Method

enumerator **HTTP_METHOD_COPY**
HTTP COPY Method

enumerator **HTTP_METHOD_MOVE**
HTTP MOVE Method

enumerator **HTTP_METHOD_LOCK**
HTTP LOCK Method

enumerator **HTTP_METHOD_UNLOCK**
HTTP UNLOCK Method
enumerator HTTP_METHOD_PROPFIND
  HTTP PROPFIND Method

details
enumerator HTTP_METHOD_PROPPATCH
  HTTP PROPPATCH Method

details
enumerator HTTP_METHOD_MKCOL
  HTTP MKCOL Method

details
enumerator HTTP_METHOD_MAX

enum esp_http_client_auth_type_t
  HTTP Authentication type.
  
    Values:

    enumerator HTTP_AUTH_TYPE_NONE
      No authentication

    enumerator HTTP_AUTH_TYPE_BASIC
      HTTP Basic authentication

    enumerator HTTP_AUTH_TYPE_DIGEST
      HTTP Digest authentication

enum HttpStatus_Code
  Enum for the HTTP status codes.
  
    Values:

    enumerator HttpStatus_Ok

    enumerator HttpStatus_MultipleChoices

    enumerator HttpStatus_MovedPermanently

    enumerator HttpStatus_Found

    enumerator HttpStatus_SeeOther

    enumerator HttpStatus_TemporaryRedirect

    enumerator HttpStatus_PermanentRedirect

    enumerator HttpStatus_BadRequest

    enumerator HttpStatus_Unauthorized
Chapter 2. API Reference

enumerator HttpStatus_Forbidden
enumerator HttpStatus_NotFound
enumerator HttpStatus_InternalError

2.2.6 ESP Local Control

Overview

ESP Local Control (esp_local_ctrl) component in ESP-IDF provides capability to control an ESP device over HTTPS or BLE. It provides access to application defined properties that are available for reading / writing via a set of configurable handlers.

Initialization of the esp_local_ctrl service over BLE transport is performed as follows:

```c
esp_local_ctrl_config_t config = {
  .transport = ESP_LOCAL_CTRL_TRANSPORT_BLE,
  .transport_config = {
    .ble = & (protocomm_ble_config_t) {
      .device_name = SERVICE_NAME,
      .service_uuid = {
        /* LSB <---------------------------------------
        * ---------------------------------------> MSB */
        0x21, 0xd5, 0x3b, 0x8d, 0xbd, 0x75, 0x68, 0x8a,
        0xb4, 0x42, 0xeb, 0x31, 0x4a, 0x1e, 0x98, 0x3d
      }
    },
    .proto_sec = {
      .version = PROTOCOL_SEC0,
      .custom_handle = NULL,
      .sec_params = NULL
    },
    .handlers = {
      /* User defined handler functions */
      .get_prop_values = get_property_values,
      .set_prop_values = set_property_values,
      .usr_ctx = NULL,
      .usr_ctx_free_fn = NULL
    },
    /* Maximum number of properties that may be set */
    .max_properties = 10
  }
  /* Start esp_local_ctrl service */
  ESP_ERROR_CHECK(esp_local_ctrl_start(config));
```

Similarly for HTTPS transport:

```c
/* Set the configuration */
httpd_ssl_config_t https_conf = HTTPD_SSL_CONFIG_DEFAULT();

/* Load server certificate */
extern const unsigned char servercert_start[] asm("_binary_servercert_pem_start");
extern const unsigned char servercert_end[] asm("_binary_servercert_pem_end");
https_conf.servercert = servercert_start;
```

(continues on next page)
**Chapter 2. API Reference**

(continued from previous page)

```c
https_conf.servercert_len = servercert_end - servercert_start;
/* Load server private key */
extern const unsigned char prvtkey_pem_start[] asm("_binary_prvtkey_pem_start");
extern const unsigned char prvtkey_pem_end[] asm("_binary_prvtkey_pem_end");
https_conf.prvtkey_pem = prvtkey_pem_start;
https_conf.prvtkey_len = prvtkey_pem_end - prvtkey_pem_start;

esp_local_ctrl_config_t config = {
  .transport = ESP_LOCAL_CTRL_TRANSPORT_HTTPD,
  .transport_config = {
    .httpd = &https_conf
  },
  .proto_sec = {
    .version = PROTOCOL_SEC0,
    .custom_handle = NULL,
    .sec_params = NULL,
  },
  .handlers = {
    /* User defined handler functions */
    .get_prop_values = get_property_values,
    .set_prop_values = set_property_values,
    .usr_ctx = NULL,
    .usr_ctx_free_fn = NULL
  },
  /* Maximum number of properties that may be set */
  .max_properties = 10
};
/* Start esp_local_ctrl service */
ESP_ERROR_CHECK(esp_local_ctrl_start(&config));
```

You may set security for transport in ESP local control using following options:

1. **PROTOCOM_SEC2**: specifies that SRP6a based key exchange and end to end encryption based on AES-GCM is used. This is the most preffered option as it adds a robust security with Augmented PAKE protocol i.e. SRP6a.
2. **PROTOCOM_SEC1**: specifies that Curve25519 based key exchange and end to end encryption based on AES-CTR is used.
3. **PROTOCOM_SEC0**: specifies that data will be exchanged as a plain text (no security).
4. **PROTOCOM_SEC_CUSTOM**: you can define your own security requirement. Please note that you will also have to provide custom_handle of type protocolcomm_security_t * in this context.

**Note:** The respective security schemes need to be enabled through the project configuration menu. Please refer to the Enabling protocom security version section in *Protocol Communication* for more details.

**Creating a property**

Now that we know how to start the esp_local_ctrl service, let’s add a property to it. Each property must have a unique name (string), a type (e.g. enum), flags (bit fields) and size.

The size is to be kept 0, if we want our property value to be of variable length (e.g. if its a string or bytestream). For fixed length property value data-types, like int, float, etc., setting the size field to the right value, helps esp_local_ctrl to perform internal checks on arguments received with write requests.

The interpretation of type and flags fields is totally up to the application, hence they may be used as enumerations, bit-fields, or even simple integers. One way is to use type values to classify properties, while flags to specify characteristics...
of a property.

Here is an example property which is to function as a timestamp. It is assumed that the application defines `TYPE_TIMESTAMP` and `READONLY`, which are used for setting the `type` and `flags` fields here.

```c
/* Create a timestamp property */
esp_local_ctrl_prop_t timestamp = {
    .name = "timestamp",
    .type = TYPE_TIMESTAMP,
    .size = sizeof(int32_t),
    .flags = READONLY,
    .ctx = func_get_time,
    .ctx_free_fn = NULL
};
/* Now register the property */
esp_local_ctrl_add_property(&timestamp);
```

Also notice that there is a `ctx` field, which is set to point to some custom `func_get_time()`. This can be used inside the property get / set handlers to retrieve timestamp.

Here is an example of `get_prop_values()` handler, which is used for retrieving the timestamp.

```c
static esp_err_t get_property_values(size_t props_count, const esp_local_ctrl_prop_t *props, esp_local_ctrl_prop_val_t *prop_values, void *usr_ctx)
{
    for (uint32_t i = 0; i < props_count; i++) {
        ESP_LOGI(TAG, "Reading %s", props[i].name);
        if (props[i].type == TYPE_TIMESTAMP) {
            /* Obtain the timer function from ctx */
            int32_t (*func_get_time)(void) = props[i].ctx;
            /* Use static variable for saving the value. *
             * This is essential because the value has to be *
             * valid even after this function returns. *
             * Alternative is to use dynamic allocation *
             * and set the free_fn field */
            static int32_t ts = func_get_time();
            prop_values[i].data = &ts;
        }
    }
    return ESP_OK;
}
```

Here is an example of `set_prop_values()` handler. Notice how we restrict from writing to read-only properties.

```c
static esp_err_t set_property_values(size_t props_count, const esp_local_ctrl_prop_t *props, const esp_local_ctrl_prop_val_t *prop_values, void *usr_ctx)
{
    for (uint32_t i = 0; i < props_count; i++) {
        if (props[i].flags & READONLY) {
            ESP_LOGE(TAG, "Cannot write to read-only property %s", props[i].name);
            return ESP_ERR_INVALID_ARG;
        } else {
            ESP_LOGI(TAG, "Setting %s", props[i].name);
        }
    }
}
```

(continues on next page)
/* For keeping it simple, lets only log the incoming data */
ESP_LOG_BUFFER_HEX_LEVEL(TAG, prop_values[i].data,
    prop_values[i].size, ESP_LOG_INFO);
}
return ESP_OK;
}

For complete example see protocols/esp_local_ctrl

Client Side Implementation

The client side implementation will have establish a protocomm session with the device first, over the supported mode of transport, and then send and receive protobuf messages understood by the esp_local_ctrl service. The service will translate these messages into requests and then call the appropriate handlers (set / get). Then, the generated response for each handler is again packed into a protobuf message and transmitted back to the client.

See below the various protobuf messages understood by the esp_local_ctrl service:

1. get_prop_count : This should simply return the total number of properties supported by the service
2. get_prop_values : This accepts an array of indices and should return the information (name, type, flags) and values of the properties corresponding to those indices
3. set_prop_values : This accepts an array of indices and an array of new values, which are used for setting the values of the properties corresponding to the indices

Note that indices may or may not be the same for a property, across multiple sessions. Therefore, the client must only use the names of the properties to uniquely identify them. So, every time a new session is established, the client should first call get_prop_count and then get_prop_values, hence form an index to name mapping for all properties. Now when calling set_prop_values for a set of properties, it must first convert the names to indexes, using the created mapping. As emphasized earlier, the client must refresh the index to name mapping every time a new session is established with the same device.

The various protocomm endpoints provided by esp_local_ctrl are listed below:

Table 1: Endpoints provided by ESP Local Control

<table>
<thead>
<tr>
<th>Endpoint Name (BLE + GATT Server)</th>
<th>URI (HTTPS Server + mDNS)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_local_ctrl/version</td>
<td>https://&lt;mdns-hostname&gt;.local/esp_local_ctrl/version</td>
<td>Endpoint used for retrieving version string</td>
</tr>
<tr>
<td>esp_local_ctrl/control</td>
<td>https://&lt;mdns-hostname&gt;.local/esp_local_ctrl/control</td>
<td>Endpoint used for sending / receiving control messages</td>
</tr>
</tbody>
</table>

API Reference

Header File

- components/esp_local_ctrl/include/esp_local_ctrl.h

Functions

const esp_local_ctrl_transport_t *esp_local_ctrl_get_transport_ble (void)
Function for obtaining BLE transport mode.

const esp_local_ctrl_transport_t *esp_local_ctrl_get_transport_httpd (void)
Function for obtaining HTTPD transport mode.
esp_err_t esp_local_ctrl_start (const esp_local_ctrl_config_t *config)

Start local control service.

Parameters config –[in] Pointer to configuration structure

Returns
• ESP_OK: Success
• ESP_FAIL: Failure

esp_err_t esp_local_ctrl_stop (void)

Stop local control service.

esp_err_t esp_local_ctrl_add_property (const esp_local_ctrl_prop_t *prop)

Add a new property.

This adds a new property and allocates internal resources for it. The total number of properties that could be
added is limited by configuration option max_properties

Parameters prop –[in] Property description structure

Returns
• ESP_OK: Success
• ESP_FAIL: Failure

esp_err_t esp_local_ctrl_remove_property (const char *name)

Remove a property.

This finds a property by name, and releases the internal resources which are associated with it.

Parameters name –[in] Name of the property to remove

Returns
• ESP_OK: Success
• ESP_ERR_NOT_FOUND: Failure

const esp_local_ctrl_prop_t *esp_local_ctrl_get_property (const char *name)

Get property description structure by name.

This API may be used to get a property’s context structure esp_local_ctrl_prop_t when its name
is known

Parameters name –[in] Name of the property to find

Returns
• Pointer to property
• NULL if not found

esp_err_t esp_local_ctrl_set_handler (const char *ep_name, protocomm_req_handler_t handler, void *
user_ctx)

Register protocomm handler for a custom endpoint.

This API can be called by the application to register a protocomm handler for an endpoint after the local control
service has started.

Note: In case of BLE transport the names and uuids of all custom endpoints must be provided beforehand as
a part of the protocomm_ble_config_t structure set in esp_local_ctrl_config_t, and passed
to esp_local_ctrl_start().

Parameters
• ep_name –[in] Name of the endpoint
• handler –[in] Endpoint handler function
• user_ctx –[in] User data

Returns
• ESP_OK: Success
• ESP_FAIL: Failure
Chapter 2. API Reference

Unions

union esp_local_ctrl_transport_config_t
#include <esp_local_ctrl.h> Transport mode (BLE / HTTPD) configuration.

Public Members

esp_local_ctrl_transport_config_ble_t *ble
This is same as protocomm_ble_config_t. See protocomm_ble.h for available configuration parameters.

esp_local_ctrl_transport_config_httpd_t *httpd
This is same as httpd_ssl_config_t. See esp_https_server.h for available configuration parameters.

Structures

struct esp_local_ctrl_prop
Property description data structure, which is to be populated and passed to the esp_local_ctrl_add_property() function.

Once a property is added, its structure is available for read-only access inside get_prop_values() and set_prop_values() handlers.

Public Members

char *name
Unique name of property

uint32_t type
Type of property. This may be set to application defined enums

size_t size
Size of the property value, which:
• if zero, the property can have values of variable size
• if non-zero, the property can have values of fixed size only, therefore, checks are performed internally by esp_local_ctrl when setting the value of such a property

uint32_t flags
Flags set for this property. This could be a bit field. A flag may indicate property behavior, e.g. read-only / constant

void *ctx
Pointer to some context data relevant for this property. This will be available for use inside the get_prop_values and set_prop_values handlers as a part of this property structure. When set, this is valid throughout the lifetime of a property, till either the property is removed or the esp_local_ctrl service is stopped.

void (*ctx_free_fn)(void *ctx)
Function used by esp_local_ctrl to internally free the property context when esp_local_ctrl_remove_property() or esp_local_ctrl_stop() is called.
struct esp_local_ctrl_prop_val
    Property value data structure. This gets passed to the get_prop_values() and set_prop_values() handlers for the purpose of retrieving or setting the present value of a property.

Public Members

void *data
    Pointer to memory holding property value

size_t size
    Size of property value

void (*free_fn)(void *data)
    This may be set by the application in get_prop_values() handler to tell esp_local_ctrl to call this function on the data pointer above, for freeing its resources after sending the get_prop_values response.

struct esp_local_ctrl_handlers
    Handlers for receiving and responding to local control commands for getting and setting properties.

Public Members

esp_err_t (*get_prop_values)(size_t props_count, const esp_local_ctrl_prop_t props[], esp_local_ctrl_prop_val_t prop_values[], void *usr_ctx)
    Handler function to be implemented for retrieving current values of properties.

Note: If any of the properties have fixed sizes, the size field of corresponding element in prop_values need to be set

Param props_count [in] Total elements in the props array
Param props [in] Array of properties, the current values for which have been requested by the client
Param prop_values [out] Array of empty property values, the elements of which need to be populated with the current values of those properties specified by props argument
Param usr_ctx [in] This provides value of the usr_ctx field of esp_local_ctrl_handlers_t structure
Return Returning different error codes will convey the corresponding protocol level errors to the client:
    • ESP_OK : Success
    • ESP_ERR_INVALID_ARG : InvalidArgument
    • ESP_ERR_INVALID_STATE : InvalidProto
    • All other error codes : InternalError

esp_err_t (*set_prop_values)(size_t props_count, const esp_local_ctrl_prop_t props[], const esp_local_ctrl_prop_val_t prop_values[], void *usr_ctx)
    Handler function to be implemented for changing values of properties.

Note: If any of the properties have variable sizes, the size field of the corresponding element in prop_values must be checked explicitly before making any assumptions on the size.
**Param props_count** [in] Total elements in the props array

**Param props** [in] Array of properties, the values for which the client requests to change

**Param prop_values** [in] Array of property values, the elements of which need to be used for updating those properties specified by props argument

**Param usr_ctx** [in] This provides value of the usr_ctx field of esp_local_ctrl_handlers_t structure

**Return** Returning different error codes will convey the corresponding protocol level errors to the client:
- ESP_OK: Success
- ESP_ERR_INVALID_ARG: InvalidArgument
- ESP_ERR_INVALID_STATE: InvalidProto
- All other error codes: InternalError

```c
void *usr_ctx
```

Context pointer to be passed to above handler functions upon invocation. This is different from the property level context, as this is valid throughout the lifetime of the esp_local_ctrl service, and freed only when the service is stopped.

```c
void (*usr_ctx_free_fn)(void *usr_ctx)
```

Pointer to function which will be internally invoked on usr_ctx for freeing the context resources when esp_local_ctrl_stop() is called.

```c
struct esp_local_ctrl_proto_sec_cfg
```

Protocom security configs

**Public Members**

```c
esp_local_ctrl_proto_sec_t version
```

This sets protocom security version, sec0/sec1 or custom If custom, user must provide handle via proto_sec_custom_handle below

```c
void *custom_handle
```

Custom security handle if security is set custom via proto_sec above This handle must follow protocomm_security_t signature

```c
const void *pop
```

Proof of possession to be used for local control. Could be NULL.

```c
const void *sec_params
```

Pointer to security params (NULL if not needed). This is not needed for protocomm security 0 This pointer should hold the struct of type esp_local_ctrl_security1_params_t for protocomm security 1 and esp_local_ctrl_security2_params_t for protocomm security 2 respectively. Could be NULL.

```c
struct esp_local_ctrl_config
```

Configuration structure to pass to esp_local_ctrl_start()
Chapter 2. API Reference

```c
typedef struct esp_local_ctrl_transport esp_local_ctrl_transport_t
    Transport mode (BLE / HTTPD) over which the service will be provided.

typedef struct esp_local_ctrl_proto_sec esp_local_ctrl_proto_sec_t
    Security types for esp_local_control.
```

### Macros

```c
ESP_LOCAL_CTRL_TRANSPORT_BLE
ESP_LOCAL_CTRL_TRANSPORT_HTTPD
```

### Type Definitions

```c
typedef struct esp_local_ctrl_prop esp_local_ctrl_prop_t
    Property description data structure, which is to be populated and passed to the
    esp_local_ctrl_add_property() function.
    Once a property is added, its structure is available for read-only access inside get_prop_values() and
    set_prop_values() handlers.

typedef struct esp_local_ctrl_prop_val esp_local_ctrl_prop_val_t
    Property value data structure. This gets passed to the get_prop_values() and set_prop_values() handlers
    for the purpose of retrieving or setting the present value of a property.

typedef struct esp_local_ctrl_handlers esp_local_ctrl_handlers_t
    Handlers for receiving and responding to local control commands for getting and setting properties.

typedef struct esp_local_ctrl_transport esp_local_ctrl_transport_t
    Transport layer over which service will be provided.

typedef struct protocomm_ble_config esp_local_ctrl_transport_config_ble_t
    Configuration for transport mode BLE.
    This is a forward declaration for protocomm_ble_config_t. To use this, application must set CONFIG_BT_BLUEDROID_ENABLED and include protocomm_ble.h.

typedef struct httpd_config esp_local_ctrl_transport_config_httpd_t
    Configuration for transport mode HTTPD.
    This is a forward declaration for httpd_ssl_config_t (for HTTPS) or httpd_config_t (for HTTP).

typedef enum esp_local_ctrl_proto_sec esp_local_ctrl_proto_sec_t
    Security version and POP
```

```c
ESP_LOCAL_CTRL_PROTO_SEC_BLE
ESP_LOCAL_CTRL_PROTO_SEC_HTTPD
```

```c
size_t max_properties
    This limits the number of properties that are available at a time
```
typedef protocomm_security1_params_t esp_local_ctrl_security1_params_t

typedef protocomm_security2_params_t esp_local_ctrl_security2_params_t

typedef struct esp_local_ctrl_proto_sec_cfg esp_local_ctrl_proto_sec_cfg_t

Protocom security configs

typedef struct esp_local_ctrl_config esp_local_ctrl_config_t

Configuration structure to pass to esp_local_ctrl_start()

Enumerations

enum esp_local_ctrl_proto_sec

Security types for esp_local_control.

Values:

enumerator PROTOCOM_SEC0

enumerator PROTOCOM_SEC1

enumerator PROTOCOM_SEC2

enumerator PROTOCOM_SEC_CUSTOM

2.2.7 ESP Serial Slave Link

Overview

Espressif provides several chips that can work as slaves. These slave devices rely on some common buses, and have their own communication protocols over those buses. The esp_serial_slave_link component is designed for the master to communicate with ESP slave devices through those protocols over the bus drivers.

After an esp_serial_slave_link device is initialized properly, the application can use it to communicate with the ESP slave devices conveniently.

Espressif Device protocols

For more details about Espressif device protocols, see the following documents.

Communication with ESP SDIO Slave  This document describes the process of initialization of an ESP SDIO Slave device and then provides details on the ESP SDIO Slave protocol - a non-standard protocol that allows an SDIO Host to communicate with an ESP SDIO slave.

The ESP SDIO Slave protocol was created to implement the communication between SDIO host and slave, because the SDIO specification only shows how to access the custom region of a card (by sending CMD52 and CMD53 to Functions 1-7) without any details regarding the underlying hardware implementation.
SDIO Slave Capabilities of Espressif chips

The services provided by the SDIO Slave peripheral of the ESP32 chip are listed in the table below:

<table>
<thead>
<tr>
<th>Services</th>
<th>ESP32</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDIO slave</td>
<td>Y</td>
</tr>
<tr>
<td>Tohost intr</td>
<td>8</td>
</tr>
<tr>
<td>From host intr</td>
<td>8</td>
</tr>
<tr>
<td>TX DMA</td>
<td>Y</td>
</tr>
<tr>
<td>RX DMA</td>
<td>Y</td>
</tr>
<tr>
<td>Shared registers</td>
<td>56*</td>
</tr>
</tbody>
</table>

* Not including the interrupt registers

ESP SDIO Slave Initialization

The host should initialize the ESP32 SDIO slave according to the standard SDIO initialization process (Section 3.1.2 of SDIO Simplified Specification). In this specification as well as below, the SDIO slave is called an (SD)IO card. Here is a brief example of an ESP SDIO Slave initialization process:

1. **SDIO reset** CMD52 (Write 0x6=0x8)
2. **SD reset** CMD0
3. **Check whether IO card (optional)** CMD8
4. **Send SDIO op cond and wait for card ready** CMD5 arg = 0x00000000
   CMD5 arg = 0x00ff8000 (according to the response above, poll until ready)
   **Example:** Arg of R4 after first CMD5 (arg=0x00000000) is 0xXXFFFF00.
   Keep sending CMD5 with arg=0x00FFFF00 until the R4 shows card ready (arg bit 31=1).
5. **Set address** CMD3
6. **Select card** CMD7 (arg address according to CMD3 response)
   **Example:** Arg of R6 after CMD3 is 0x0001xxxx.
   Arg of CMD7 should be 0x00010000.
7. **Select 4-bit mode (optional)** CMD52 (Write 0x07=0x02)
8. **Enable func1** CMD52 (Write 0x02=0x02)
9. **Enable SDIO interrupt (required if interrupt line (DAT1) is used)** CMD52 (Write 0x04=0x03)
10. **Set Func0 blocksize (optional, default value is 512 (0x200))** CMD52/53 (Read 0x10~0x11)
    CMD52/53 (Write 0x10=0x00)
    CMD52/53 (Write 0x11=0x02)
    CMD52/53 (Read 0x10~0x11, read to check the final value)
11. **Set Func1 blocksize (optional, default value is 512 (0x200))** CMD52/53 (Read 0x110~0x111)
    CMD52/53 (Write 0x110=0x00)
    CMD52/53 (Write 0x111=0x02)
    CMD52/53 (Read 0x110~0x111, read to check the final value)

ESP SDIO Slave Protocol

The ESP SDIO Slave protocol is based on the SDIO Specification’s I/O Read/Write commands, i.e., CMD52 and CMD53. The protocol offers the following services:

- Sending FIFO and receiving FIFO
- 52 8-bit R/W registers shared by host and slave (For details, see ESP32 Technical Reference Manual > SDIO Slave Controller > Register Summary > SDIO SLC Host registers [PDF])
- 16 general purpose interrupt sources, 8 from host to slave and 8 from slave to host

To begin communication, the host needs to enable the I/O Function 1 in the slave and access its registers as described below.

Check the code example peripherals/sdio.

The ESP Serial Slave Link component implements the logic of this protocol for ESP32 SDIO Host when communicating with an ESP32 SDIO slave.

Slave register table
Chapter 2. API Reference

32-bit
- 0x044 (TOKEN_RDATA): in which bit 27-16 holds the number of the receiving buffer.
- 0x058 (INT_ST): holds the interrupt source bits from slave to host.
- 0x060 (PKT_LEN): holds the accumulated data length (in bytes) already read by host plus the data copied to
  the buffer but yet to be read.
- 0x0D4 (INT_CLR): write 1 to clear interrupt bits corresponding to INT_ST.
- 0x0DC (INT_ENA): mask bits for interrupts from slave to host.

8-bit
Shared general purpose registers:
- 0x06C-0x077: R/W registers 0-11 shared by slave and host.
- 0x07A-0x07B: R/W registers 14-15 shared by slave and host.
- 0x07E-0x07F: R/W registers 18-19 shared by slave and host.
- 0x088-0x08B: R/W registers 24-27 shared by slave and host.
- 0x09C-0x0BB: R/W registers 32-63 shared by slave and host.

Interrupt Registers: - 0x08D (SLAVE_INT): bits for host to interrupt slave. auto clear.

FIFO (sending and receiving)  0x090 - 0x1F7FF are reserved for FIFOs.
The address of CMD53 is related to the length requested to read from or write to the slave in a single transfer, as
demonstrated by the equation below:
requested length = 0x1F800-address

The slave will respond with data that has a length equal to the length field of CMD53. In cases where the data is longer
than the requested length, the data will be zero filled (when sending) or discarded (when receiving). This includes
both the block and the byte mode of CMD53.

Note: The function number should be set to 1, OP Code should be set to 1 (for CMD53).

In order to achieve higher efficiency when accessing the FIFO by an arbitrary length, the block and byte modes of
CMD53 can be used in combination. For example, given that the block size is set to 512 by default, you can write/get
1031 bytes of data from the FIFO by doing the following:
1. Send CMD53 in block mode, block count=2 (1024 bytes) to address 0x1F3F9=0x1F800-1031.
2. Then send CMD53 in byte mode, byte count=8 (or 7 if your controller supports that) to address
   0x1F7F9=0x1F800-7.

Interrupts  SDIO interrupts are “level sensitive”. For host interrupts, the slave sends an interrupt by pulling the
DAT1 line down at a proper time. The host detects when the interrupt line is pulled down and reads the INT_ST
register to determine the source of the interrupt. After that, the host can clear the interrupt bits by writing the
INT_CLR register and process the interrupt. The host can also mask unneeded sources by clearing the bits in the
INT_ENA register corresponding to the sources. If all the sources are cleared (or masked), the DAT1 line goes
inactive.

On ESP32, the corresponding host_int bits are: bit 0 to bit 7.

For slave interrupts, the host sends a transfer to write the SLAVE_INT register. Once a bit is set to 1, the slave
hardware and the driver will detect it and inform the application.

Receiving FIFO  To write to the slave’s receiving FIFO, the host should complete the following steps:
1. Read the TOKEN1 field (bits 27-16) of the register TOKEN_RDATA (0x044). The buffer number re-
   maining is TOKEN1 minus the number of buffers used by host.
2. Make sure the buffer number is sufficient (buffer_size x buffer_num is greater than the data to write,
   buffer_size is pre-defined between the host and the slave before the communication starts). Otherwise, keep
   returning to Step 1 until the buffer size is sufficient.
3. **Write to the FIFO address with CMD53.** Note that the *requested length* should not exceed the length calculated at Step 2, and the FIFO address is related to *requested length*.

4. **Calculate used buffers.** Note that a partially used buffer at the tail is counted as used.

**Sending FIFO**  
To read the slave’s sending FIFO, the host should complete the following steps:

1. **Wait for the interrupt line to become active** (optional, low by default).
2. **Read (poll) the interrupt bits in the INT_ST register** to monitor if new packets exist.
3. **If new packets are ready, read the PKT_LEN register.** Before reading the packets, determine the length of data to be read. As the host keeps the length of data already read from the slave, subtract this value from PKT_LEN, the result will be the maximum length of data available for reading. If no data has been added to the sending FIFO yet, wait and poll until the slave is ready and update PKT_LEN.
4. **Read from the FIFO using CMD53.** Note that the *requested length* should not be greater than calculated at Step 3, and the FIFO address is related to *requested length*.
5. **Update the read length.**

**Warning:** The driver for ESP32 hasn’t been developed yet.

---

**ESP SPI Slave HD (Half Duplex) Mode Protocol**

**SPI Slave Capabilities of Espressif chips**

<table>
<thead>
<tr>
<th>ESP32</th>
<th>ESP32-S2</th>
<th>ESP32-C3</th>
<th>ESP32-S3</th>
<th>ESP32-C2</th>
<th>ESP32-C6</th>
<th>ESP32-H2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI Slave HD</td>
<td>N</td>
<td>Y (v2)</td>
<td>Y (v2)</td>
<td>Y (v2)</td>
<td>Y (v2)</td>
<td>Y (v2)</td>
</tr>
<tr>
<td>To host intr</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>From host intr</td>
<td>2 *</td>
<td>2 *</td>
<td>2 *</td>
<td>2 *</td>
<td>2 *</td>
<td>2 *</td>
</tr>
<tr>
<td>TX DMA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>RX DMA</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Shared registers</td>
<td>72</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

**Introduction**  
In the half duplex mode, the master has to use the protocol defined by the slave to communicate with the slave. Each transaction may consist of the following phases (list by the order they should exist):

- **Command:** 8-bit, master to slave  
  This phase determines the rest phases of the transactions. See *Supported Commands*.

  - **Address:** 8-bit, master to slave, optional  
    For some commands (WRBUF, RDBUF), this phase specifies the address of the shared buffer to write to/read from. For other commands with this phase, they are meaningless but still have to exist in the transaction.

  - **Dummy:** 8-bit, floating, optional  
    This phase is the turnaround time between the master and the slave on the bus, and also provides enough time for the slave to prepare the data to send to the master.

  - **Data:** variable length, the direction is also determined by the command.  
    This may be a data OUT phase, in which the direction is slave to master, or a data IN phase, in which the direction is master to slave.

The *direction* means which side (master or slave) controls the MOSI, MISO, WP, and HD pins.

**Data IO Modes**  
In some IO modes, more data wires can be used to send the data. As a result, the SPI clock cycles required for the same amount of data will be less than in the 1-bit mode. For example, in QIO mode, address and data (IN and OUT) should be sent on all 4 data wires (MOSI, MISO, WP, and HD). Here are the modes supported by the ESP32-S2 SPI slave and the wire number used in corresponding modes.
Normally, which mode is used is determined by the command sent by the master (See Supported Commands), except the QPI mode.

**QPI Mode** The QPI mode is a special state of the SPI Slave. The master can send the ENQPI command to put the slave into the QPI mode state. In the QPI mode, the command is also sent in 4-bit, thus it’s not compatible with the normal modes. The master should only send QPI commands when the slave is in QPI mode. To exit from the QPI mode, master can send the EXQPI command.

**Supported Commands**

**Note:** The command name is in a master-oriented direction. For example, WRBUF means master writes the buffer of slave.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Command</th>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRBUF</td>
<td>Write buffer</td>
<td>0x01</td>
<td>Buf addr</td>
<td>master to slave, no longer than buffer size</td>
</tr>
<tr>
<td>RDBUF</td>
<td>Read buffer</td>
<td>0x02</td>
<td>Buf addr</td>
<td>slave to master, no longer than buffer size</td>
</tr>
<tr>
<td>WRDMA</td>
<td>Write DMA</td>
<td>0x03</td>
<td>8 bits</td>
<td>master to slave, no longer than length provided by slave</td>
</tr>
<tr>
<td>RDDMA</td>
<td>Read DMA</td>
<td>0x04</td>
<td>8 bits</td>
<td>slave to master, no longer than length provided by slave</td>
</tr>
<tr>
<td>SEG_DONE</td>
<td>Segments done</td>
<td>0x05</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>ENQPI</td>
<td>Enter QPI mode</td>
<td>0x06</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>WR_DONE</td>
<td>Write segments done</td>
<td>0x07</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>CMD8</td>
<td>Interrupt</td>
<td>0x08</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>CMD9</td>
<td>Interrupt</td>
<td>0x09</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>CMDA</td>
<td>Interrupt</td>
<td>0x0A</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>EXQPI</td>
<td>Exit QPI mode</td>
<td>0xDD</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

Moreover, WRBUF, RDBUF, WRDMA, RDDMA commands have their 2-bit and 4-bit version. To do transactions in 2-bit or 4-bit mode, send the original command ORed by the corresponding command mask below. For example, command 0xA1 means WRBUF in QIO mode.
### Segment Transaction Mode
Segment transaction mode is the only mode supported by the SPI Slave HD driver for now. In this mode, for a transaction the slave loads onto the DMA, the master is allowed to read or write in segments. This way the master doesn’t have to prepare a large buffer as the size of data provided by the slave. After the master finishes reading/writing a buffer, it has to send the corresponding termination command to the slave as a synchronization signal. The slave driver will update new data (if exist) onto the DMA upon seeing the termination command.

The termination command is WR_DONE (0x07) for the WRDMA and CMD8 (0x08) for the RDDMA.

Here’s an example for the flow the master read data from the slave DMA:

1. The slave loads 4092 bytes of data onto the RDDMA
2. The master do seven RDDMA transactions, each of them is 512 bytes long, and reads the first 3584 bytes from the slave
3. The master do the last RDDMA transaction of 512 bytes (equal, longer, or shorter than the total length loaded by the slave are all allowed). The first 508 bytes are valid data from the slave, while the last 4 bytes are meaningless bytes.
4. The master sends CMD8 to the slave
5. The slave loads another 4092 bytes of data onto the RDDMA
6. The master can start new reading transactions after it sends the CMD8

### Terminology

- **ESSL**: Abbreviation for ESP Serial Slave Link, the component described by this document.
- **Master**: The device running the esp_serial_slave_link component.
- **ESSL device**: a virtual device on the master associated with an ESP slave device. The device context has the knowledge of the slave protocol above the bus, relying on some bus drivers to communicate with the slave.
- **ESSL device handle**: a handle to ESSL device context containing the configuration, status and data required by the ESSL component. The context stores the driver configurations, communication state, data shared by master and slave, etc.
  The context should be initialized before it is used, and get deinitialized if not used any more. The master application operates on the ESSL device through this handle.
- **ESP slave**: the slave device connected to the bus, which ESSL component is designed to communicate with.
- **Bus**: The bus over which the master and the slave communicate with each other.
- **Slave protocol**: The special communication protocol specified by Espressif HW/SW over the bus.
- **TX buffer num**: a counter, which is on the slave and can be read by the master, indicates the accumulated buffer numbers that the slave has loaded to the hardware to receive data from the master.
- **RX data size**: a counter, which is on the slave and can be read by the master, indicates the accumulated data size that the slave has loaded to the hardware to send to the master.

### Services provided by ESP slave

There are some common services provided by the Espressif slaves:

1. Tohost Interrupts: The slave can inform the master about certain events by the interrupt line. (optional)
2. Frhost Interrupts: The master can inform the slave about certain events.
3. Tx FIFO (master to slave): the slave can send data in stream to the master. The SDIO slave can also indicate it has new data to send to master by the interrupt line.
Chapter 2. API Reference

The slave updates the TX buffer num to inform the master how much data it can receive, and the master then read the TX buffer num, and take off the used buffer number to know how many buffers are remaining.

4. Rx FIFO (slave to master): the slave can receive data from the master in units of receiving buffers.
   The slave updates the RX data size to inform the master how much data it has prepared to send, and then the master read the data size, and take off the data length it has already received to know how many data is remaining.

5. Shared registers: the master can read some part of the registers on the slave, and also write these registers to let the slave read.

The services provided by the slave depends on the slave’s model. See SDIO Slave Capabilities of Espressif chips and SPI Slave Capabilities of Espressif chips for more details.

Initialization of ESP Serial Slave Link

ESP SDIO Slave The ESP SDIO slave link (ESSL SDIO) devices relies on the sdmmc component. It includes the usage of communicating with ESP SDIO Slave device via SDSPI feature. The ESSL device should be initialized as below:

1. Initialize a sdmmc card (see `Document of SDMMC driver </api-reference/storage/sdmmc>`) structure.
2. Call `sdmmc_card_init()` to initialize the card.
3. Initialize the ESSL device with `essl_sdio_config_t`. The `card` member should be the `sdmmc_card_t` got in step 2, and the `recv_buffer_size` member should be filled correctly according to pre-negotiated value.
4. Call `essl_init()` to do initialization of the SDIO part.
5. Call `essl_wait_for_ready()` to wait for the slave to be ready.

ESP SPI Slave

**Note:** If you are communicating with the ESP SDIO Slave device through SPI interface, you should use the SDIO interface instead.

Hasn’t been supported yet.

APIs

After the initialization process above is performed, you can call the APIs below to make use of the services provided by the slave:

To host Interrupts (optional)

1. Call `essl_get_intr_ena()` to know which events will trigger the interrupts to the master.
2. Call `essl_set_intr_ena()` to set the events that will trigger interrupts to the master.
3. Call `essl_wait_int()` to wait until interrupt from the slave, or timeout.
4. When interrupt is triggered, call `essl_get_intr()` to know which events are active, and call `essl_clear_intr()` to clear them.

F rom host Interrupts

1. Call `essl_send_slave_intr()` to trigger general purpose interrupt of the slave.

TX FIFO

1. Call `essl_get_tx_buffer_num()` to know how many buffers the slave has prepared to receive data from the master. This is optional. The master will poll `tx_buffer_num` when it try to send packets to the slave, until the slave has enough buffer or timeout.
2. Call `essl_send_packet()` to send data to the slave.
RX FIFO

1. Call `essl_get_rx_data_size()` to know how many data the slave has prepared to send to the master. This is optional. When the master tries to receive data from the slave, it will update the `rx_data_size` for once, if the current `rx_data_size` is shorter than the buffer size the master prepared to receive. And it may poll the `rx_data_size` if the `rx_dat_size` keeps 0, until timeout.

2. Call `essl_get_packet()` to receive data from the slave.

Reset counters (Optional)  Call `essl_reset_cnt()` to reset the internal counter if you find the slave has reset its counter.

Application Example

The example below shows how ESP32 SDIO host and slave communicate with each other. The host use the ESSL SDIO.

Please refer to the specific example README.md for details.

API Reference

Header File

- components/driver/test_apps/components/esp_serial_slave_link/include/esp_serial_slave_link/essl.h

Functions

```c
esp_err_t essl_init(essl_handle_t handle, uint32_t wait_ms)
```

Initialize the slave.

**Parameters**

- `handle` – Handle of an ESSL device.
- `wait_ms` – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**

- ESP_OK: If success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- Other value returned from lower layer `init`.

```c
esp_err_t essl_wait_for_ready(essl_handle_t handle, uint32_t wait_ms)
```

Wait for interrupt of an ESSL slave device.

**Parameters**

- `handle` – Handle of an ESSL device.
- `wait_ms` – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**

- ESP_OK: If success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

```c
esp_err_t essl_get_tx_buffer_num(essl_handle_t handle, uint32_t *out_tx_num, uint32_t wait_ms)
```

Get buffer num for the host to send data to the slave. The buffers are size of `buffer_size`.

**Parameters**

- `handle` – Handle of a ESSL device.
- `out_tx_num` – Output of buffer num that host can send data to ESSL slave.
- `wait_ms` – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**

- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: This API is not supported in this mode
• One of the error codes from SDMMC/SPI host controller

```c
esp_err_t essl_get_rx_data_size(essl_handle_t handle, uint32_t *out_rx_size, uint32_t wait_ms)
```

Get the size, in bytes, of the data that the ESSL slave is ready to send

**Parameters**
- **handle** – Handle of an ESSL device.
- **out_rx_size** – Output of data size to read from slave, in bytes
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: This API is not supported in this mode
- One of the error codes from SDMMC/SPI host controller

```c
esp_err_t essl_reset_cnt(essl_handle_t handle)
```

Reset the counters of this component. Usually you don’t need to do this unless you know the slave is reset.

**Parameters**
- **handle** – Handle of an ESSL device.

**Returns**
- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: This API is not supported in this mode
- ESP_ERR_INVALID_ARG: Invalid argument, handle is not init.

```c
esp_err_t essl_send_packet(essl_handle_t handle, const void* start, size_t length, uint32_t wait_ms)
```

Send a packet to the ESSL Slave. The Slave receives the packet into buffers whose size is `buffer_size` (configured during initialization).

**Parameters**
- **handle** – Handle of an ESSL device.
- **start** – Start address of the packet to send
- **length** – Length of data to send, if the packet is over-size, the it will be divided into blocks and hold into different buffers automatically.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG: Invalid argument, handle is not init or other argument is not valid.
- ESP_ERR_TIMEOUT: No buffer to use, or error from SDMMC host controller.
- ESP_ERR_NOT_FOUND: Slave is not ready for receiving.
- ESP_ERR_NOT_SUPPORTED: This API is not supported in this mode
- One of the error codes from SDMMC/SPI host controller.

```c
esp_err_t essl_get_packet(essl_handle_t handle, void*out_data, size_t size, size_t*out_length, uint32_t wait_ms)
```

Get a packet from ESSL slave.

**Parameters**
- **handle** – Handle of an ESSL device.
- **out_data** – Data output address
- **size** – The size of the output buffer, if the buffer is smaller than the size of data to receive from slave, the driver returns ESP_ERR_NOT_FINISHED
- **out_length** – Output of length the data actually received from slave.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK Success: All the data has been read from the slave.
- ESP_ERR_INVALID_ARG: Invalid argument, The handle is not initialized or the other arguments are invalid.
- ESP_ERR_NOT_FINISHED: Read was successful, but there is still data remaining.
- ESP_ERR_NOT_FOUND: Slave is not ready to send data.
- ESP_ERR_NOT_SUPPORTED: This API is not supported in this mode
- One of the error codes from SDMMC/SPI host controller.
**esp_err_t essl_write_reg(essl_handle_t handle, uint8_t addr, uint8_t value, uint8_t *value_o, uint32_t wait_ms)**

Write general purpose R/W registers (8-bit) of ESSL slave.

**Note:** sdio 28-31 are reserved, the lower API helps to skip.

**Parameters**
- **handle** – Handle of an ESSL device.
- **addr** – Address of register to write. For SDIO, valid address: 0-59. For SPI, see `esll_spi.h`
- **value** – Value to write to the register.
- **value_o** – Output of the returned written value.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK Success
- One of the error codes from SDMMC/SPI host controller

**esp_err_t essl_read_reg(essl_handle_t handle, uint8_t add, uint8_t *value_o, uint32_t wait_ms)**

Read general purpose R/W registers (8-bit) of ESSL slave.

**Parameters**
- **handle** – Handle of an ESSL device.
- **add** – Address of register to read. For SDIO, Valid address: 0-27, 32-63 (28-31 reserved, return interrupt bits on read). For SPI, see `esll_spi.h`
- **value_o** – Output value read from the register.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK Success
- One of the error codes from SDMMC/SPI host controller

**esp_err_t essl_wait_int(essl_handle_t handle, uint32_t wait_ms)**

wait for an interrupt of the slave

**Parameters**
- **handle** – Handle of an ESSL device.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: If interrupt is triggered.
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- ESP_ERR_TIMEOUT: No interrupts before timeout.

**esp_err_t essl_clear_intr(essl_handle_t handle, uint32_t intr_mask, uint32_t wait_ms)**

Clear interrupt bits of ESSL slave. All the bits set in the mask will be cleared, while other bits will stay the same.

**Parameters**
- **handle** – Handle of an ESSL device.
- **intr_mask** – Mask of interrupt bits to clear.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

**esp_err_t essl_get_intr(essl_handle_t handle, uint32_t *intr_raw, uint32_t *intr_st, uint32_t wait_ms)**

Get interrupt bits of ESSL slave.

**Parameters**
- **handle** – Handle of an ESSL device.
- **intr_raw** – Output of the raw interrupt bits. Set to NULL if only masked bits are read.
- **intr_st** – Output of the masked interrupt bits. Set to NULL if only raw bits are read.
- **wait_ms** – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: Success
- ESP_INVALID_ARG: If both `intr_raw` and `intr_st` are NULL.
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

```c
esp_err_t essl_set_intr_ena(essl_handle_t handle, uint32_t ena_mask, uint32_t wait_ms)
```

Set interrupt enable bits of ESSL slave. The slave only sends interrupt on the line when there is a bit both the raw status and the enable are set.

**Parameters**
- `handle` – Handle of an ESSL device.
- `ena_mask` – Mask of the interrupt bits to enable.
- `wait_ms` – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

```c
esp_err_t essl_get_intr_ena(essl_handle_t handle, uint32_t *ena_mask_o, uint32_t wait_ms)
```

Get interrupt enable bits of ESSL slave.

**Parameters**
- `handle` – Handle of an ESSL device.
- `ena_mask_o` – Output of interrupt bit enable mask.
- `wait_ms` – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: Success
- One of the error codes from SDMMC host controller

```c
esp_err_t essl_send_slave_intr(essl_handle_t handle, uint32_t intr_mask, uint32_t wait_ms)
```

Send interrupts to slave. Each bit of the interrupt will be triggered.

**Parameters**
- `handle` – Handle of an ESSL device.
- `intr_mask` – Mask of interrupt bits to send to slave.
- `wait_ms` – Millisecond to wait before timeout, will not wait at all if set to 0-9.

**Returns**
- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

**Type Definitions**

typedef struct essl_dev_t *essl_handle_t

Handle of an ESSL device.

**Header File**

- `components/driver/test_apps/components/esp_serial_slave_link/include/esp_serial_slave_link/essl_sdio.h`

**Functions**

```c
esp_err_t essl_sdio_init_dev(essl_handle_t *out_handle, const essl_sdio_config_t *config)
```

Initialize the ESSL SDIO device and get its handle.

**Parameters**
Chapter 2. API Reference

- **out_handle** - Output of the handle.
- **config** - Configuration for the ESSL SDIO device.

**Returns**
- ESP_OK: on success
- ESP_ERR_NO_MEM: memory exhausted.

`esp_err_t essl_sdio_deinit_dev(essl_handle_t handle)`

Deinitialize and free the space used by the ESSL SDIO device.

**Parameters**
- **handle** - Handle of the ESSL SDIO device to deinit.

**Returns**
- ESP_OK: on success
- ESP_ERR_INVALID_ARG: wrong handle passed

**Structures**

`struct essl_sdio_config_t`  
Configuration for the ESSL SDIO device.

**Public Members**

- **sdmmc_card_t *card**  
The initialized sdmmc card pointer of the slave.

- **int recv_buffer_size**  
The pre-negotiated recv buffer size used by both the host and the slave.

**Header File**

- components/driver/test_apps/components/esp_serial_slave_link/include/esp_serial_slave_link/essl_spi.h

**Functions**

`esp_err_t essl_spi_init_dev(essl_handle_t *out_handle, const essl_spi_config_t *init_config)`  
Initialize the ESSL SPI device function list and get its handle.

**Parameters**
- **out_handle** - [out] Output of the handle
- **init_config** - Configuration for the ESSL SPI device

**Returns**
- ESP_OK: On success
- ESP_ERR_NO_MEM: Memory exhausted
- ESP_ERR_INVALID_STATE: SPI driver is not initialized
- ESP_ERR_INVALID_ARG: Wrong register ID

`esp_err_t essl_spi_deinit_dev(essl_handle_t handle)`  
Deinitialize the ESSL SPI device and free the memory used by the device.

**Parameters**
- **handle** - Handle of the ESSL SPI device

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_STATE: ESSL SPI is not in use

`esp_err_t essl_spi_read_reg(void *arg, uint8_t addr, uint8_t *out_value, uint32_t wait_ms)`  
Read from the shared registers.
Note: The registers for Master/Slave synchronization are reserved. Do not use them. (see rx_sync_reg in essl_spi_config_t)

Parameters

- **arg** – Context of the component. (Member arg from essl_handle_t)
- **addr** – Address of the shared registers. (Valid: 0 ~ SOC_SPI_MAXIMUM_BUFFER_SIZE, registers for M/S sync are reserved, see note1).
- **out_value** – [out] Read buffer for the shared registers.
- **wait_ms** – Time to wait before timeout (reserved for future use, user should set this to 0).

Returns

- ESP_OK: success
- ESP_ERR_INVALID_STATE: ESSL SPI has not been initialized.
- ESP_ERR_INVALID_ARG: The address argument is not valid. See note 1.
- or other return value from: cpp:func:spi_device_transmit.

**esp_err_t essl_spi_get_packet**(void *arg, void *out_data, size_t size, uint32_t wait_ms)

Get a packet from Slave.

Parameters

- **arg** – Context of the component. (Member arg from essl_handle_t)
- **out_data** – [out] Output data address
- **size** – The size of the output data.
- **wait_ms** – Time to wait before timeout (reserved for future use, user should set this to 0).

Returns

- ESP_OK: On Success
- ESP_ERR_INVALID_STATE: ESSL SPI has not been initialized.
- ESP_ERR_INVALID_ARG: The output data address is neither DMA capable nor 4 byte-aligned
- ESP_ERR_INVALID_SIZE: Master requires size bytes of data but Slave did not load enough bytes.

**esp_err_t essl_spi_write_reg**(void *arg, uint8_t addr, uint8_t value, uint8_t *out_value, uint32_t wait_ms)

Write to the shared registers.

Note: The registers for Master/Slave synchronization are reserved. Do not use them. (see tx_sync_reg in essl_spi_config_t)

Note: Feature of checking the actual written value (out_value) is not supported.

Parameters

- **arg** – Context of the component. (Member arg from essl_handle_t)
- **addr** – Address of the shared registers. (Valid: 0 ~ SOC_SPI_MAXIMUM_BUFFER_SIZE, registers for M/S sync are reserved, see note1)
- **value** – Buffer for data to send, should be align to 4.
- **out_value** – [out] Not supported, should be set to NULL.
- **wait_ms** – Time to wait before timeout (reserved for future use, user should set this to 0).

Returns

- ESP_OK: success
• ESP_ERR_INVALID_STATE: ESSL SPI has not been initialized.
• ESP_ERR_INVALID_ARG: The address argument is not valid. See note 1.
• ESP_ERR_NOT_SUPPORTED: Should set out_value to NULL. See note 2.
• or other return value from: cpp:func:spi_device_transmit.

**esp_err_t essl_spi_send_packet** (void *arg, const void *data, size_t size, uint32_t wait_ms)

Send a packet to Slave.

**Parameters**
- **arg** – Context of the component. (Member arg from essl_handle_t)
- **data** – Address of the data to send
- **size** – Size of the data to send.
- **wait_ms** – Time to wait before timeout (reserved for future use, user should set this to 0).

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_STATE: ESSL SPI has not been initialized.
- ESP_ERR_INVALID_ARG: The data address is not DMA capable
- ESP_ERR_INVALID_SIZE: Master will send size bytes of data but Slave did not load enough RX buffer

**void essl_spi_reset_cnt** (void *arg)

Reset the counter in Master context.

**Note:** Shall only be called if the slave has reset its counter. Else, Slave and Master would be desynchronized

**Parameters**
- **arg** – Context of the component. (Member arg from essl_handle_t)

**esp_err_t essl_spi_rdbuf(spi_device_handle_t spi, uint8_t*out_data, int addr, int len, uint32_t flags)**

Read the shared buffer from the slave in ISR way.

**Note:** The slave’s HW doesn’t guarantee the data in one SPI transaction is consistent. It sends data in unit of byte. In other words, if the slave SW attempts to update the shared register when a rdbuf SPI transaction is in-flight, the data got by the master will be the combination of bytes of different writes of slave SW.

**Note:** out_data should be prepared in words and in the DRAM. The buffer may be written in words by the DMA. When a byte is written, the remaining bytes in the same word will also be overwritten, even the len is shorter than a word.

**Parameters**
- **spi** – SPI device handle representing the slave
- **out_data** – [out] Buffer for read data, strongly suggested to be in the DRAM and aligned to 4
- **addr** – Address of the slave shared buffer
- **len** – Length to read
- **flags** – SPI_TRANS_* flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: on success
- or other return value from: cpp:func:spi_device_transmit.

**esp_err_t essl_spi_rdbuf_polling** (spi_device_handle_t spi, uint8_t*out_data, int addr, int len, uint32_t flags)

Read the shared buffer from the slave in polling way.
Note: out_data should be prepared in words and in the DRAM. The buffer may be written in words by the DMA. When a byte is written, the remaining bytes in the same word will also be overwritten, even the len is shorter than a word.

**Parameters**
- spi – SPI device handle representing the slave
- out_data - [out] Buffer for read data, strongly suggested to be in the DRAM and aligned to 4
- addr – Address of the slave shared buffer
- len – Length to read
- flags –SPI_TRANS_* flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: on success
- or other return value from :cpp:func:`spi_device_transmit`.

```c
esp_err_t essl_spi_wrbuf (spi_device_handle_t spi, const uint8_t* data, int addr, int len, uint32_t flags)
```
Write the shared buffer of the slave in ISR way.

**Parameters**
- spi – SPI device handle representing the slave
- data – Buffer for data to send, strongly suggested to be in the DRAM
- addr – Address of the slave shared buffer,
- len – Length to write
- flags –SPI_TRANS_* flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from :cpp:func:`spi_device_transmit`.

```c
esp_err_t essl_spi_wrbuf_polling (spi_device_handle_t spi, const uint8_t* data, int addr, int len, uint32_t flags)
```
Write the shared buffer of the slave in polling way.

**Parameters**
- spi – SPI device handle representing the slave
- data – Buffer for data to send, strongly suggested to be in the DRAM
- addr – Address of the slave shared buffer,
- len – Length to write
- flags –SPI_TRANS_* flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from :cpp:func:`spi_device_polling_transmit`.

```c
esp_err_t essl_spi_rddma (spi_device_handle_t spi, uint8_t* out_data, int len, int seg_len, uint32_t flags)
```
Receive long buffer in segments from the slave through its DMA.
Chapter 2. API Reference

Note: This function combines several `cpp:func:essl_spi_rddma_seg` and one `cpp:func:essl_spi_rddma_done` at the end. Used when the slave is working in segment mode.

**Parameters**
- `spi` - SPI device handle representing the slave
- `out_data` – [out] Buffer to hold the received data, strongly suggested to be in the DRAM and aligned to 4
- `len` – Total length of data to receive.
- `seg_len` – Length of each segment, which is not larger than the maximum transaction length allowed for the spi device. Suggested to be multiples of 4. When set < 0, means send all data in one segment (the `rddma_done` will still be sent.)
- `flags` – `SPI_TRANS_*` flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from `cpp:func:spi_device_transmit`.

```c
esp_err_t essl_spi_rddma_seg (spi_device_handle_t spi, uint8_t *out_data, int seg_len, uint32_t flags)
```

Read one data segment from the slave through its DMA.

Note: To read long buffer, call `cpp:func:essl_spi_rddma` instead.

**Parameters**
- `spi` - SPI device handle representing the slave
- `out_data` – [out] Buffer to hold the received data, strongly suggested to be in the DRAM and aligned to 4
- `seg_len` – Length of this segment
- `flags` – `SPI_TRANS_*` flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from `cpp:func:spi_device_transmit`.

```c
esp_err_t essl_spi_rddma_done (spi_device_handle_t spi, uint32_t flags)
```

Send the `rddma_done` command to the slave. Upon receiving this command, the slave will stop sending the current buffer even there are data unsent, and maybe prepare the next buffer to send.

Note: This is required only when the slave is working in segment mode.

**Parameters**
- `spi` - SPI device handle representing the slave
- `flags` – `SPI_TRANS_*` flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from `cpp:func:spi_device_transmit`.

```c
esp_err_t essl_spi_wrdma (spi_device_handle_t spi, const uint8_t *data, int len, int seg_len, uint32_t flags)
```

Send long buffer in segments to the slave through its DMA.

Note: This function combines several `cpp:func:essl_spi_wrdma_seg` and one `cpp:func:essl_spi_wrdma_done` at the end. Used when the slave is working in segment mode.

**Parameters**
### Chapter 2. API Reference

- **spi** – SPI device handle representing the slave
- **data** – Buffer for data to send, strongly suggested to be in the DRAM
- **len** – Total length of data to send.
- **seg_len** – Length of each segment, which is not larger than the maximum transaction length allowed for the spi device. Suggested to be multiples of 4. When set < 0, means send all data in one segment (the wrdma_done will still be sent.)
- **flags** – SPI_TRANS_* flags to control the transaction mode of the transaction to send.

#### Returns
- ESP_OK: success
- or other return value from `cpp:func:spi_device_transmit`.

#### esp_err_t essl_spi_wrdma_seg(spi_device_handle_t spi, const uint8_t* data, int seg_len, uint32_t flags)
Send one data segment to the slave through its DMA.

**Note:** To send long buffer, call `cpp:func:essl_spi_wrdma` instead.

**Parameters**
- **spi** – SPI device handle representing the slave
- **data** – Buffer for data to send, strongly suggested to be in the DRAM
- **seg_len** – Length of this segment
- **flags** – SPI_TRANS_* flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from `cpp:func:spi_device_transmit`.

#### esp_err_t essl_spi_wrdma_done(spi_device_handle_t spi, uint32_t flags)
Send the wrdma_done command to the slave. Upon receiving this command, the slave will stop receiving, process the received data, and maybe prepare the next buffer to receive.

**Note:** This is required only when the slave is working in segment mode.

**Parameters**
- **spi** – SPI device handle representing the slave
- **flags** – SPI_TRANS_* flags to control the transaction mode of the transaction to send.

**Returns**
- ESP_OK: success
- or other return value from `cpp:func:spi_device_transmit`.

### Structures

- **struct essl_spi_config_t**
  Configuration of ESSL SPI device.

### Public Members

- **spi_device_handle_t *spi**
  Pointer to SPI device handle.

- **uint32_t tx_buf_size**
  The pre-negotiated Master TX buffer size used by both the host and the slave.
uint8_t tx_sync_reg

The pre-negotiated register ID for Master-TX-SLAVE-RX synchronization. 1 word (4 Bytes) will be reserved for the synchronization.

uint8_t rx_sync_reg

The pre-negotiated register ID for Master-RX-Slave-TX synchronization. 1 word (4 Bytes) will be reserved for the synchronization.

### 2.2.8 ESP x509 Certificate Bundle

**Overview**

The ESP x509 Certificate Bundle API provides an easy way to include a bundle of custom x509 root certificates for TLS server verification.

**Note:** The bundle is currently not available when using WolfSSL.

The bundle comes with the complete list of root certificates from Mozilla’s NSS root certificate store. Using the gen_crt_bundle.py python utility the certificates’ subject name and public key are stored in a file and embedded in the ESP32 binary.

When generating the bundle you may choose between:

- The full root certificate bundle from Mozilla, containing more than 130 certificates. The current bundle was updated Tue Jan 10 04:12:06 2023 GMT.
- A pre-selected filter list of the name of the most commonly used root certificates, reducing the amount of certificates to around 41 while still having around 90% absolute usage coverage and 99% market share coverage according to SSL certificate authorities statistics.

In addition it is possible to specify a path to a certificate file or a directory containing certificates which then will be added to the generated bundle.

**Note:** Trusting all root certificates means the list will have to be updated if any of the certificates are retracted. This includes removing them from cacrt_all.pem.

**Configuration**

Most configuration is done through menuconfig. CMake will generate the bundle according to the configuration and embed it.

- `CONFIG_MBEDTLS_CERTIFICATE_BUNDLE`: automatically build and attach the bundle.
- `CONFIG_MBEDTLS_DEFAULT_CERTIFICATE_BUNDLE`: decide which certificates to include from the complete root list.
- `CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE_PATH`: specify the path of any additional certificates to embed in the bundle.

To enable the bundle when using ESP-TLS simply pass the function pointer to the bundle attach function:

```c
esp_tls_cfg_t cfg = {
    .crt_bundle_attach = esp_crt_bundle_attach,
};
```

This is done to avoid embedding the certificate bundle unless activated by the user.

If using mbedTLS directly then the bundle may be activated by directly calling the attach function during the setup process:
Generating the List of Root Certificates

The list of root certificates comes from Mozilla’s NSS root certificate store, which can be found [here](#). The list can be downloaded and created by running the script `mk-ca-bundle.pl` that is distributed as a part of `curl`. Another alternative would be to download the finished list directly from the `curl` website: [CA certificates extracted from Mozilla](#).

The common certificates bundle were made by selecting the authorities with a market share of more than 1% from `w3tech`’s SSL Survey. These authorities were then used to pick the names of the certificates for the filter list, `cmn_crtAuthorities.csv`, from this list provided by Mozilla.

Updating the Certificate Bundle

The bundle is embedded into the app and can be updated along with the app by an OTA update. If you want to include a more up-to-date bundle than the bundle currently included in ESP-IDF, then the certificate list can be downloaded from Mozilla as described in *Generating the List of Root Certificates*.

Application Example

Simple HTTPS example that uses ESP-TLS to establish a secure socket connection using the certificate bundle with two custom certificates added for verification: `protocols/https_x509_bundle`.

HTTPS example that uses ESP-TLS and the default bundle: `protocols/https_request`.

HTTPS example that uses mbedTLS and the default bundle: `protocols/https_mbedtls`.

API Reference

Header File

- components/mbedtls/esp_crt_bundle/include/esp_crt_bundle.h

Functions

```c
esp_err_t esp.crt_bundle_attach(void *conf)
```

Attach and enable use of a bundle for certificate verification.

- **Parameters**
  - `conf` - [in] The config struct for the SSL connection.

- **Returns**
  - ESP_OK if adding certificates was successful.
  - Other if an error occurred or an action must be taken by the calling process.

```c
void esp.crt_bundle_detach(mbedtls_ssl_config *conf)
```

Disable and dealloc the certification bundle.

- **Parameters**
  - `conf` - [in] The config struct for the SSL connection.
esp_err_t esp_crt_bundle_set(const uint8_t *x509_bundle, size_t bundle_size)

Set the default certificate bundle used for verification.

Overrides the default certificate bundle only in case of successful initialization. In most use cases the bundle should be set through menuconfig. The bundle needs to be sorted by subject name since binary search is used to find certificates.

**Parameters**

- **x509_bundle** — [in] A pointer to the certificate bundle.
- **bundle_size** — [in] Size of the certificate bundle in bytes.

**Returns**

- ESP_OK if adding certificates was successful.
- Other if an error occurred or an action must be taken by the calling process.

## 2.2.9 HTTP Server

### Overview

The HTTP Server component provides an ability for running a lightweight web server on ESP32. Following are detailed steps to use the API exposed by HTTP Server:

- **httpd_start()**: Creates an instance of HTTP server, allocate memory/resources for it depending upon the specified configuration and outputs a handle to the server instance. The server has both, a listening socket (TCP) for HTTP traffic, and a control socket (UDP) for control signals, which are selected in a round robin fashion in the server task loop. The task priority and stack size are configurable during server instance creation by passing httpd_config_t structure to httpd_start(). TCP traffic is parsed as HTTP requests and, depending on the requested URI, user registered handlers are invoked which are supposed to send back HTTP response packets.

- **httpd_stop()**: This stops the server with the provided handle and frees up any associated memory/resources. This is a blocking function that first signals a halt to the server task and then waits for the task to terminate. While stopping, the task will close all open connections, remove registered URI handlers and reset all session context data to empty.

- **httpd_register_uri_handler()**: A URI handler is registered by passing object of type httpd_uri_t structure which has members including uri name, method type (eg. HTTPD_GET/HTTPD_POST/HTTPD_PUT etc.), function pointer of type esp_err_t *handler (httpd_req_t *req) and user_ctx pointer to user context data.

### Application Example

```c
/* Our URI handler function to be called during GET /uri request */
esp_err_t get_handler(httpd_req_t *req)
{
    /* Send a simple response */
    const char resp[] = "URI GET Response";
    httpd_resp_send(req, resp, HTTPD_RESP_USE_STRLEN);
    return ESP_OK;
}

/* Our URI handler function to be called during POST /uri request */
esp_err_t post_handler(httpd_req_t *req)
{
    /* Destination buffer for content of HTTP POST request.
     * httpd_req_recv() accepts char* only, but content could
     * as well be any binary data (needs type casting).
     * In case of string data, null termination will be absent, and
     */
```
content length would give length of string */
char content[100];

/* Truncate if content length larger than the buffer */
size_t recv_size = MIN(req->content_len, sizeof(content));

int ret = httpd_req_recv(req, content, recv_size);
if (ret <= 0) { /* 0 return value indicates connection closed */
  /* Check if timeout occurred */
  if (ret == HTTPD_SOCK_ERR_TIMEOUT) {
    /* In case of timeout one can choose to retry calling
     * httpd_req_recv(), but to keep it simple, here we
     * respond with an HTTP 408 (Request Timeout) error */
    httpd_resp_send_408(req);
  }
  /* In case of error, returning ESP_FAIL will
   * ensure that the underlying socket is closed */
  return ESP_FAIL;
}

/* Send a simple response */
const char resp[] = "URI POST Response";
httpd_resp_send(req, resp, HTTPD_RESP_USE_STRLEN);
return ESP_OK;

/* URI handler structure for GET /uri */
httpd_uri_t uri_get = {
  .uri = "/uri",
  .method = HTTP_GET,
  .handler = get_handler,
  .user_ctx = NULL
};

/* URI handler structure for POST /uri */
httpd_uri_t uri_post = {
  .uri = "/uri",
  .method = HTTP_POST,
  .handler = post_handler,
  .user_ctx = NULL
};

/* Function for starting the webserver */
httpd_handle_t start_webserver(void)
{
  /* Generate default configuration */
  httpd_config_t config = HTTPD_DEFAULT_CONFIG();

  /* Empty handle to esp_http_server */
  httpd_handle_t server = NULL;

  /* Start the httpd server */
  if (httpd_start(&server, &config) == ESP_OK) {
    /* Register URI handlers */
    httpd_register_uri_handler(server, &uri_get);
    httpd_register_uri_handler(server, &uri_post);
  }
  /* If server failed to start, handle will be NULL */
  return server;
}
/* Function for stopping the webserver */
void stop_webserver(httpd_handle_t server)
{
    if (server) {
        /* Stop the httpd server */
        httpd_stop(server);
    }
}

Simple HTTP Server Example  Check HTTP server example under protocols/http_server/simple where handling of arbitrary content lengths, reading request headers and URL query parameters, and setting response headers is demonstrated.

Persistent Connections

HTTP server features persistent connections, allowing for the re-use of the same connection (session) for several transfers, all the while maintaining context specific data for the session. Context data may be allocated dynamically by the handler in which case a custom function may need to be specified for freeing this data when the connection/session is closed.

Persistent Connections Example

```c
/* Custom function to free context */
void free_ctx_func(void *ctx)
{
    /* Could be something other than free */
    free(ctx);
}

esp_err_t adder_post_handler(httpd_req_t *req)
{
    /* Create session's context if not already available */
    if (!req->sess_ctx) {
        req->sess_ctx = malloc(sizeof(ANY_DATA_TYPE));  /* Pointer to context data */
        req->free_ctx = free_ctx_func;  /* Function to free context data */
    }

    /* Access context data */
    ANY_DATA_TYPE *ctx_data = (ANY_DATA_TYPE *)req->sess_ctx;

    /* Respond */
    ...............
    ...............
    return ESP_OK;
}
```

Check the example under protocols/http_server/persistent_sockets.

Websocket Server

The HTTP server component provides websocket support. The websocket feature can be enabled in menuconfig using the CONFIG_HTTPD_WS_SUPPORT option. Please refer to the protocols/http_server/ws_echo_server example which demonstrates usage of the websocket feature.
Event Handling

ESP HTTP server has various events for which a handler can be triggered by the Event Loop library when the particular event occurs. The handler has to be registered using esp_event_handler_register(). This helps in event handling for ESP HTTP server.

`esp_http_server_event_id_t` has all the events which can happen for ESP HTTP server.

Expected data type for different ESP HTTP server events in event loop:

- `HTTP_SERVER_EVENT_ERROR`: `httpd_err_code_t`
- `HTTP_SERVER_EVENT_START`: `NULL`
- `HTTP_SERVER_EVENT_ON_CONNECTED`: `int`
- `HTTP_SERVER_EVENT_ON_HEADER`: `int`
- `HTTP_SERVER_EVENT_HEADERS_SENT`: `int`
- `HTTP_SERVER_EVENT_ON_DATA`: `esp_http_server_event_data`
- `HTTP_SERVER_EVENT_SENT_DATA`: `esp_http_server_event_data`
- `HTTP_SERVER_EVENT_DISCONNECTED`: `int`
- `HTTP_SERVER_EVENT_STOP`: `NULL`

API Reference

Header File

- `components/esp_http_server/include/esp_http_server.h`

Functions

`esp_err_t httpd_register_uri_handler(httpd_handle_t handle, const httpd_uri_t *uri_handler)`

Registers a URI handler.

Example usage:

```
esp_err_t my_uri_handler(httpd_req_t* req)
{
    // Recv, Process and Send
    ....
    ....
    ....

    // Fail condition
    if (....) {
        // Return fail to close session
        return ESP_FAIL;
    }

    // On success
    return ESP_OK;
}

// URI handler structure
httpd_uri_t my_uri {
    .uri = "/my_uri/path/xyz",
    .method = HTTPD_GET,
    .handler = my_uri_handler,
    .user_ctx = NULL
};

// Register handler
if (httpd_register_uri_handler(server_handle, &my_uri) != ESP_OK) {
(continues on next page)
```
// If failed to register handler

    
}

**Note:** URI handlers can be registered in real time as long as the server handle is valid.

### Parameters
- **handle** [in] handle to HTTPD server instance
- **uri_handler** [in] pointer to handler that needs to be registered

### Returns
- **ESP_OK:** On successfully registering the handler
- **ESP_ERR_INVALID_ARG:** Null arguments
- **ESP_ERR_HTTPD_HANDLERS_FULL:** If no slots left for new handler
- **ESP_ERR_HTTPD_HANDLER_EXISTS:** If handler with same URI and method is already registered

```c
esp_err_t httpd_unregister_uri_handler(httpd_handle_t handle, const char* uri, httpd_method_t method)
```

Unregister a URI handler.

### Parameters
- **handle** [in] handle to HTTPD server instance
- **uri** [in] URI string
- **method** [in] HTTP method

### Returns
- **ESP_OK:** On successfully deregistering the handler
- **ESP_ERR_INVALID_ARG:** Null arguments
- **ESP_ERR_NOT_FOUND:** Handler with specified URI and method not found

```c
esp_err_t httpd_unregister_uri(httpd_handle_t handle, const char* uri)
```

Unregister all URI handlers with the specified uri string.

### Parameters
- **handle** [in] handle to HTTPD server instance
- **uri** [in] uri string specifying all handlers that need to be deregistered

### Returns
- **ESP_OK:** On successfully deregistering all such handlers
- **ESP_ERR_INVALID_ARG:** Null arguments
- **ESP_ERR_NOT_FOUND:** No handler registered with specified uri string

```c
esp_err_t httpd_sess_set_recv_override(httpd_handle_t hd, int sockfd, httpd_recv_func_t recv_func)
```

Override web server’s receive function (by session FD)

This function overrides the web server’s receive function. This same function is used to read HTTP request packets.

**Note:** This API is supposed to be called either from the context of
- an http session APIs where sockfd is a valid parameter
- a URI handler where sockfd is obtained using httpd_req_to_sockfd()
ESP_OK: On successfully registering override
ESP_ERR_INVALID_ARG: Null arguments

**esp_err_t** `httpd_sess_set_send_override` (*httpd_handle_t* hd, int sockfd, *httpd_send_func_t* send_func)

Override web server’s send function (by session FD)

This function overrides the web server’s send function. This same function is used to send out any response to any HTTP request.

**Note:** This API is supposed to be called either from the context of

* an http session APIs where sockfd is a valid parameter
* a URI handler where sockfd is obtained using `httpd_req_to_sockfd()`

**Parameters**

- **hd** - [in] HTTPD instance handle
- **sockfd** - [in] Session socket FD
- **send_func** - [in] The send function to be set for this session

**Returns**

- ESP_OK: On successfully registering override
- ESP_ERR_INVALID_ARG: Null arguments

ESP_OK: On successfully registering override
ESP_ERR_INVALID_ARG: Null arguments

**esp_err_t** `httpd_sess_set_pending_override` (*httpd_handle_t* hd, int sockfd, *httpd_pending_func_t* pending_func)

Override web server’s pending function (by session FD)

This function overrides the web server’s pending function. This function is used to test for pending bytes in a socket.

**Note:** This API is supposed to be called either from the context of

* an http session APIs where sockfd is a valid parameter
* a URI handler where sockfd is obtained using `httpd_req_to_sockfd()`

**Parameters**

- **hd** - [in] HTTPD instance handle
- **sockfd** - [in] Session socket FD
- **pending_func** - [in] The receive function to be set for this session

**Returns**

- ESP_OK: On successfully registering override
- ESP_ERR_INVALID_ARG: Null arguments

**int** `httpd_req_to_sockfd` (*httpd_req_t* `*r`)

Get the Socket Descriptor from the HTTP request.

This API will return the socket descriptor of the session for which URI handler was executed on reception of HTTP request. This is useful when user wants to call functions that require session socket fd, from within a URI handler, i.e.: `httpd_sess_get_ctx()`, `httpd_sess_trigger_close()`, `httpd_sess_update_lru_counter()`.

**Note:** This API is supposed to be called only from the context of a URI handler where `httpd_req_t*` request pointer is valid.

**Parameters**

- **r** - [in] The request whose socket descriptor should be found

**Returns**

- Socket descriptor: The socket descriptor for this request
Chapter 2. API Reference

• -1 : Invalid/NULL request pointer

int httpd_req_recv (httpd_req_t *r, char *buf, size_t buf_len)

API to read content data from the HTTP request.

This API will read HTTP content data from the HTTP request into provided buffer. Use content_len provided in httpd_req_t structure to know the length of data to be fetched. If content_len is too large for the buffer then user may have to make multiple calls to this function, each time fetching 'buf_len' number of bytes, while the pointer to content data is incremented internally by the same number.

Note:
• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
• If an error is returned, the URI handler must further return an error. This will ensure that the erroneous socket is closed and cleaned up by the web server.
• Presently Chunked Encoding is not supported

Parameters
• r –[in] The request being responded to
• buf –[in] Pointer to a buffer that the data will be read into
• buf_len –[in] Length of the buffer

Returns
• Bytes : Number of bytes read into the buffer successfully
• 0 : Buffer length parameter is zero / connection closed by peer
• HTTPD_SOCK_ERR_INVALID : Invalid arguments
• HTTPD_SOCK_ERR_TIMEOUT : Timeout/interrupted while calling socket recv()
• HTTPD_SOCK_ERR_FAIL : Unrecoverable error while calling socket recv()

size_t httpd_req_get_hdr_value_len (httpd_req_t *r, const char *field)

Search for a field in request headers and return the string length of it’s value.

Note:
• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
• Once httpd_resp_send() API is called all request headers are purged, so request headers need be copied into separate buffers if they are required later.

Parameters
• r –[in] The request being responded to
• field –[in] The header field to be searched in the request

Returns
• Length : If field is found in the request URL
• Zero : Field not found / Invalid request / Null arguments

esp_err_t httpd_req_get_hdr_value_str (httpd_req_t *r, const char *field, char *val, size_t val_size)

Get the value string of a field from the request headers.

Note:
• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
• Once httpd_resp_send() API is called all request headers are purged, so request headers need be copied into separate buffers if they are required later.
If output size is greater than input, then the value is truncated, accompanied by truncation error as return value.

Use httpd_req_get_hdr_value_len() to know the right buffer length.

### Parameters
- **r** - [in] The request being responded to
- **field** - [in] The field to be searched in the header
- **val** - [out] Pointer to the buffer into which the value will be copied if the field is found
- **val_size** - [in] Size of the user buffer “val”

### Returns
- ESP_OK: Field found in the request header and value string copied
- ESP_ERR_NOT_FOUND: Key not found
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_INVALID_REQ: Invalid HTTP request pointer
- ESP_ERR_HTTPD_RESULT_TRUNC: Value string truncated

```c
size_t httpd_req_get_url_query_len(httpd_req_t *r)
```
Get Query string length from the request URL.

**Note:** This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid

### Parameters
- **r** - [in] The request being responded to

### Returns
- Length: Query is found in the request URL
- Zero: Query not found / Null arguments / Invalid request

```c
esp_err_t httpd_req_get_url_query_str(httpd_req_t *r, char* buf, size_t buf_len)
```
Get Query string from the request URL.

**Note:**
- Presently, the user can fetch the full URL query string, but decoding will have to be performed by the user. Request headers can be read using httpd_req_get_hdr_value_str() to know the ‘Content-Type’ (eg. Content-Type: application/x-www-form-urlencoded) and then the appropriate decoding algorithm needs to be applied.
- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid
- If output size is greater than input, then the value is truncated, accompanied by truncation error as return value
- Prior to calling this function, one can use httpd_req_get_url_query_len() to know the query string length beforehand and hence allocate the buffer of right size (usually query string length + 1 for null termination) for storing the query string

### Parameters
- **r** - [in] The request being responded to
- **buf** - [out] Pointer to the buffer into which the query string will be copied (if found)
- **buf_len** - [in] Length of output buffer

### Returns
- ESP_OK: Query is found in the request URL and copied to buffer
- ESP_ERR_NOT_FOUND: Query not found
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_INVALID_REQ: Invalid HTTP request pointer
- ESP_ERR_HTTPD_RESULT_TRUNC: Query string truncated
esp_err_t httpd_query_key_value (const char *qry, const char *key, char *val, size_t val_size)

Helper function to get a URL query tag from a query string of the type param1=val1&param2=val2.

Note:
- The components of URL query string (keys and values) are not URLdecoded. The user must check for 'Content-Type' field in the request headers and then depending upon the specified encoding (URLencoded or otherwise) apply the appropriate decoding algorithm.
- If actual value size is greater than val_size, then the value is truncated, accompanied by truncation error as return value.

Parameters
- qry [in] Pointer to query string
- key [in] The key to be searched in the query string
- val [out] Pointer to the buffer into which the value will be copied if the key is found
- val_size [in] Size of the user buffer “val”

Returns
- ESP_OK: Key is found in the URL query string and copied to buffer
- ESP_ERR_NOT_FOUND: Key not found
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_RESULT_TRUNC: Value string truncated

esp_err_t httpd_req_get_cookie_val (httpd_req_t *req, const char*cookie_name, char *val, size_t *val_size)

Get the value string of a cookie value from the “Cookie” request headers by cookie name.

Parameters
- req [in] Pointer to the HTTP request
- cookie_name [in] The cookie name to be searched in the request
- val [out] Pointer to the buffer into which the value of cookie will be copied if the cookie is found
- val_size [inout] Pointer to size of the user buffer “val”. This variable will contain cookie length if ESP_OK is returned and required buffer length incase ESP_ERR_HTTPD_RESULT_TRUNC is returned.

Returns
- ESP_OK: Key is found in the cookie string and copied to buffer
- ESP_ERR_NOT_FOUND: Key not found
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_RESULT_TRUNC: Value string truncated
- ESP_ERR_NO_MEM: Memory allocation failure

bool httpd_uri_match_wildcard (const char *uri_template, const char *uri_to_match, size_t match_upto)

Test if a URI matches the given wildcard template.

Template may end with "?" to make the previous character optional (typically a slash), "*" for a wildcard match, and "?*" to make the previous character optional, and if present, allow anything to follow.

Example:
- * matches everything
- /foo/ matches /foo and /foo/
- /foo/* (sans the backslash) matches /foo/ and /foo/bar, but not /foo or /fo
- /foo/* or /foo/*/ (sans the backslash) matches /foo/, /foo/bar, and also /foo, but not /foox or /fo

The special characters "?" and "*" anywhere else in the template will be taken literally.

Parameters
- uri_template [in] URI template (pattern)
- uri_to_match [in] URI to be matched
Chapter 2. API Reference

- **match_upto**  - [in] how many characters of the URI buffer to test (there may be trailing query string etc.)

Returns  true if a match was found

```c
esp_err_t httpd_resp_send(httpd_req_t *r, const char *buf, ssize_t buf_len)
```

API to send a complete HTTP response.

This API will send the data as an HTTP response to the request. This assumes that you have the entire response ready in a single buffer. If you wish to send response in incremental chunks use `httpd_resp_send_chunk()` instead.

If no status code and content-type were set, by default this will send 200 OK status code and content type as text/html. You may call the following functions before this API to configure the response headers: `httpd_resp_set_status()` - for setting the HTTP status string, `httpd_resp_set_type()` - for setting the Content Type, `httpd_resp_set_hdr()` - for appending any additional field value entries in the response header.

**Note:**
- This API is supposed to be called only from the context of a URI handler where `httpd_req_t` request pointer is valid.
- Once this API is called, the request has been responded to.
- No additional data can then be sent for the request.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

**Parameters**
- `r`  - [in] The request being responded to
- `buf`  - [in] Buffer from where the content is to be fetched
- `buf_len`  - [in] Length of the buffer, `HTTPD_RESP_USE_STRLEN` to use strlen()

**Returns**
- ESP_OK  : On successfully sending the response packet
- ESP_ERR_INVALID_ARG  : Null request pointer
- ESP_ERR_HTTPD_RESP_HDR  : Essential headers are too large for internal buffer
- ESP_ERR_HTTPD_RESP_SEND  : Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ  : Invalid request

```c
esp_err_t httpd_resp_send_chunk(httpd_req_t *r, const char *buf, ssize_t buf_len)
```

API to send one HTTP chunk.

This API will send the data as an HTTP response to the request. This API will use chunked-encoding and send the response in the form of chunks. If you have the entire response contained in a single buffer, please use `httpd_resp_send()` instead.

If no status code and content-type were set, by default this will send 200 OK status code and content type as text/html. You may call the following functions before this API to configure the response headers: `httpd_resp_set_status()` - for setting the HTTP status string, `httpd_resp_set_type()` - for setting the Content Type, `httpd_resp_set_hdr()` - for appending any additional field value entries in the response header.

**Note:**
- This API is supposed to be called only from the context of a URI handler where `httpd_req_t` request pointer is valid.
- When you are finished sending all your chunks, you must call this function with `buf_len` as 0.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

**Parameters**
- `r`  - [in] The request being responded to
**buf** - [in] Pointer to a buffer that stores the data
**buf_len** - [in] Length of the buffer, HTTPD_RESP_USE_STRLEN to use strlen()

**Returns**
- ESP_OK : On successfully sending the response packet chunk
- ESP_ERR_INVALID_ARG : Null request pointer
- ESP_ERR_HTTPD_RESP_HDR : Essential headers are too large for internal buffer
- ESP_ERR_HTTPD_RESP_SEND : Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

static inline esp_err_t httpd_resp_sendstr (httpd_req_t *r, const char *str)

API to send a complete string as HTTP response.

This API simply calls http.resp_send with buffer length set to string length assuming the buffer contains a null terminated string

**Parameters**
- **r** - [in] The request being responded to
- **str** - [in] String to be sent as response body

**Returns**
- ESP_OK : On successfully sending the response packet
- ESP_ERR_INVALID_ARG : Null request pointer
- ESP_ERR_HTTPD_RESP_HDR : Essential headers are too large for internal buffer
- ESP_ERR_HTTPD_RESP_SEND : Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ : Invalid request

static inline esp_err_t httpd_resp_sendstr_chunk (httpd_req_t *r, const char *str)

API to send a string as an HTTP response chunk.

This API simply calls http.resp_send_chunk with buffer length set to string length assuming the buffer contains a null terminated string

**Parameters**
- **r** - [in] The request being responded to
- **str** - [in] String to be sent as response body (NULL to finish response packet)

**Returns**
- ESP_OK : On successfully sending the response packet
- ESP_ERR_INVALID_ARG : Null request pointer
- ESP_ERR_HTTPD_RESP_HDR : Essential headers are too large for internal buffer
- ESP_ERR_HTTPD_RESP_SEND : Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ : Invalid request

**esp_err_t httpd_resp_set_status (httpd_req_t *r, const char *status)**

API to set the HTTP status code.

This API sets the status of the HTTP response to the value specified. By default, the ‘200 OK’ response is sent as the response.

**Note:**
- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- This API only sets the status to this value. The status isn’t sent out until any of the send APIs is executed.
- Make sure that the lifetime of the status string is valid till send function is called.

**Parameters**
- **r** - [in] The request being responded to
- **status** - [in] The HTTP status code of this response

**Returns**
- ESP_OK : On success
- ESP_ERR_INVALID_ARG : Null arguments
• ESP_ERR_HTTPD_INVALID_REQ: Invalid request pointer

`esp_err_t httpd_resp_set_type(httpd_req_t *r, const char *type)`

API to set the HTTP content type.

This API sets the ‘Content Type’ field of the response. The default content type is ‘text/html’.

**Note:**
- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- This API only sets the content type to this value. The type isn’t sent out until any of the send APIs is executed.
- Make sure that the lifetime of the type string is valid till send function is called.

**Parameters**
- `r` - [in] The request being responded to
- `type` - [in] The Content Type of the response

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_INVALID_REQ: Invalid request pointer

`esp_err_t httpd_resp_set_hdr(httpd_req_t *r, const char *field, const char *value)`

API to append any additional headers.

This API sets any additional header fields that need to be sent in the response.

**Note:**
- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- The header isn’t sent out until any of the send APIs is executed.
- The maximum allowed number of additional headers is limited to value of max_resp_headers in config structure.
- Make sure that the lifetime of the field value strings are valid till send function is called.

**Parameters**
- `r` - [in] The request being responded to
- `field` - [in] The field name of the HTTP header
- `value` - [in] The value of this HTTP header

**Returns**
- ESP_OK: On successfully appending new header
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_RESP_HDR: Total additional headers exceed max allowed
- ESP_ERR_HTTPD_INVALID_REQ: Invalid request pointer

`esp_err_t httpd_resp_send_err(httpd_req_t *req, httpd_err_code_t error, const char *msg)`

For sending out error code in response to HTTP request.

**Note:**
- This API is supposed to be called only from the context of a URI handler where httpd_req_t* request pointer is valid.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.
If you wish to send additional data in the body of the response, please use the lower-level functions directly.

### Parameters
- **req** [in] Pointer to the HTTP request for which the response needs to be sent
- **error** [in] Error type to send
- **msg** [in] Error message string (pass NULL for default message)

### Returns
- ESP_OK: On successfully sending the response packet
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_RESP_SEND: Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ: Invalid request pointer

static inline esp_err_t httpd_resp_send_404(httpd_req_t *r)

Helper function for HTTP 404.

Send HTTP 404 message. If you wish to send additional data in the body of the response, please use the lower-level functions directly.

**Note:**
- This API is supposed to be called only from the context of a URI handler where `httpd_req_t*` request pointer is valid.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

### Parameters
- **r** [in] The request being responded to

### Returns
- ESP_OK: On successfully sending the response packet
- ESP_ERR_INVALID_ARG: Null arguments
- ESP_ERR_HTTPD_RESP_SEND: Error in raw send
- ESP_ERR_HTTPD_INVALID_REQ: Invalid request pointer

static inline esp_err_t httpd_resp_send_408(httpd_req_t *r)

Helper function for HTTP 408.

Send HTTP 408 message. If you wish to send additional data in the body of the response, please use the lower-level functions directly.

**Note:**
- This API is supposed to be called only from the context of a URI handler where `httpd_req_t*` request pointer is valid.
- Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.
static inline esp_err_t httpd_resp_send_500 (httpd_req_t *r)  
Helper function for HTTP 500.

Send HTTP 500 message. If you wish to send additional data in the body of the response, please use the 
lower-level functions directly.

Note:

• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request 
  pointer is valid.

• Once this API is called, all request headers are purged, so request headers need be copied into separate 
  buffers if they are required later.

Parameters  r - [in] The request being responded to

Returns

• ESP_OK : On successfully sending the response packet

• ESP_ERR_INVALID_ARG : Null arguments

• ESP_ERR_HTTPD_RESP_SEND : Error in raw send

• ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

int httpd_send (httpd_req_t *r, const char *buf, size_t buf_len)  
Raw HTTP send.

Call this API if you wish to construct your custom response packet. When using this, all essential header, eg. 
HTTP version, Status Code, Content Type and Length, Encoding, etc. will have to be constructed manually, 
and HTTP delimiters (CRLF) will need to be placed correctly for separating sub-sections of the HTTP response 
packet.

If the send override function is set, this API will end up calling that function eventually to send data out.

Note:

• This API is supposed to be called only from the context of a URI handler where httpd_req_t* request 
  pointer is valid.

• Unless the response has the correct HTTP structure (which the user must now ensure) it is not guaranteed 
  that it will be recognized by the client. For most cases, you wouldn’t have to call this API, but you would 
  rather use either of : httpd_resp_send(), httpd_resp_send_chunk()

Parameters  

• r - [in] The request being responded to

• buf - [in] Buffer from where the fully constructed packet is to be read

• buf_len - [in] Length of the buffer

Returns

• Bytes : Number of bytes that were sent successfully

• HTTPD_SOCKET_ERR_INVALID : Invalid arguments

• HTTPD_SOCKET_ERR_TIMEOUT : Timeout/interrupted while calling socket send()

• HTTPD_SOCKET_ERR_FAIL : Unrecoverable error while calling socket send()

int httpd_socket_send (httpd_handle_t hd, int sockfd, const char *buf, size_t buf_len, int flags)  
A low level API to send data on a given socket

This internally calls the default send function, or the function registered by httpd_sess_set_send_override().

Note: This API is not recommended to be used in any request handler. Use this only for advanced use cases, 
wherein some asynchronous data is to be sent over a socket.
**Parameters**
- \( \text{hd} \) - [in] server instance
- \( \text{sockfd} \) - [in] session socket file descriptor
- \( \text{buf} \) - [in] buffer with bytes to send
- \( \text{buf\_len} \) - [in] data size
- \( \text{flags} \) - [in] flags for the send() function

**Returns**
- Bytes: The number of bytes sent successfully
- HTTPD\_SOCK\_ERR\_INVALID: Invalid arguments
- HTTPD\_SOCK\_ERR\_TIMEOUT: Timeout/interrupted while calling socketsend()
- HTTPD\_SOCK\_ERR\_FAIL: Unrecoverable error while calling socketsend()

```c
int httpd_socket_recv (httpd_handle_t hd, int sockfd, char *buf, size_t buf_len, int flags)
```

A low level API to receive data from a given socket

This internally calls the default recv function, or the function registered by httpd_sess_set_recv_override().

**Note:** This API is not recommended to be used in any request handler. Use this only for advanced use cases, wherein some asynchronous communication is required.

**Parameters**
- \( \text{hd} \) - [in] server instance
- \( \text{sockfd} \) - [in] session socket file descriptor
- \( \text{buf} \) - [in] buffer with bytes to send
- \( \text{buf\_len} \) - [in] data size
- \( \text{flags} \) - [in] flags for the send() function

**Returns**
- Bytes: The number of bytes received successfully
- 0: Buffer length parameter is zero / connection closed by peer
- HTTPD\_SOCK\_ERR\_INVALID: Invalid arguments
- HTTPD\_SOCK\_ERR\_TIMEOUT: Timeout/interrupted while calling socket recv()
- HTTPD\_SOCK\_ERR\_FAIL: Unrecoverable error while calling socket recv()

```c
esp_err_t httpd_register_err_handler (httpd_handle_t handle, httpd_err_code_t error, httpd_err_handler_func_t handler_fn)
```

Function for registering HTTP error handlers.

This function maps a handler function to any supported error code given by httpd_err_code_t. See prototype httpd_err_handler_func_t above for details.

**Parameters**
- \( \text{handle} \) - [in] HTTP server handle
- \( \text{error} \) - [in] Error type
- \( \text{handler\_fn} \) - [in] User implemented handler function (Pass NULL to unset any previously set handler)

**Returns**
- ESP\_OK: handler registered successfully
- ESP\_ERR\_INVALID\_ARG: invalid error code or server handle

```c
esp_err_t httpd_start (httpd_handle_t *handle, const httpd_config_t *config)
```

Starts the web server.

Create an instance of HTTP server and allocate memory/resources for it depending upon the specified configuration.

Example usage:
// Function for starting the webserver
httpd_handle_t start_webserver(void)
{
    // Generate default configuration
    httpd_config_t config = HTTPD_DEFAULT_CONFIG();

    // Empty handle to http_server
    httpd_handle_t server = NULL;

    // Start the httpd server
    if (httpd_start(&server, &config) == ESP_OK) {
        // Register URI handlers
        httpd_register_uri_handler(server, &uri_get);
        httpd_register_uri_handler(server, &uri_post);
    }
    // If server failed to start, handle will be NULL
    return server;
}

Parameters
- config [in] Configuration for new instance of the server
- handle [out] Handle to newly created instance of the server. NULL on error

Returns
- ESP_OK : Instance created successfully
- ESP_ERR_INVALID_ARG : Null argument(s)
- ESP_ERR_HTTPD_ALLOC_MEM : Failed to allocate memory for instance
- ESP_ERR_HTTPD_TASK : Failed to launch server task

esp_err_t httpd_stop(httpd_handle_t handle)
Stops the web server.

Deallocates memory/resources used by an HTTP server instance and deletes it. Once deleted the handle can no longer be used for accessing the instance.

Example usage:

// Function for stopping the webserver
void stop_webserver(httpd_handle_t server)
{
    // Ensure handle is non NULL
    if (server != NULL) {
        // Stop the httpd server
        httpd_stop(server);
    }
}

Parameters handle [in] Handle to server returned by httpd_start

Returns
- ESP_OK : Server stopped successfully
- ESP_ERR_INVALID_ARG : Handle argument is null

esp_err_t httpd_queue_work(httpd_handle_t handle, httpd_work_fn_t work, void *arg)

Queue execution of a function in HTTPD’s context.

This API queues a work function for asynchronous execution

Note: Some protocols require that the web server generate some asynchronous data and send it to the persistently opened connection. This facility is for use by such protocols.
Chapter 2. API Reference

Parameters

- **handle** - [in] Handle to server returned by httpd_start
- **work** - [in] Pointer to the function to be executed in the HTTPD’s context
- **arg** - [in] Pointer to the arguments that should be passed to this function

Returns

- **ESP_OK**: On successfully queueing the work
- **ESP_FAIL**: Failure in ctrl socket
- **ESP_ERR_INVALID_ARG**: Null arguments

```c
void *httpd_sess_get_ctx(httpd_handle_t handle, int sockfd)
```

Get session context from socket descriptor.

Typically if a session context is created, it is available to URI handlers through the httpd_req_t structure. But, there are cases where the web server’s send/receive functions may require the context (for example, for accessing keying information etc). Since the send/receive function only have the socket descriptor at their disposal, this API provides them with a way to retrieve the session context.

Parameters

- **handle** - [in] Handle to server returned by httpd_start
- **sockfd** - [in] The socket descriptor for which the context should be extracted.

Returns

- **void**: Pointer to the context associated with this session
- **NULL**: Empty context / Invalid handle / Invalid socket fd

```c
void httpd_sess_set_ctx(httpd_handle_t handle, int sockfd, void *ctx, httpd_free_ctx_fn_t free_fn)
```

Set session context by socket descriptor.

Parameters

- **handle** - [in] Handle to server returned by httpd_start
- **sockfd** - [in] The socket descriptor for which the context should be extracted.
- **ctx** - [in] Context object to assign to the session
- **free_fn** - [in] Function that should be called to free the context

```c
void *httpd_sess_get_transport_ctx(httpd_handle_t handle, int sockfd)
```

Get session ‘transport’ context by socket descriptor.

This context is used by the send/receive functions, for example to manage SSL context.

See also:

httpd_sess_get_ctx()

Parameters

- **handle** - [in] Handle to server returned by httpd_start
- **sockfd** - [in] The socket descriptor for which the context should be extracted.

Returns

- **void**: Pointer to the transport context associated with this session
- **NULL**: Empty context / Invalid handle / Invalid socket fd

```c
void httpd_sess_set_transport_ctx(httpd_handle_t handle, int sockfd, void *ctx, httpd_free_ctx_fn_t free_fn)
```

Set session ‘transport’ context by socket descriptor.

See also:

httpd_sess_set_ctx()
Chapter 2. API Reference

- **sockfd** - [in] The socket descriptor for which the context should be extracted.
- **ctx** - [in] Transport context object to assign to the session
- **free_fn** - [in] Function that should be called to free the transport context

```c
void *httpd_get_global_user_ctx (httpd_handle_t handle)
Get HTTPD global user context (it was set in the server config struct)

Parameters
- handle - [in] Handle to server returned by httpd_start

Returns
- global user context
```

```c
void *httpd_get_global_transport_ctx (httpd_handle_t handle)
Get HTTPD global transport context (it was set in the server config struct)

Parameters
- handle - [in] Handle to server returned by httpd_start

Returns
- global transport context
```

```c
esp_err_t httpd_sess_trigger_close (httpd_handle_t handle, int sockfd)
Trigger an httpd session close externally.

Note: Calling this API is only required in special circumstances wherein some application requires to close an httpd client session asynchronously.
```

```c
Parameters
- handle - [in] Handle to server returned by httpd_start
- sockfd - [in] The socket descriptor of the session to be closed

Returns
- ESP_OK: On successfully initiating closure
- ESP_FAIL: Failure to queue work
- ESP_ERR_NOT_FOUND: Socket fd not found
- ESP_ERR_INVALID_ARG: Null arguments
```

```c
esp_err_t httpd_sess_update_lru_counter (httpd_handle_t handle, int sockfd)
Update LRU counter for a given socket.

LRU Counters are internally associated with each session to monitor how recently a session exchanged traffic. When LRU purge is enabled, if a client is requesting for connection but maximum number of sockets/sessions is reached, then the session having the earliest LRU counter is closed automatically.

Updating the LRU counter manually prevents the socket from being purged due to the Least Recently Used (LRU) logic, even though it might not have received traffic for some time. This is useful when all open sockets/session are frequently exchanging traffic but the user specifically wants one of the sessions to be kept open, irrespective of when it last exchanged a packet.

Note: Calling this API is only necessary if the LRU Purge Enable option is enabled.
```

```c
Parameters
- handle - [in] Handle to server returned by httpd_start
- sockfd - [in] The socket descriptor of the session for which LRU counter is to be updated

Returns
- ESP_OK: Socket found and LRU counter updated
- ESP_ERR_NOT_FOUND: Socket not found
- ESP_ERR_INVALID_ARG: Null arguments
```

```c
esp_err_t httpd_get_client_list (httpd_handle_t handle, size_t *fds, int *client_fds)
Returns list of current socket descriptors of active sessions.
```
Chapter 2. API Reference

**Note:** Size of provided array has to be equal or greater then maximum number of opened sockets, configured upon initialization with max_open_sockets field in httpd_config_t structure.

### Parameters
- **handle** - [in] Handle to server returned by httpd_start
- **fds** - [in][out] In: Size of provided client_fds array Out: Number of valid client fds returned in client_fds,
- **client_fds** - [out] Array of client fds

### Returns
- ESP_OK: Successfully retrieved session list
- ESP_ERR_INVALID_ARG: Wrong arguments or list is longer than provided array

### Structures

**struct esp_http_server_event_data**

Argument structure for HTTP_SERVER_EVENT_ON_DATA and HTTP_SERVER_EVENT_SENT_DATA event

#### Public Members

- **int fd**
  - Session socket file descriptor
- **int data_len**
  - Data length

**struct httpd_config**

HTTP Server Configuration Structure.

**Note:** Use HTTPD_DEFAULT_CONFIG() to initialize the configuration to a default value and then modify only those fields that are specifically determined by the use case.

#### Public Members

- **unsigned task_priority**
  - Priority of FreeRTOS task which runs the server
- **size_t stack_size**
  - The maximum stack size allowed for the server task
- ** BaseType_t core_id**
  - The core the HTTP server task will run on
- **uint16_t server_port**
  - TCP Port number for receiving and transmitting HTTP traffic
uint16_t ctrl_port
  UDP Port number for asynchronously exchanging control signals between various components of the
  server

uint16_t max_open_sockets
  Max number of sockets_clients connected at any time (3 sockets are reserved for internal working of the
  HTTP server)

uint16_t max_uri_handlers
  Maximum allowed uri handlers

uint16_t max_resp_headers
  Maximum allowed additional headers in HTTP response

uint16_t backlog_conn
  Number of backlog connections

bool lru_purge_enable
  Purge “Least Recently Used” connection

uint16_t recv_wait_timeout
  Timeout for recv function (in seconds)

uint16_t send_wait_timeout
  Timeout for send function (in seconds)

void *global_user_ctx
  Global user context.
  This field can be used to store arbitrary user data within the server context. The value can be retrieved
  using the server handle, available e.g. in the httpd_req_t struct.
  When shutting down, the server frees up the user context by calling free() on the global_user_ctx field.
  If you wish to use a custom function for freeing the global user context, please specify that here.

httpd_free_ctx_fn_t global_user_ctx_free_fn
  Free function for global user context

void *global_transport_ctx
  Global transport context.
  Similar to global_user_ctx, but used for session encoding or encryption (e.g. to hold the SSL context). It
  will be freed using free(), unless global_transport_ctx_free_fn is specified.

httpd_free_ctx_fn_t global_transport_ctx_free_fn
  Free function for global transport context

bool enable_so_linger
  bool to enable/disable linger

int linger_timeout
  linger timeout (in seconds)
bool keep_alive_enable
   Enable keep-alive timeout

int keep_alive_idle
   Keep-alive idle time. Default is 5 (second)

int keep_alive_interval
   Keep-alive interval time. Default is 5 (second)

int keep_alive_count
   Keep-alive packet retry send count. Default is 3 counts

httpd_open_func_t open_fn
   Custom session opening callback.
   Called on a new session socket just after accept(), but before reading any data.
   This is an opportunity to set up e.g. SSL encryption using global_transport_ctx and the send/recv/pending
   session overrides.
   If a context needs to be maintained between these functions, store it in the session using
   httpd_sess_set_transport_ctx() and retrieve it later with httpd_sess_get_transport_ctx()
   Returning a value other than ESP_OK will immediately close the new socket.

httpd_close_func_t close_fn
   Custom session closing callback.
   Called when a session is deleted, before freeing user and transport contexts and before closing the socket.
   This is a place for custom de-init code common to all sockets.
   The server will only close the socket if no custom session closing callback is set. If a custom callback is
   used, close(sockfd) should be called in here for most cases.
   Set the user or transport context to NULL if it was freed here, so the server does not try to free it again.
   This function is run for all terminated sessions, including sessions where the socket was closed by the
   network stack - that is, the file descriptor may not be valid anymore.

httpd_uri_match_func_t uri_match_fn
   URI matcher function.
   Called when searching for a matching URI: 1) whose request handler is to be executed right after an HTTP
   request is successfully parsed 2) in order to prevent duplication while registering a new URI handler using
   httpd_register_uri_handler()
   Available options are: 1) NULL : Internally do basic matching using strncmp() 2)
   httpd_uri_match_wildcard() : URI wildcard matcher
   Users can implement their own matching functions (See description of the
   httpd_uri_match_func_t function prototype)

struct httpd_req
   HTTP Request Data Structure.

Public Members
**httpd_handle_t handle**

Handle to server instance

**int method**

The type of HTTP request, -1 if unsupported method

**const char uri[HTTPD_MAX_URI_LEN + 1]**

The URI of this request (1 byte extra for null termination)

**size_t content_len**

Length of the request body

**void *aux**

Internally used members

**void *user_ctx**

User context pointer passed during URI registration.

**void *sess_ctx**

Session Context Pointer

A session context. Contexts are maintained across ‘sessions’ for a given open TCP connection. One session could have multiple request responses. The web server will ensure that the context persists across all these request and responses.

By default, this is NULL. URI Handlers can set this to any meaningful value.

If the underlying socket gets closed, and this pointer is non-NULL, the web server will free up the context by calling free(), unless free_ctx function is set.

**httpd_free_ctx_fn_t free_ctx**

Pointer to free context hook

Function to free session context

If the web server’s socket closes, it frees up the session context by calling free() on the sess_ctx member. If you wish to use a custom function for freeing the session context, please specify that here.

**bool ignore_sess_ctx_changes**

Flag indicating if Session Context changes should be ignored

By default, if you change the sess_ctx in some URI handler, the http server will internally free the earlier context (if non NULL), after the URI handler returns. If you want to manage the allocation/reallocation/freeing of sess_ctx yourself, set this flag to true, so that the server will not perform any checks on it. The context will be cleared by the server (by calling free_ctx or free()) only if the socket gets closed.

**struct httpd_uri**

Structure for URI handler.

**Public Members**

**const char *uri**

The URI to handle
**httpd_method_t method**
Method supported by the URI

**esp_err_t (httpd_method_t method)**
Handler to call for supported request method. This must return ESP_OK, or else the underlying socket will be closed.

**void *user_ctx**
Pointer to user context data which will be available to handler

**Macros**

HTTPD_MAX_REQ_HDR_LEN
HTTPD_MAX_URI_LEN
HTTPD_SOCK_ERR_FAIL
HTTPD_SOCK_ERR_INVALID
HTTPD_SOCK_ERR_TIMEOUT
HTTPD_200
HTTP Response 200
HTTPD_204
HTTP Response 204
HTTPD_207
HTTP Response 207
HTTPD_400
HTTP Response 400
HTTPD_404
HTTP Response 404
HTTPD_408
HTTP Response 408
HTTPD_500
HTTP Response 500
HTTPD_TYPE_JSON
HTTP Content type JSON
HTTPD_TYPE_TEXT
HTTP Content type text/HTML
HTTPD_TYPE_OCTET
  HTTP Content type octet-stream

ESP_HTTPD_DEF_CTRL_PORT
  HTTP Server control socket port

HTTP_DEFAULT_CONFIG()

ESP_ERR_HTTPD_BASE
  Starting number of HTTPD error codes

ESP_ERR_HTTPD_HANDLERS_FULL
  All slots for registering URI handlers have been consumed

ESP_ERR_HTTPD_HANDLER_EXISTS
  URI handler with same method and target URI already registered

ESP_ERR_HTTPD_INVALID_REQ
  Invalid request pointer

ESP_ERR_HTTPD_RESULT_TRUNC
  Result string truncated

ESP_ERR_HTTPD_RESP_HDR
  Response header field larger than supported

ESP_ERR_HTTPD_RESP_SEND
  Error occurred while sending response packet

ESP_ERR_HTTPD_ALLOC_MEM
  Failed to dynamically allocate memory for resource

ESP_ERR_HTTPD_TASK
  Failed to launch server task/thread

HTTPD_RESP_USE_STRLEN

Type Definitions

typedef struct httpd_req httpd_req_t
  HTTP Request Data Structure.

typedef struct httpd_uri httpd_uri_t
  Structure for URI handler.

typedef int (*httpd_send_func_t)(httpd_handle_t hd, int sockfd, const char *buf, size_t buf_len, int flags)
  Prototype for HTTPDs low-level send function.
Chapter 2. API Reference

**Note:** User specified send function must handle errors internally, depending upon the set value of errno, and return specific HTTPD_SOCK_ERR_ codes, which will eventually be conveyed as return value of httpd_send() function.

<table>
<thead>
<tr>
<th>Param hd</th>
<th>[in] server instance</th>
</tr>
</thead>
<tbody>
<tr>
<td>sockfd</td>
<td>[in] session socket file descriptor</td>
</tr>
<tr>
<td>buf</td>
<td>[in] buffer with bytes to send</td>
</tr>
<tr>
<td>buf_len</td>
<td>[in] data size</td>
</tr>
<tr>
<td>flags</td>
<td>[in] flags for the send() function</td>
</tr>
</tbody>
</table>

**Return**
- Bytes: The number of bytes sent successfully
- HTTPD_SOCK_ERR_INVALID: Invalid arguments
- HTTPD_SOCK_ERR_TIMEOUT: Timeout/interrupted while calling socket send()
- HTTPD_SOCK_ERR_FAIL: Unrecoverable error while calling socket send()

```c
typedef int (*httpd_recv_func_t)(httpd_handle_t hd, int sockfd, char *buf, size_t buf_len, int flags)
```

Prototype for HTTPDs low-level recv function.

**Note:** User specified recv function must handle errors internally, depending upon the set value of errno, and return specific HTTPD_SOCK_ERR_ codes, which will eventually be conveyed as return value of httpd_req_recv() function.

<table>
<thead>
<tr>
<th>Param hd</th>
<th>[in] server instance</th>
</tr>
</thead>
<tbody>
<tr>
<td>sockfd</td>
<td>[in] session socket file descriptor</td>
</tr>
<tr>
<td>buf</td>
<td>[in] buffer with bytes to send</td>
</tr>
<tr>
<td>buf_len</td>
<td>[in] data size</td>
</tr>
<tr>
<td>flags</td>
<td>[in] flags for the send() function</td>
</tr>
</tbody>
</table>

**Return**
- Bytes: The number of bytes received successfully
- 0: Buffer length parameter is zero / connection closed by peer
- HTTPD_SOCK_ERR_INVALID: Invalid arguments
- HTTPD_SOCK_ERR_TIMEOUT: Timeout/interrupted while calling socket recv()
- HTTPD_SOCK_ERR_FAIL: Unrecoverable error while calling socket recv()

```c
typedef int (*httpd_pending_func_t)(httpd_handle_t hd, int sockfd)
```

Prototype for HTTPDs low-level “get pending bytes” function.

**Note:** User specified pending function must handle errors internally, depending upon the set value of errno, and return specific HTTPD_SOCK_ERR_ codes, which will be handled accordingly in the server task.

<table>
<thead>
<tr>
<th>Param hd</th>
<th>[in] server instance</th>
</tr>
</thead>
<tbody>
<tr>
<td>sockfd</td>
<td>[in] session socket file descriptor</td>
</tr>
</tbody>
</table>

**Return**
- Bytes: The number of bytes waiting to be received
- HTTPD_SOCK_ERR_INVALID: Invalid arguments
- HTTPD_SOCK_ERR_TIMEOUT: Timeout/interrupted while calling socket pending()
- HTTPD_SOCK_ERR_FAIL: Unrecoverable error while calling socket pending()

```c
typedef esp_err_t (*httpd_err_handler_func_t)(httpd_req_t *req, httpd_err_code_t error)
```

Function prototype for HTTP error handling.

Submit Document Feedback
This function is executed upon HTTP errors generated during internal processing of an HTTP request. This is used to override the default behavior on error, which is to send HTTP error response and close the underlying socket.

**Note:**
- If implemented, the server will not automatically send out HTTP error response codes, therefore, `httpd_resp_send_err()` must be invoked inside this function if user wishes to generate HTTP error responses.
- When invoked, the validity of `uri, method, content_len` and `user_ctx` fields of the `httpd_req_t` parameter is not guaranteed as the HTTP request may be partially received/parsed.
- The function must return `ESP_OK` if underlying socket needs to be kept open. Any other value will ensure that the socket is closed. The return value is ignored when error is of type `HTTPD_500_INTERNAL_SERVER_ERROR` and the socket closed anyway.

| Param req | [in] HTTP request for which the error needs to be handled |
| Param error | [in] Error type |

**Return**
- `ESP_OK`: error handled successful
- `ESP_FAIL`: failure indicates that the underlying socket needs to be closed

typedef void *httpd_handle_t

HTTP Server Instance Handle.

Every instance of the server will have a unique handle.

typedef enum http_method httpd_method_t

HTTP Method Type wrapper over “enum http_method” available in “http_parser” library.

typedef void (*httpd_free_ctx_fn_t)(void *ctx)

Prototype for freeing context data (if any)

**Param ctx** | [in] object to free |

typedef esp_err_t (*httpd_open_func_t)(httpd_handle_t hd, int sockfd)

Function prototype for opening a session.

Called immediately after the socket was opened to set up the send/recv functions and other parameters of the socket.

**Param hd** | [in] server instance |
**Param sockfd** | [in] session socket file descriptor |

**Return**
- `ESP_OK`: On success
- Any value other than ESP_OK will signal the server to close the socket immediately

typedef void (*httpd_close_func_t)(httpd_handle_t hd, int sockfd)

Function prototype for closing a session.

**Note:** It’s possible that the socket descriptor is invalid at this point, the function is called for all terminated sessions. Ensure proper handling of return codes.

**Param hd** | [in] server instance |
**Param sockfd** | [in] session socket file descriptor |
typedef bool (*httpd_uri_match_func_t)(const char *reference_uri, const char *uri_to_match, size_t match_upto)

Function prototype for URI matching.

- **Param reference_uri** [in] URI/template with respect to which the other URI is matched
- **Param uri_to_match** [in] URI/template being matched to the reference URI/template
- **Param match_upto** [in] For specifying the actual length of `uri_to_match` up to which the matching algorithm is to be applied (The maximum value is `strlen(uri_to_match)`, independent of the length of `reference_uri`)

- **Return** `true` on match

typedef struct httpd_config httpd_config_t

HTTP Server Configuration Structure.

**Note:** Use `HTTPD_DEFAULT_CONFIG()` to initialize the configuration to a default value and then modify only those fields that are specifically determined by the use case.

typedef void (*httpd_work_fn_t)(void *arg)

Prototype of the HTTPD work function. Please refer to `httpd_queue_work()` for more details.

- **Param arg** [in] The arguments for this work function

**Enumerations**

enum httpd_err_code_t

Error codes sent as HTTP response in case of errors encountered during processing of an HTTP request.

**Values:**

- enumerator `HTTPD_500_INTERNAL_SERVER_ERROR`
- enumerator `HTTPD_501_METHOD_NOT_IMPLEMENTED`
- enumerator `HTTPD_505_VERSION_NOT_SUPPORTED`
- enumerator `HTTPD_400_BAD_REQUEST`
- enumerator `HTTPD_401_UNAUTHORIZED`
- enumerator `HTTPD_403_FORBIDDEN`
- enumerator `HTTPD_404_NOT_FOUND`
- enumerator `HTTPD_405_METHOD_NOT_ALLOWED`
- enumerator `HTTPD_408_REQ_TIMEOUT`
- enumerator `HTTPD_411_LENGTH_REQUIRED`
Chapter 2. API Reference

enumerator **HTTPD_414_URI_TOO_LONG**

enumerator **HTTPD_431_REQ_HDR_FIELDS_TOO_LARGE**

enumerator **HTTPD_ERR_CODE_MAX**

enum **esp_http_server_event_id_t**

HTTP Server events id.

*Values:*

enumerator **HTTP_SERVER_EVENT_ERROR**

This event occurs when there are any errors during execution

enumerator **HTTP_SERVER_EVENT_START**

This event occurs when HTTP Server is started

enumerator **HTTP_SERVER_EVENT_ON_CONNECTED**

Once the HTTP Server has been connected to the client, no data exchange has been performed

enumerator **HTTP_SERVER_EVENT_ON_HEADER**

Occurs when receiving each header sent from the client

enumerator **HTTP_SERVER_EVENT_HEADERS_SENT**

After sending all the headers to the client

enumerator **HTTP_SERVER_EVENT_ON_DATA**

Occurs when receiving data from the client

enumerator **HTTP_SERVER_EVENT_SENT_DATA**

Occurs when an ESP HTTP server session is finished

enumerator **HTTP_SERVER_EVENT_DISCONNECTED**

The connection has been disconnected

enumerator **HTTP_SERVER_EVENT_STOP**

This event occurs when HTTP Server is stopped

### 2.2.10 HTTPS Server

**Overview**

This component is built on top of *HTTP Server*. The HTTPS server takes advantage of hook registration functions in the regular HTTP server to provide callback function for SSL session.

All documentation for *HTTP Server* applies also to a server you create this way.
Used APIs

The following APIs of HTTP Server should not be used with HTTPS Server, as they are used internally to handle secure sessions and to maintain internal state:

- send, receive and pending callback registration functions - secure socket handling
  - httpd_sess_set_send_override()
  - httpd_sess_set_recv_override()
  - httpd_sess_set_pending_override()
- “transport context” - both global and session
  - httpd_sess_get_transport_ctx() - returns SSL used for the session
  - httpd_sess_set_transport_ctx()
  - httpd_get_global_transport_ctx() - returns the shared SSL context
  - httpd_config::global_transport_ctx
  - httpd_config::global_transport_ctx_free_fn
  - httpd_config::open_fn - used to set up secure sockets

Everything else can be used without limitations.

Usage

Please see the example protocols/https_server to learn how to set up a secure server.

Basically, all you need is to generate a certificate, embed it into the firmware, and pass the init struct into the start function after the certificate address and lengths are correctly configured in the init struct.

The server can be started with or without SSL by changing a flag in the init struct - httpd_ssl_config::transport_mode. This could be used, e.g., for testing or in trusted environments where you prefer speed over security.

Performance

The initial session setup can take about two seconds, or more with slower clock speed or more verbose logging. Subsequent requests through the open secure socket are much faster (down to under 100 ms).

API Reference

Header File

- components/esp_https_server/include/esp_https_server.h

Functions

esp_err_t httpd_ssl_start (httpd_handle_t *handle, httpd_ssl_config_t *config)

Create a SSL capable HTTP server (secure mode may be disabled in config)

Parameters

- config [inout] - server config, must not be const. Does not have to stay valid after calling this function.
- handle [out] - storage for the server handle, must be a valid pointer

Returns

success

esp_err_t httpd_ssl_stop (httpd_handle_t handle)

Stop the server. Blocks until the server is shut down.

Parameters handle [in]

Returns

- ESP_OK: Server stopped successfully
- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_FAIL: Failure to shut down server
Chapter 2. API Reference

Structures

struct **esp_https_server_user_cb_arg**
Callback data struct, contains the ESP-TLS connection handle and the connection state at which the callback is executed.

Public Members

```
httpd_ssl_user_cb_state_t **user_cb_state**
State of user callback

esp_tls_t **tls**
ESP-TLS connection handle
```

struct **httpd_ssl_config**
HTTPS server config struct
Please use HTTPD_SSL_CONFIG_DEFAULT() to initialize it.

Public Members

```
httpd_config_t **httpd**
Underlying HTTPD server config
Parameters like task stack size and priority can be adjusted here.

const uint8_t **servercert**
Server certificate

size_t **servercert_len**
Server certificate byte length

const uint8_t **cacert_pem**
CA certificate ((CA used to sign clients, or client cert itself)

size_t **cacert_len**
CA certificate byte length

const uint8_t **prvtkey_pem**
Private key

size_t **prvtkey_len**
Private key byte length

httpd_ssl_transport_mode_t **transport_mode**
Transport Mode (default secure)

uint16_t **port_secure**
Port used when transport mode is secure (default 443)
uint16_t port_insecure
   Port used when transport mode is insecure (default 80)

bool session_tickets
   Enable tls session tickets

bool use_secure_element
   Enable secure element for server session

*esp_https_server_user_cb*user_cb
   User callback for esp_https_server

void *ssl_userdata
   user data to add to the ssl context

esp_tls_handshake_callback cert_select_cb
   Certificate selection callback to use

const char **alpn_protos
   Application protocols the server supports in order of prefernece. Used for negotiating during the TLS
   handshake, first one the client supports is selected. The data structure must live as long as the https server
   itself!

Macros

HTTPD_SSL_CONFIG_DEFAULT()
   Default config struct init
   (http_server default config had to be copied for customization)

Notes:
   • port is set when starting the server, according to ‘transport_mode’
   • one socket uses ~ 40kB RAM with SSL, we reduce the default socket count to 4
   • SSL sockets are usually long-lived, closing LRU prevents pool exhaustion DOS
   • Stack size may need adjustments depending on the user application

Type Definitions

typedef struct esp_https_server_user_cb_arg esp_https_server_user_cb_arg_t
   Callback data struct, contains the ESP-TLS connection handle and the connection state at which the callback
   is executed.
typedef void esp_https_server_user_cb (esp_https_server_user_cb_arg_t *user_cb)
   Callback function prototype Can be used to get connection or client information (SSL context) E.g. Client
   certificate, Socket FD, Connection state, etc.

   Param user_cb Callback data struct

typedef struct httpd_ssl_config httpd_ssl_config_t

Enumerations

enum httpd_ssl_transport_mode_t
   Values:
**enumerator HTTPD_SSL_TRANSPORT_SECURE**

**enumerator HTTPD_SSL_TRANSPORT_INSECURE**

**enum httpd_ssl_user_cb_state_t**

Indicates the state at which the user callback is executed, i.e. at session creation or session close.

*Values:*

**enumerator HTTPD_SSL_USER_CB_SESS_CREATE**

**enumerator HTTPD_SSL_USER_CB_SESS_CLOSE**

### 2.2.11 ICMP Echo

**Overview**

ICMP (Internet Control Message Protocol) is used for diagnostic or control purposes or generated in response to errors in IP operations. The common network utility ping is implemented based on the ICMP packets with the type field value of 0, also called *Echo Reply*.

During a ping session, the source host firstly sends out an ICMP echo request packet and wait for an ICMP echo reply with specific times. In this way, it also measures the round-trip time for the messages. After receiving a valid ICMP echo reply, the source host will generate statistics about the IP link layer (e.g. packet loss, elapsed time, etc).

It is common that IoT device needs to check whether a remote server is alive or not. The device should show the warnings to users when it got offline. It can be achieved by creating a ping session and sending/parsing ICMP echo packets periodically.

To make this internal procedure much easier for users, ESP-IDF provides some out-of-box APIs.

**Create a new ping session** To create a ping session, you need to fill in the `esp_ping_config_t` configuration structure firstly, specifying target IP address, interval times, and etc. Optionally, you can also register some callback functions with the `esp_ping_callbacks_t` structure.

Example method to create a new ping session and register callbacks:

```c
static void test_on_ping_success(esp_ping_handle_t hdl, void *args)
{
    // optionally, get callback arguments
    // const char* str = (const char*) args;
    // printf("%s\r\n", str); // "foo"
    uint8_t ttl;
    uint16_t seqno;
    uint32_t elapsed_time, recv_len;
    ip_addr_t target_addr;
    esp_ping_get_profile(hdl, ESP_PING_PROF_SEQNO, &seqno, sizeof(seqno));
    esp_ping_get_profile(hdl, ESP_PING_PROF_TTL, &ttl, sizeof(ttl));
    esp_ping_get_profile(hdl, ESP_PING_PROF_IPADDR, &target_addr, sizeof(target_addr));
    esp_ping_get_profile(hdl, ESP_PING_PROF_SIZE, &recv_len, sizeof(recv_len));
    esp_ping_get_profile(hdl, ESP_PING_PROF_TIMEGAP, &elapsed_time, sizeof(elapsed_time));
    printf("%d bytes from %s icmp_seq=%d ttl=%d time=%d ms\n",
           recv_len, inet_ntoa(target_addr.u_addr.ip4), seqno, ttl, elapsed_time);
}
```

(continues on next page)
static void test_on_ping_timeout(esp_ping_handle_t hdl, void *args)
{
    uint16_t seqno;
    ip_addr_t target_addr;
    esp_ping_get_profile(hdl, ESP_PING_PROF_SEQNO, &seqno, sizeof(seqno));
    esp_ping_get_profile(hdl, ESP_PING_PROF_IPADDR, &target_addr, sizeof(target_addr));
    printf("From %s icmp_seq=%d timeout\n", inet_ntoa(target_addr.u_addr.ip4), seqno);
}

static void test_on_ping_end(esp_ping_handle_t hdl, void *args)
{
    uint32_t transmitted;
    uint32_t received;
    uint32_t total_time_ms;
    esp_ping_get_profile(hdl, ESP_PING_PROF_REQUEST, &transmitted, sizeof(transmitted));
    esp_ping_get_profile(hdl, ESP_PING_PROF_REPLY, &received, sizeof(received));
    esp_ping_get_profile(hdl, ESP_PING_PROF_DURATION, &total_time_ms, sizeof(total_time_ms));
    printf("%d packets transmitted, %d received, time %dms\n", transmitted, received, total_time_ms);
}

void initialize_ping()
{
    /* convert URL to IP address */
    ip_addr_t target_addr;
    struct addrinfo hint;
    struct addrinfo *res = NULL;
    memset(&hint, 0, sizeof(hint));
    memset(&target_addr, 0, sizeof(target_addr));
    getaddrinfo("www.espressif.com", NULL, &hint, &res);
    struct in_addr addr4 = ((struct sockaddr_in *) (res->ai_addr))->sin_addr;
    inet_addr_to_ip4addr(ip_2_ip4(&target_addr), &addr4);
    freeaddrinfo(res);

    esp_ping_config_t ping_config = ESP_PING_DEFAULT_CONFIG();
    ping_config.target_addr = target_addr; // target IP address
    ping_config.count = ESP_PING_COUNT_INFINITE; // ping in infinite mode, esp_ping_stop can stop it

    /* set callback functions */
    esp_ping_callbacks_t cbs;
    cbs.on_ping_success = test_on_ping_success;
    cbs.on_ping_timeout = test_on_ping_timeout;
    cbs.on_ping_end = test_on_ping_end;
    cbs.cb_args = "foo"; // arguments that will feed to all callback functions, can be NULL
    cbs.cb_args = eth_event_group;

    esp_ping_handle_t ping;
    esp_ping_new_session(&ping_config, &cbs, &ping);
}

Start and Stop ping session You can start and stop ping session with the handle returned by esp_ping_new_session. Note that, the ping session won’t start automatically after creation. If the ping session is stopped, and restart again, the sequence number in ICMP packets will recount from zero again.
Delete a ping session If a ping session won’t be used any more, you can delete it with `esp_ping_delete_session`. Please make sure the ping session is in stop state (i.e. you have called `esp_ping_stop` before or the ping session has finished all the procedures) when you call this function.

Get runtime statistics As the example code above, you can call `esp_ping_get_profile` to get different runtime statistics of ping session in the callback function.

Application Example

ICMP echo example: protocols/icmp_echo

API Reference

Header File

• components/lwip/include/apps/ping/ping_sock.h

Functions

`esp_err_t esp_ping_new_session (const esp_ping_config_t *config, const esp_ping_callbacks_t *cbs, esp_ping_handle_t *hdl_out)`

Create a ping session.

Parameters

• `config` – ping configuration
• `cbs` – a bunch of callback functions invoked by internal ping task
• `hdl_out` – handle of ping session

Returns

• `ESP_ERR_INVALID_ARG`: invalid parameters (e.g. configuration is null, etc)
• `ESP_ERR_NO_MEM`: out of memory
• `ESP_FAIL`: other internal error (e.g. socket error)
• `ESP_OK`: create ping session successfully, user can take the ping handle to do follow-on jobs

`esp_err_t esp_ping_delete_session (esp_ping_handle_t hdl)`

Delete a ping session.

Parameters

• `hdl` – handle of ping session

Returns

• `ESP_ERR_INVALID_ARG`: invalid parameters (e.g. ping handle is null, etc)
• `ESP_OK`: delete ping session successfully

`esp_err_t esp_ping_start (esp_ping_handle_t hdl)`

Start the ping session.

Parameters

• `hdl` – handle of ping session

Returns

• `ESP_ERR_INVALID_ARG`: invalid parameters (e.g. ping handle is null, etc)
• `ESP_OK`: start ping session successfully

`esp_err_t esp_ping_stop (esp_ping_handle_t hdl)`

Stop the ping session.

Parameters

• `hdl` – handle of ping session

Returns

• `ESP_ERR_INVALID_ARG`: invalid parameters (e.g. ping handle is null, etc)
• `ESP_OK`: stop ping session successfully
\textbf{esp_err_t} \textbf{esp_ping_get_profile} (esp_ping_handle_t hdl, esp_ping_profile_t profile, void *data, uint32_t size)

Get runtime profile of ping session.

**Parameters**

- \textbf{hdl} – handle of ping session
- \textbf{profile} – type of profile
- \textbf{data} – profile data
- \textbf{size} – profile data size

**Returns**

- ESP_ERR_INVALID_ARG: invalid parameters (e.g. ping handle is null, etc)
- ESP_ERR_INVALID_SIZE: the actual profile data size doesn’t match the “size” parameter
- ESP_OK: get profile successfully

**Structures**

\textbf{struct esp_ping_callbacks_t}

Type of “ping” callback functions.

**Public Members**

void *\textbf{cb_args}

arguments for callback functions

void (*\textbf{on_ping_success})(esp_ping_handle_t hdl, void *args)

Invoked by internal ping thread when received ICMP echo reply packet.

void (*\textbf{on_ping_timeout})(esp_ping_handle_t hdl, void *args)

Invoked by internal ping thread when receive ICMP echo reply packet timeout.

void (*\textbf{on_ping_end})(esp_ping_handle_t hdl, void *args)

Invoked by internal ping thread when a ping session is finished.

\textbf{struct esp_ping_config_t}

Type of “ping” configuration.

**Public Members**

uint32_t \textbf{count}

A “ping” session contains count procedures

uint32_t \textbf{interval_ms}

Milliseconds between each ping procedure

uint32_t \textbf{timeout_ms}

Timeout value (in milliseconds) of each ping procedure

uint32_t \textbf{data_size}

Size of the data next to ICMP packet header
int **tos**
Type of Service, a field specified in the IP header

int **ttl**
Time to Live, a field specified in the IP header

ip_addr_t **target_addr**
Target IP address, either IPv4 or IPv6

uint32_t **task_stack_size**
Stack size of internal ping task

uint32_t **task_prio**
Priority of internal ping task

uint32_t **interface**
Netif index, interface=0 means NETIF_NO_INDEX

**Macros**

ESP_PING_DEFAULT_CONFIG ()
Default ping configuration.

ESP_PING_COUNT_INFINITE
Set ping count to zero will ping target infinitely

**Type Definitions**

typedef void *esp_ping_handle_t
Type of “ping” session handle.

**Enumerations**
enum esp_ping_profile_t
Profile of ping session.

Values:

enumerator ESP_PING_PROF_SEQNO
Sequence number of a ping procedure

enumerator ESP_PING_PROF_TOS
Type of service of a ping procedure

enumerator ESP_PING_PROF_TTL
Time to live of a ping procedure

enumerator ESP_PING_PROF_REQUEST
Number of request packets sent out
Chapter 2. API Reference

enumerator ESP_PING_PROF_REPLY
   Number of reply packets received

enumerator ESP_PING_PROF_IPADDR
   IP address of replied target

enumerator ESP_PING_PROF_SIZE
   Size of received packet

enumerator ESP_PING_PROF_TIMEGAP
   Elapsed time between request and reply packet

enumerator ESP_PING_PROF_DURATION
   Elapsed time of the whole ping session

2.2.12 mDNS Service

mDNS is a multicast UDP service that is used to provide local network service and host discovery.
The ESP-IDF component mDNS has been moved from ESP-IDF since version v5.0 to a separate repository:
   • mDNS component on GitHub

To add mDNS component in your project, please run idf.py add-dependency espressif/mdns.

Hosted Documentation

The documentation can be found on the link below:
   • mDNS documentation

2.2.13 Mbed TLS

Mbed TLS is a C library that implements cryptographic primitives, X.509 certificate manipulation and the SSL/TLS and DTLS protocols. Its small code footprint makes it suitable for embedded systems.

Note: ESP-IDF uses a fork of Mbed TLS which includes a few patches (related to hardware routines of certain modules like bignum (MPI) and ECC) over vanilla Mbed TLS.

Mbed TLS supports SSL 3.0 up to TLS 1.3 and DTLS 1.0 to 1.2 communication by providing the following:
   • TCP/IP communication functions: listen, connect, accept, read/write.
   • SSL/TLS communication functions: init, handshake, read/write.
   • X.509 functions: CRT, CRL and key handling
   • Random number generation
   • Hashing
   • Encryption/decryption

Note: Mbed TLS is in the process of migrating all the documentation to a single place. In the meantime, users can find the documentation at the old Mbed TLS site.
Mbed TLS Support in ESP-IDF

Please find the information about the Mbed TLS versions present in different branches of ESP-IDF here.

Note: Please refer to the ESP-IDF Migration Guide to migrate from Mbed TLS version 2.x to version 3.0 or greater.

Application Examples

Examples in ESP-IDF use ESP-TLS which provides a simplified API interface for accessing the commonly used TLS functionality.

Refer to the examples protocols/https_server/simple (Simple HTTPS server) and protocols/https_request (Make HTTPS requests) for more information.

If the Mbed TLS API is to be used directly, refer to the example protocols/https_mbedtls.

Alternatives

ESP-TLS acts as an abstraction layer over the underlying SSL/TLS library and thus has an option to use Mbed TLS or wolfSSL as the underlying library. By default, only Mbed TLS is available and used in ESP-IDF whereas wolfSSL is available publicly at https://github.com/espressif/esp-wolfSSL with the upstream submodule pointer.

Please refer to ESP-TLS: Underlying SSL/TLS Library Options docs for more information on this and comparison of Mbed TLS and wolfSSL.

Important Config Options

Following is a brief list of important config options accessible at Component Config -> mbedTLS. The full list of config options can be found here.

- CONFIG_MBEDTLS_SSL_PROTO_TLS1_2: Support for TLS 1.2
- CONFIG_MBEDTLS_SSL_PROTO_TLS1_3: Support for TLS 1.3
- CONFIG_MBEDTLS_CERTIFICATE_BUNDLE: Support for trusted root certificate bundle (more about this: ESP x509 Certificate Bundle)
- CONFIG_MBEDTLS_CLIENT_SSL_SESSION_TICKETS: Support for TLS Session Resumption: Client session tickets
- CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS: Support for TLS Session Resumption: Server session tickets
- CONFIG_MBEDTLS_HARDWARE_SHA: Support for hardware SHA acceleration
- CONFIG_MBEDTLS_HARDWARE_AES: Support for hardware AES acceleration
- CONFIG_MBEDTLS_HARDWARE_MPI: Support for hardware MPI (bignum) acceleration

Note: Mbed TLS v3.0.0 and later support only TLS 1.2 and TLS 1.3 (SSL 3.0, TLS 1.0, TLS 1.1 and DTLS 1.0 are not supported). The support for TLS 1.3 is experimental and only supports the client-side. More information about this can be found out here.

Performance and Memory Tweaks

Reducing Heap Usage The following table shows typical memory usage with different configs when the protocols/https_request example (with Server Validation enabled) was run with Mbed TLS as the SSL/TLS library.
## Chapter 2. API Reference

### 2.2.14 IP Network Layer

Documentation for IP Network Layer protocols (below the Application Protocol layer) are provided in Networking APIs.

### 2.3 Bluetooth API

#### 2.3.1 BT COMMON

**BT GENERIC DEFINES**

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_bt_defs.h

**Structures**

struct **esp_bt_uuid_t**

- UUID type.

**Public Members**

- uint16_t **len**
  
  UUID length, 16bit, 32bit or 128bit

---

<table>
<thead>
<tr>
<th>Mbed Test</th>
<th>TLS</th>
<th>Related Configs</th>
<th>Heap Usage (approx.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default</td>
<td>NA</td>
<td></td>
<td>42196 B</td>
</tr>
<tr>
<td>Enable SSL Variable Length</td>
<td><code>CONFIG_MBEDTLS_SSL_VARIABLE_BUFFER_LENGTH</code></td>
<td>42120 B</td>
<td></td>
</tr>
<tr>
<td>Disable Keep Peer Certificate</td>
<td><code>CONFIG_MBEDTLS_SSL_KEEP_PEER_CERTIFICATE</code></td>
<td>38533 B</td>
<td></td>
</tr>
<tr>
<td>Enable Dynamic TX/RX Buffer</td>
<td><code>CONFIG_MBEDTLS_DYNAMIC_BUFFER</code></td>
<td><code>CONFIG_MBEDTLS_DYNAMIC_FREE_CONFIG_DATA</code></td>
<td><code>CONFIG_MBEDTLS_DYNAMIC_FREE_CA_CERT</code></td>
</tr>
</tbody>
</table>

**Note:** These values are subject to change with change in configuration options and versions of Mbed TLS.

**Reducing Binary Size**

Under Component Config -> mbedTLS, there are multiple Mbed TLS features which are enabled by default but can be disabled if not needed to save code size. More information can be about this can be found in Minimizing Binary Size docs.

Code examples for this API section are provided in the protocols directory of ESP-IDF examples.
uint16_t uuid16
16bit UUID

uint32_t uuid32
32bit UUID

uint8_t uuid128[ESP_UUID_LEN_128]
128bit UUID

union esp_btuuid_t::[anonymous] uuid
UUID

Macros
ESP_BLUEDROID_STATUS_CHECK (status)
ESP_BT_STATUS_BASE_FOR_HCI_ERR
ESP_BT_OCTET16_LEN
ESP_BT_OCTET8_LEN
ESP_DEFAULT_GATT_IF
Default GATT interface id.
ESP_BLE_PRIM_ADV_INT_MIN
Minimum advertising interval for undirected and low duty cycle directed advertising
ESP_BLE_PRIM_ADV_INT_MAX
Maximum advertising interval for undirected and low duty cycle directed advertising
ESP_BLE_CONN_INT_MIN
relate to BTM_BLE_CONN_INT_MIN in stack/btm_ble_api.h
ESP_BLE_CONN_INT_MAX
relate to BTM_BLE_CONN_INT_MAX in stack/btm_ble_api.h
ESP_BLE_CONN_LATENCY_MAX
relate to ESP_BLE_CONN_LATENCY_MAX in stack/btm_ble_api.h
ESP_BLE_CONN_SUP_TOUT_MIN
relate to BTM_BLE_CONN_SUP_TOUT_MIN in stack/btm_ble_api.h
ESP_BLE_CONN_SUP_TOUT_MAX
relate to ESP_BLE_CONN_SUP_TOUT_MAX in stack/btm_ble_api.h
ESP_BLE_IS_VALID_PARAM (x, min, max)
Check the param is valid or not.
ESP_UUID_LEN_16
Chapter 2. API Reference

ESP_UUID_LEN_32

ESP_UUID_LEN_128

ESP_BD ADDR_LEN
    Bluetooth address length.

ESP_BLE_ENC_KEY_MASK
    Used to exchange the encryption key in the init key & response key.

ESP_BLE_ID_KEY_MASK
    Used to exchange the IRK key in the init key & response key.

ESP_BLE_CSR_KEY_MASK
    Used to exchange the CSRK key in the init key & response key.

ESP_BLE_LINK_KEY_MASK
    Used to exchange the link key (this key just used in the BLE & BR/EDR coexist mode) in the init key & response key.

ESP_APP_ID_MIN
    Minimum of the application id.

ESP_APP_ID_MAX
    Maximum of the application id.

ESP_BD ADDR_STR

ESP_BD ADDR_HEX (addr)

Type Definitions

typedef uint8_t esp_bt_octet16_t[ESP_BT_OCTET16_LEN]

typedef uint8_t esp_bt_octet8_t[ESP_BT_OCTET8_LEN]

typedef uint8_t esp_link_key[ESP_BT_OCTET16_LEN]

typedef uint8_t esp_bd_addr_t[ESP_BD_ADDR_LEN]
    Bluetooth device address.

typedef uint8_t esp_ble_key_mask_t

Enumerations

enum esp_bt_status_t
    Status Return Value.

Values:
enumerator `ESP_BT_STATUS_SUCCESS`

enumerator `ESP_BT_STATUS_FAIL`

enumerator `ESP_BT_STATUS_NOT_READY`

enumerator `ESP_BT_STATUS_NOMEM`

enumerator `ESP_BT_STATUS_BUSY`

enumerator `ESP_BT_STATUS_DONE`

enumerator `ESP_BT_STATUS_UNSUPPORTED`

enumerator `ESP_BT_STATUS_PARM_INVALID`

enumerator `ESP_BT_STATUS_UNHANDED`

enumerator `ESP_BT_STATUS_AUTH_FAILURE`

enumerator `ESP_BT_STATUS_RMT_DEV_DOWN`

enumerator `ESP_BT_STATUS_AUTH_REJECTED`

enumerator `ESP_BT_STATUS_INVALID_STATIC_RAND_ADDR`

enumerator `ESP_BT_STATUS_PENDING`

enumerator `ESP_BT_STATUS_UNACCEPT_CONN_INTERVAL`

enumerator `ESP_BT_STATUS_PARAM_OUT_OF_RANGE`

enumerator `ESP_BT_STATUS_TIMEOUT`

enumerator `ESP_BT_STATUS_PEER_LE_DATA_LEN_UNSUPPORTED`

enumerator `ESP_BT_STATUS_CONTROL_LE_DATA_LEN_UNSUPPORTED`

enumerator `ESP_BT_STATUS_ERR_ILLEGAL_PARAMETER_FMT`

enumerator `ESP_BT_STATUS_MEMORY_FULL`

enumerator `ESP_BT_STATUS_EIR_TOO_LARGE`

enumerator `ESP_BT_STATUS_HCI_SUCCESS`
enumerator ESP_BT_STATUS_HCI_ILLEGAL_COMMAND
enumerator ESP_BT_STATUS_HCI_NO_CONNECTION
enumerator ESP_BT_STATUS_HCI_HW_FAILURE
enumerator ESP_BT_STATUS_HCI_PAGE_TIMEOUT
enumerator ESP_BT_STATUS_HCI_AUTH_FAILURE
enumerator ESP_BT_STATUS_HCI_KEY_MISSING
enumerator ESP_BT_STATUS_HCI_MEMORY_FULL
enumerator ESP_BT_STATUS_HCI_CONNECTION_TOUT
enumerator ESP_BT_STATUS_HCI_MAX_NUM_OF_CONNECTIONS
enumerator ESP_BT_STATUS_HCI_MAX_NUM_OF_SCOS
enumerator ESP_BT_STATUS_HCI_CONNECTION_EXISTS
enumerator ESP_BT_STATUS_HCI_COMMAND_DISALLOWED
enumerator ESP_BT_STATUS_HCI_HOST_REJECT_RESOURCES
enumerator ESP_BT_STATUS_HCI_HOST_REJECT_SECURITY
enumerator ESP_BT_STATUS_HCI_HOST_REJECT_DEVICE
enumerator ESP_BT_STATUS_HCI_HOST_TIMEOUT
enumerator ESP_BT_STATUS_HCI_UNSUPPORTED_VALUE
enumerator ESP_BT_STATUS_HCI_ILLEGAL_PARAMETER_FMT
enumerator ESP_BT_STATUS_HCI_PEER_USER
enumerator ESP_BT_STATUS_HCI_PEER_LOW_RESOURCES
enumerator ESP_BT_STATUS_HCI_PEER_POWER_OFF
enumerator ESP_BT_STATUS_HCI_CONN_CAUSE_LOCAL_HOST
enumerator ESP_BT_STATUS_HCI_REPEATED_ATTEMPTS
enumerator ESP_BT_STATUS_HCI_PAIRING_NOT_ALLOWED
enumerator ESP_BT_STATUS_HCI_UNKNOWN_LMP_PDU
enumerator ESP_BT_STATUS_HCI_UNSUPPORTED_REM_FEATURE
enumerator ESP_BT_STATUS_HCI_SCO_OFFSET_REJECTED
enumerator ESP_BT_STATUS_HCI_SCO_INTERVAL_REJECTED
enumerator ESP_BT_STATUS_HCI_SCO_AIR_MODE
enumerator ESP_BT_STATUS_HCI_INVALID_LMP_PARAM
enumerator ESP_BT_STATUS_HCI_UNSPECIFIED
enumerator ESP_BT_STATUS_HCI_UNSUPPORTED_LMP_PARAMETERS
enumerator ESP_BT_STATUS_HCI_ROLE_CHANGE_NOT_ALLOWED
enumerator ESP_BT_STATUS_HCI_LMP_RESPONSE_TIMEOUT
enumerator ESP_BT_STATUS_HCI_LMP_ERR_TRANS_COLLISION
enumerator ESP_BT_STATUS_HCI_LMP_PDU_NOT_ALLOWED
enumerator ESP_BT_STATUS_HCI_ENCRY_MODE_NOT_ACCEPTABLE
enumerator ESP_BT_STATUS_HCI_UNIT_KEY_USED
enumerator ESP_BT_STATUS_HCI_QOS_NOT_SUPPORTED
enumerator ESP_BT_STATUS_HCI_INSTANT_PASSED
enumerator ESP_BT_STATUS_HCI_PAIRING_WITH_UNIT_KEY_NOT_SUPPORTED
enumerator ESP_BT_STATUS_HCI_DIFF_TRANSACTION_COLLISION
enumerator ESP_BT_STATUS_HCI_UNDEFINED_0x2B
enumerator ESP_BT_STATUS_HCI_QOS_UNACCEPTABLE_PARAM
enumerator ESP_BT_STATUS_HCI_QOS_REJECTED
enumerator ESP_BT_STATUS_HCI_CHAN_CLASSIF_NOT_SUPPORTED
enumerator `ESP_BT_STATUS_HCI_INSUFFICIENT_SECURITY`

enumerator `ESP_BT_STATUS_HCI_PARAM_OUT_OF_RANGE`

enumerator `ESP_BT_STATUS_HCI_UNDEFINED_0x31`

enumerator `ESP_BT_STATUS_HCI_ROLE_SWITCH_PENDING`

enumerator `ESP_BT_STATUS_HCI_UNDEFINED_0x33`

enumerator `ESP_BT_STATUS_HCI_RESERVED_SLOT_VIOLATION`

enumerator `ESP_BT_STATUS_HCI_ROLE_SWITCH_FAILED`

enumerator `ESP_BT_STATUS_HCI_INQ_RSP_DATA_TOO_LARGE`

enumerator `ESP_BT_STATUS_HCI_SIMPLE_PAIRING_NOT_SUPPORTED`

enumerator `ESP_BT_STATUS_HCI_HOST_BUSY_PAIRING`

enumerator `ESP_BT_STATUS_HCI_REJ_NO_SUITABLE_CHANNEL`

enumerator `ESP_BT_STATUS_HCI_CONTROLLER_BUSY`

enumerator `ESP_BT_STATUS_HCI_UNACCEPT_CONN_INTERVAL`

enumerator `ESP_BT_STATUS_HCI_DIRECTED_ADVERTISING_TIMEOUT`

enumerator `ESP_BT_STATUS_HCI_CONN_TOUT_DUE_TO_MIC_FAILURE`

enumerator `ESP_BT_STATUS_HCI_CONN_FAILED_ESTABLISHMENT`

enumerator `ESP_BT_STATUS_HCI_MAC_CONNECTION_FAILED`

define `esp_bt_dev_type_t`

Bluetooth device type.

Values:

enumerator `ESP_BT_DEVICE_TYPE_BREDR`

enumerator `ESP_BT_DEVICE_TYPE_BLE`

enumerator `ESP_BT_DEVICE_TYPE_DUMO`
enum esp_ble_addr_type_t
BLE device address type.

Values:

enumerator BLE_ADDR_TYPE_PUBLIC
Public Device Address

enumerator BLE_ADDR_TYPE_RANDOM
Random Device Address. To set this address, use the function esp_ble_gap_set_rand_addr.esp_bd_addr_t rand_addr)

enumerator BLE_ADDR_TYPE_RPA_PUBLIC
Resolvable Private Address (RPA) with public identity address

enumerator BLE_ADDR_TYPE_RPA_RANDOM
Resolvable Private Address (RPA) with random identity address. To set this address, use the function esp_ble_gap_set_rand_addr.esp_bd_addr_t rand_addr)

enum esp_ble_wl_addr_type_t
white list address type

Values:

enumerator BLE_WL_ADDR_TYPE_PUBLIC

enumerator BLE_WL_ADDR_TYPE_RANDOM

BT MAIN API

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_bt_main.h

Functions

esp_bluedroid_status_t esp_bluedroid_get_status (void)
Get bluetooth stack status.

Returns Bluetooth stack status

esp_err_t esp_bluedroid_enable (void)
Enable bluetooth, must after esp_bluedroid_init().

Returns
- ESP_OK : Succeed
- Other : Failed

esp_err_t esp_bluedroid_disable (void)
Disable bluetooth, must prior to esp_bluedroid_deinit().

Returns
- ESP_OK : Succeed
- Other : Failed
Chapter 2. API Reference

`esp_err_t esp_bluedroid_init (void)`

Init and alloc the resource for bluetooth, must be prior to every bluetooth stuff.

**Returns**
- ESP_OK : Succeed
- Other : Failed

`esp_err_t esp_bluedroid_deinit (void)`

Deinit and free the resource for bluetooth, must be after every bluetooth stuff.

**Returns**
- ESP_OK : Succeed
- Other : Failed

**Enumerations**

enum `esp_bluedroid_status_t`

Bluetooth stack status type, to indicate whether the bluetooth stack is ready.

*Values:*

- Enumerator `ESP_BLUEDROID_STATUS_UNINITIALIZED`:
  - Bluetooth not initialized
- Enumerator `ESP_BLUEDROID_STATUS_INITIALIZED`:
  - Bluetooth initialized but not enabled
- Enumerator `ESP_BLUEDROID_STATUS_ENABLED`
  - Bluetooth initialized and enabled

**BT DEVICE APIs**

**Overview** Bluetooth device reference APIs.

**API Reference**

**Header File**
- components/bt/host/bluedroid/api/include/api/esp_bt_device.h

**Functions**

const uint8_t *`esp_bt_dev_get_address (void)`

Get bluetooth device address. Must use after “esp_bluedroid_enable”.

**Returns** bluetooth device address (six bytes), or NULL if bluetooth stack is not enabled

`esp_err_t esp_bt_dev_set_device_name (const char *name)`

Set bluetooth device name. This function should be called after esp_bluedroid_enable() completes successfully.

A BR/EDR/LE device type shall have a single Bluetooth device name which shall be identical irrespective of the physical channel used to perform the name discovery procedure.

**Parameters** `name` - [in]: device name to be set

**Returns**
- ESP_OK : Succeed
- ESP_ERR_INVALID_ARG : if name is NULL pointer or empty, or string length out of limit

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• ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL : others

2.3.2 BT LE

GAP API

Application Example  Check bluetooth/bluedroid/ble folder in ESP-IDF examples, which contains the following demos and their tutorials:

• This is a SMP security client demo and its tutorial. This demo initiates its security parameters and acts as a GATT client, which can send a security request to the peer device and then complete the encryption procedure.
  – bluetooth/bluedroid/ble/gatt_security_client
  – GATT Security Client Example Walkthrough
• This is a SMP security server demo and its tutorial. This demo initiates its security parameters and acts as a GATT server, which can send a pair request to the peer device and then complete the encryption procedure.
  – bluetooth/bluedroid/ble/gatt_security_server
  – GATT Security Server Example Walkthrough

API Reference

Header File

• components/bt/host/bluedroid/api/include/api/esp_gap_ble_api.h

Functions

`esp_err_t esp_ble_gap_register_callback (esp_gap_ble_cb_t callback)`

This function is called to occur gap event, such as scan result.

Parameters  callback –[in] callback function

Returns

• ESP_OK : success
• other : failed

`esp_err_t esp_ble_gap_config_adv_data (esp_ble_adv_data_t *adv_data)`

This function is called to override the BTA default ADV parameters.

Parameters  adv_data –[in] Pointer to User defined ADV data structure. This memory space can not be freed until callback of config_adv_data is received.

Returns

• ESP_OK : success
• other : failed

`esp_err_t esp_ble_gap_set_scan_params (esp_ble_scan_params_t *scan_params)`

This function is called to set scan parameters.

Parameters  scan_params –[in] Pointer to User defined scan_params data structure. This memory space can not be freed until callback of set_scan_params

Returns

• ESP_OK : success
• other : failed

`esp_err_t esp_ble_gap_start_scanning (uint32_t duration)`

This procedure keep the device scanning the peer device which advertising on the air.

Parameters  duration –[in] Keeping the scanning time, the unit is second.

Returns

• ESP_OK : success
• other : failed
### esp_err_t esp_ble_gap_stop_scanning (void)

This function call to stop the device scanning the peer device which advertising on the air.

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_start_advertising (esp_ble_adv_params_t *adv_params)

This function is called to start advertising.

**Parameters** adv_params – [in]  pointer to User defined adv_params data structure.

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_stop_advertising (void)

This function is called to stop advertising.

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_update_conn_params (esp_ble_conn_update_params_t *params)

Update connection parameters, can only be used when connection is up.

**Parameters** params – [in] - connection update parameters

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_set_pkt_data_len (esp_bd_addr_t remote_device, uint16_t tx_data_length)

This function is to set maximum LE data packet size.

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_set_rand_addr (esp_bd_addr_t rand_addr)

This function allows configuring either a Non-Resolvable Private Address or a Static Random Address.

**Parameters** rand_addr – [in]  The address to be configured. Refer to the table below for possible address subtypes:

<table>
<thead>
<tr>
<th>address [47:46]</th>
<th>Address Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0b00</td>
<td>Non-Resolvable Private</td>
</tr>
<tr>
<td></td>
<td>Address</td>
</tr>
<tr>
<td>0b11</td>
<td>Static Random Address</td>
</tr>
</tbody>
</table>

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_clear_rand_addr (void)

This function clears the random address for the application.

**Returns**
- ESP_OK : success
- other : failed

### esp_err_t esp_ble_gap_config_local_privacy (bool privacy_enable)

Enable/disable privacy (including address resolution) on the local device.
Parameters `privacy_enable` - [in] - enable/disable privacy on remote device.

Returns
- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gap_config_local_icon(uint16_t icon)`
set local gap appearance icon

Parameters `icon` - [in] - External appearance value, these values are defined by the Bluetooth SIG, please refer to https://www.bluetooth.com/specifications/assigned-numbers/

Returns
- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gap_update_whitelist(bool add_remove, esp_bd_addr_t remote_bda, esp_ble_wl_addr_type_t wl_addr_type)`
Add or remove device from white list.

Parameters
- `add_remove` - [in] the value is true if added the ble device to the white list, and false remove to the white list.
- `remote_bda` - [in] the remote device address add/remove from the white list.
- `wl_addr_type` - [in] whitelist address type

Returns
- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gap_clear_whitelist(void)`
Clear all white list.

Returns
- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gap_get_whitelist_size(uint16_t*length)`
Get the whitelist size in the controller.

Parameters `length` - [out] the white list length.

Returns
- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gap_set_prefer_conn_params(esp_bd_addr_t bd_addr, uint16_t min_conn_int, uint16_t max_conn_int, uint16_t slave_latency, uint16_t supervision_tout)`
This function is called to set the preferred connection parameters when default connection parameter is not desired before connecting. This API can only be used in the master role.

Parameters
- `bd_addr` - [in] BD address of the peripheral
- `min_conn_int` - [in] minimum preferred connection interval
- `max_conn_int` - [in] maximum preferred connection interval
- `slave_latency` - [in] preferred slave latency
- `supervision_tout` - [in] preferred supervision timeout

Returns
- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gap_set_device_name(const char *name)`
Set device name to the local device Note: This API don’t affect the advertising data.

Parameters `name` - [in] - device name.

Returns
• ESP_OK: success
• other: failed

`esp_err_t esp_ble_gap_get_device_name(void)`

Get device name of the local device.

Returns
• ESP_OK: success
• other: failed

`esp_err_t esp_ble_gap_get_local_used_addr(esp_bd_addr_t local_used_addr, uint8_t *addr_type)`

This function is called to get local used address and address type. `uint8_t *esp_bt_dev_get_address(void)` get the public address.

Parameters
- `local_used_addr` [in] - current local used ble address (six bytes)
- `addr_type` [in] - ble address type

Returns
- ESP_OK: success
• other: failed

`uint8_t *esp_ble_resolve_adv_data(uint8_t* adv_data, uint8_t type, uint8_t *length)`

This function is called to get ADV data for a specific type.

Parameters
- `adv_data` [in] - pointer of ADV data which to be resolved
- `type` [in] - finding ADV data type
- `length` [out] - return the length of ADV data not including type

Returns
pointer of ADV data

`esp_err_t esp_ble_gap_config_adv_data_raw(uint8_t* raw_data, uint32_t raw_data_len)`

This function is called to set raw advertising data. User need to fill ADV data by self.

Parameters
- `raw_data` [in] : raw advertising data with the format: [Length 1][Data Type 1][Data 1][Length 2][Data Type 2][Data 2] ...
- `raw_data_len` [in] : raw advertising data length, less than 31 bytes

Returns
• ESP_OK: success
• other: failed

`esp_err_t esp_ble_gap_config_scan_rsp_data_raw(uint8_t* raw_data, uint32_t raw_data_len)`

This function is called to set raw scan response data. User need to fill scan response data by self.

Parameters
- `raw_data` [in] : raw scan response data
- `raw_data_len` [in] : raw scan response data length, less than 31 bytes

Returns
• ESP_OK: success
• other: failed

`esp_err_t esp_ble_gap_read_rssi(esp_bd_addr_t remote_addr)`

This function is called to read the RSSI of remote device. The address of link policy results are returned in the gap callback function with ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT event.

Parameters
- `remote_addr` [in] : The remote connection device address.

Returns
• ESP_OK: success
• other: failed

`esp_err_t esp_ble_gap_add_duplicate_scan_exceptional_device(esp_ble_duplicate_exceptional_info_type_t type, esp_duplicate_info_t device_info)`

This function is called to add a device info into the duplicate scan exceptional list.
**Parameters**

- **type** - [in] device info type, it is defined in `esp_ble_duplicate_exceptional_info_type_t` when type is MESH_BEACON_TYPE, MESH_PROV_SRV_ADV or MESH_PROXY_SRV_ADV; device_info is invalid.

- **device_info** - [in] the device information.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_remove_duplicate_scan_exceptional_device(
    esp_ble_duplicate_exceptional_info_type_t type,
    esp_duplicate_info_t device_info)
```

This function is called to remove a device info from the duplicate scan exceptional list.

**Parameters**

- **type** - [in] device info type, it is defined in `esp_ble_duplicate_exceptional_info_type_t` when type is MESH_BEACON_TYPE, MESH_PROV_SRV_ADV or MESH_PROXY_SRV_ADV; device_info is invalid.

- **device_info** - [in] the device information.

**Returns**

- ESP_OK: success
- other : failed

```c
esp_err_t esp_ble_gap_clean_duplicate_scan_exceptional_list(
    esp_duplicate_scan_exceptional_list_type_t list_type)
```

This function is called to clean the duplicate scan exceptional list. This API will delete all device information in the duplicate scan exceptional list.

**Parameters**

- **list_type** - [in] duplicate scan exceptional list type, the value can be one or more of `esp_duplicate_scan_exceptional_list_type_t`.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_set_security_param(
    esp_ble_sm_param_t param_type, void *value, uint8_t len)
```

Set a GAP security parameter value. Overrides the default value.

---

Secure connection is highly recommended to avoid some major vulnerabilities like 'Impersonation in the Pin Pairing Protocol' (CVE-2020-26555) and 'Authentication of the LE Legacy Pairing Protocol'.

To accept only `secure connection mode`, it is necessary to do as:

1. Set bit `ESP_LE_AUTH_REQ_SC_ONLY` (`param_type` is `ESP_BLE_SM_AUTHEN_REQ_MODE`), bit `ESP_LE_AUTH_BOND` and bit `ESP_LE_AUTH_REQ_MITM` is optional as required.

2. Set to `ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_ENABLE` (`param_type` is `ESP_BLE_SM_ONLY_ACCEPT_SPECIFIED_SEC_AUTH`).

---

**Parameters**

- **param_type** - [in]: the type of the param which to be set
- **value** - [in]: the param value
- **len** - [in]: the length of the param value
Returns - ESP_OK : success
• other : failed

\texttt{esp\_err\_t esp\_ble\_gap\_security\_rsp} (\texttt{esp\_bd\_addr\_t \ bd\_addr, bool \ accept})
Grant security request access.

Parameters
• \texttt{bd\_addr} -[in] : BD address of the peer
• \texttt{accept} -[in] : accept the security request or not

Returns - ESP_OK : success
• other : failed

\texttt{esp\_err\_t esp\_ble\_set\_encryption} (\texttt{esp\_bd\_addr\_t \ bd\_addr, esp\_ble\_sec\_act\_t \ sec\_act})
Set a gap parameter value. Use this function to change the default GAP parameter values.

Parameters
• \texttt{bd\_addr} -[in] : the address of the peer device need to encryption
• \texttt{sec\_act} -[in] : This is the security action to indicate what kind of BLE security level is required for the BLE link if the BLE is supported

Returns - ESP_OK : success
• other : failed

\texttt{esp\_err\_t esp\_ble\_passkey\_reply} (\texttt{esp\_bd\_addr\_t \ bd\_addr, bool \ accept, uint32\_t \ passkey})
Reply the key value to the peer device in the legacy connection stage.

Parameters
• \texttt{bd\_addr} -[in] : BD address of the peer
• \texttt{accept} -[in] : passkey entry successful or declined.
• \texttt{passkey} -[in] : passkey value, must be a 6 digit number, can be lead by 0.

Returns - ESP_OK : success
• other : failed

\texttt{esp\_err\_t esp\_ble\_confirm\_reply} (\texttt{esp\_bd\_addr\_t \ bd\_addr, bool \ accept})
Reply the confirm value to the peer device in the secure connection stage.

Parameters
• \texttt{bd\_addr} -[in] : BD address of the peer device
• \texttt{accept} -[in] : numbers to compare are the same or different.

Returns - ESP_OK : success
• other : failed

\texttt{esp\_err\_t esp\_ble\_remove\_bond\_device} (\texttt{esp\_bd\_addr\_t \ bd\_addr})
Removes a device from the security database list of peer device. It manages unpairing event while connected.

Parameters \texttt{bd\_addr} -[in] : BD address of the peer device

Returns - ESP_OK : success
• other : failed

\texttt{int esp\_ble\_get\_bond\_device\_num} (void)
Get the device number from the security database list of peer device. It will return the device bonded number immediately.

Returns - \texttt{>= 0} : bonded devices number.
• ESP\_FAIL : failed

\texttt{esp\_err\_t esp\_ble\_get\_bond\_device\_list} (\texttt{int \*dev\_num, esp\_ble\_bond\_dev\_t \*dev\_list})
Get the device from the security database list of peer device. It will return the device bonded information immediately.

Parameters
• \texttt{dev\_num} -[inout] Indicate the dev\_list array(buffer) size as input. If dev\_num is large enough, it means the actual number as output. Suggest that dev\_num value equal to \texttt{esp\_ble\_get\_bond\_device\_num}().
Chapter 2. API Reference

- **dev_list**: an array(buffer) of `esp_ble_bond_dev_t` type. Use for storing the bonded devices address. The dev_list should be allocated by who call this API.

  **Returns**
  - ESP_OK : success
  - other : failed

`esp_err_t esp_ble_oob_req_reply (esp_bd_addr_t bd_addr, uint8_t *TK, uint8_t len)`

This function is called to provide the OOB data for SMP in response to ESP_GAP_BLE_OOB_REQ_EVT.

  **Parameters**
  - `bd_addr` : [in] BD address of the peer device.
  - `TK` : [in] Temporary Key value, the TK value shall be a 128-bit random number
  - `len` : [in] length of temporary key, should always be 128-bit

  **Returns**
  - ESP_OK : success
  - other : failed

`esp_err_t esp_ble_sc_oob_req_reply (esp_bd_addr_t bd_addr, uint8_t p_c[16], uint8_t p_r[16])`

This function is called to provide the OOB data for SMP in response to ESP_GAP_BLE_SC_OOB_REQ_EVT.

  **Parameters**
  - `bd_addr` : [in] BD address of the peer device.
  - `p_c` : [in] Confirmation value, it shall be a 128-bit random number
  - `p_r` : [in] Randomizer value, it should be a 128-bit random number

  **Returns**
  - ESP_OK : success
  - other : failed

`esp_err_t esp_ble_create_sc_oob_data (void)`

This function is called to create the OOB data for SMP when secure connection.

  **Returns**
  - ESP_OK : success
  - other : failed

`esp_err_t esp_gap_ble_disconnect (esp_bd_addr_t remote_device)`

This function is called to disconnect the peer device gattc may have multiple virtual GATT server connections when multiple app_id registered. `esp_ble_gattc_close (esp_gatt_if_t gattc_if, uint16_t conn_id)` only close one virtual GATT server connection. if there exist other virtual GATT server connections, it does not disconnect the physical connection. `esp_ble_gap_disconnect(esp_bd_addr_t remote_device)` disconnect the physical connection directly.

  **Parameters**
  - `remote_device` : [in] BD address of the peer device

  **Returns**
  - ESP_OK : success
  - other : failed

`esp_err_t esp_ble_get_current_conn_params (esp_bd_addr_t bd_addr, esp_gap_conn_params_t *conn_params)`

This function is called to read the connection parameters information of the device.

  **Parameters**
  - `bd_addr` : [in] BD address of the peer device.
  - `conn_params` : [out] the connection parameters information

  **Returns**
  - ESP_OK : success
  - other : failed

`esp_err_t esp_gap_ble_set_channels (esp_gap_ble_channels channels)`

BLE set channels.

  **Parameters**
  - `channels` : [in] : The n th such field (in the range 0 to 36) contains the value for the link layer channel index n. 0 means channel n is bad. 1 means channel n is unknown. The most significant bits are reserved and shall be set to 0. At least one channel shall be marked as unknown.

  **Returns**
  - ESP_OK : success
  - ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
  - other : failed
**esp_err_t** esp_gap_ble_set_authorization(esp_bd_addr_t bd_addr, bool authorize)

This function is called to authorize a link after Authentication (MITM protection)

**Parameters**
- **bd_addr** [in]: BD address of the peer device.
- **authorize** [out]: Authorized the link or not.

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t** esp_ble_gap_read_phy(esp_bd_addr_t bd_addr)

This function is used to read the current transmitter PHY and receiver PHY on the connection identified by remote address.

**Parameters**
- **bd_addr** [in]: BD address of the peer device

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t** esp_ble_gap_set_preferred_default_phy(esp_ble_gap_phy_mask_t tx_phy_mask, esp_ble_gap_phy_mask_t rx_phy_mask)

This function is used to allows the Host to specify its preferred values for the transmitter PHY and receiver PHY to be used for all subsequent connections over the LE transport.

**Parameters**
- **tx_phy_mask** [in]: indicates the transmitter PHYs that the Host prefers the Controller to use
- **rx_phy_mask** [in]: indicates the receiver PHYs that the Host prefers the Controller to use

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t** esp_ble_gap_set_preferred_phy(esp_bd_addr_t bd_addr, esp_ble_gap_all_phys_t all_phys_mask, esp_ble_gap_phy_mask_t tx_phy_mask, esp_ble_gap_phy_mask_t rx_phy_mask, esp_ble_gap_prefer_phy_options_t phy_options)

This function is used to set the PHY preferences for the connection identified by the remote address. The Controller might not be able to make the change (e.g. because the peer does not support the requested PHY) or may decide that the current PHY is preferable.

**Parameters**
- **bd_addr** [in]: remote address
- **all_phys_mask** [in]: a bit field that allows the Host to specify
- **tx_phy_mask** [in]: a bit field that indicates the transmitter PHYs that the Host prefers the Controller to use
- **rx_phy_mask** [in]: a bit field that indicates the receiver PHYs that the Host prefers the Controller to use
- **phy_options** [in]: a bit field that allows the Host to specify options for PHYs

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t** esp_ble_gap_ext_adv_set_rand_addr(uint8_t instance, esp_bd_addr_t rand_addr)

This function is used by the Host to set the random device address specified by the Random_Address parameter.

**Parameters**
- **instance** [in]: Used to identify an advertising set
- **rand_addr** [in]: Random Device Address

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t** esp_ble_gap_ext_adv_set_params(uint8_t instance, const esp_ble_gap_ext_adv_params_t *params)

This function is used by the Host to set the advertising parameters.
**Parameters**

- **instance** - [in]: identifies the advertising set whose parameters are being configured.
- **params** - [in]: advertising parameters

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_config_ext_adv_data_raw(uint8_t instance, uint16_t length, const uint8_t *data)
```

This function is used to set the data used in advertising PDUs that have a data field.

**Parameters**

- **instance** - [in]: identifies the advertising set whose data are being configured
- **length** - [in]: data length
- **data** - [in]: data information

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_config_ext_scan_rsp_data_raw(uint8_t instance, uint16_t length, const uint8_t *scan_rsp_data)
```

This function is used to provide scan response data used in scanning response PDUs.

**Parameters**

- **instance** - [in]: identifies the advertising set whose response data are being configured.
- **length** - [in]: responsedata length
- **scan_rsp_data** - [in]: response data information

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_ext_adv_start(uint8_t num_adv, const esp_ble_gap_ext_adv_t *ext_adv)
```

This function is used to request the Controller to enable one or more advertising sets using the advertising sets identified by the instance parameter.

**Parameters**

- **num_adv** - [in]: Number of advertising sets to enable or disable
- **ext_adv** - [in]: adv parameters

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_ext_adv_stop(uint8_t num_adv, const uint8_t *ext_adv_inst)
```

This function is used to request the Controller to disable one or more advertising sets using the advertising sets identified by the instance parameter.

**Parameters**

- **num_adv** - [in]: Number of advertising sets to enable or disable
- **ext_adv_inst** - [in]: ext adv instance

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_ext_adv_set_remove(uint8_t instance)
```

This function is used to remove an advertising set from the Controller.

**Parameters**

- **instance** - [in]: Used to identify an advertising set

**Returns**

- ESP_OK: success
- other : failed

```c
esp_err_t esp_ble_gap_ext_adv_set_clear(void)
```

This function is used to remove all existing advertising sets from the Controller.

**Returns**

- ESP_OK: success
- other : failed

```c
esp_err_t esp_ble_gap_periodic_adv_set_params(uint8_t instance, const esp_ble_gap_periodic_adv_params_t *params)
```
This function is used by the Host to set the parameters for periodic advertising.

**Parameters**

- **instance** [in]: identifies the advertising set whose periodic advertising parameters are being configured.
- **params** [in]: periodic adv parameters

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_config_periodic_adv_data_raw(uint8_t instance, uint16_t length, const uint8_t* data)
```

This function is used to set the data used in periodic advertising PDUs.

**Parameters**

- **instance** [in]: identifies the advertising set whose periodic advertising parameters are being configured.
- **length** [in]: the length of periodic data
- **data** [in]: periodic data information

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_start (uint8_t instance)
```

This function is used to request the Controller to enable the periodic advertising for the advertising set specified.

**Parameters**

- **instance** [in]: Used to identify an advertising set

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_stop (uint8_t instance)
```

This function is used to request the Controller to disable the periodic advertising for the advertising set specified.

**Parameters**

- **instance** [in]: Used to identify an advertising set

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_create_sync (const esp_ble_gap_periodic_adv_sync_params_t *params)
```

This function is used to synchronize with periodic advertising from an advertiser and begin receiving periodic advertising packets.

**Parameters**

- **params** [in]: scan parameters

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_start_ext_scan (uint32_t duration, uint16_t period)
```

This function is used to enable scanning.

**Parameters**

- **duration** [in]: Scan duration
- **period** [in]: Time interval from when the Controller started its last Scan Duration until it begins the subsequent Scan Duration.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_stop_ext_scan (void)
```

This function is used to disable scanning.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_create_sync (const esp_ble_gap_periodic_adv_sync_params_t *params)
```

This function is used to synchronize with periodic advertising from an advertiser and begin receiving periodic advertising packets.
Parameters **params** [in] : sync parameters

Returns - ESP_OK : success
  • other : failed

**esp_err_t esp_ble_gap_periodic_adv_sync_cancel** (void)

This function is used to cancel the LE_Periodic_Advertising_Create_Sync command while it is pending.

Returns - ESP_OK : success
  • other : failed

**esp_err_t esp_ble_gap_periodic_adv_sync_terminate** (uint16_t sync_handle)

This function is used to stop reception of the periodic advertising identified by the Sync Handle parameter.

Parameters **sync_handle** [in] : identify the periodic advertiser

Returns - ESP_OK : success
  • other : failed

**esp_err_t esp_ble_gap_periodic_adv_add_dev_to_list** (esp_ble_addr_type_t addr_type, esp_bd_addr_t addr, uint8_t sid)

This function is used to add a single device to the Periodic Advertiser list stored in the Controller.

Parameters
  • **addr_type** [in] : address type
  • **addr** [in] : Device Address
  • **sid** [in] : Advertising SID subfield in the ADI field used to identify the Periodic Advertising

Returns - ESP_OK : success
  • other : failed

**esp_err_t esp_ble_gap_periodic_adv_remove_dev_from_list** (esp_ble_addr_type_t addr_type, esp_bd_addr_t addr, uint8_t sid)

This function is used to remove one device from the list of Periodic Advertisers stored in the Controller. Removals from the Periodic Advertisers List take effect immediately.

Parameters
  • **addr_type** [in] : address type
  • **addr** [in] : Device Address
  • **sid** [in] : Advertising SID subfield in the ADI field used to identify the Periodic Advertising

Returns - ESP_OK : success
  • other : failed

**esp_err_t esp_ble_gap_periodic_adv_clear_dev** (void)

This function is used to remove all devices from the list of Periodic Advertisers in the Controller.

Returns - ESP_OK : success
  • other : failed

**esp_err_t esp_ble_gap_prefer_ext_connect_params_set** (esp_bd_addr_t addr,
  esp_ble_gap_phy_mask_t phy_mask,
  const esp_ble_gap_conn_params_t *phy_1m_conn_params,
  const esp_ble_gap_conn_params_t *phy_2m_conn_params,
  const esp_ble_gap_conn_params_t *phy_coded_conn_params)

This function is used to set aux connection parameters.

Parameters
  • **addr** [in] : device address
  • **phy_mask** [in] : indicates the PHY(s) on which the advertising packets should be received on the primary advertising channel and the PHYs for which connection parameters have been specified.
• **phy_1m_conn_params** - [in]: Scan connectable advertisements on the LE 1M PHY. Connection parameters for the LE 1M PHY are provided.
• **phy_2m_conn_params** - [in]: Connection parameters for the LE 2M PHY are provided.
• **phy_coded_conn_params** - [in]: Scan connectable advertisements on the LE Coded PHY. Connection parameters for the LE Coded PHY are provided.

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_recv_enable (uint16_t sync_handle, uint8_t enable)
```
This function is used to set periodic advertising receive enable.

**Parameters**
- **sync_handle** - [in]: Handle of periodic advertising sync
- **enable** - [in]: Determines whether reporting and duplicate filtering are enabled or disabled

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_sync_trans (esp_bd_addr_t addr, uint16_t service_data, uint16_t sync_handle)
```
This function is used to transfer periodic advertising sync.

**Parameters**
- **addr** - [in]: Peer device address
- **service_data** - [in]: Service data used by Host
- **sync_handle** - [in]: Handle of periodic advertising sync

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_periodic_adv_set_info_trans (esp_bd_addr_t addr, uint16_t service_data, uint8_t adv_handle)
```
This function is used to transfer periodic advertising set info.

**Parameters**
- **addr** - [in]: Peer device address
- **service_data** - [in]: Service data used by Host
- **adv_handle** - [in]: Handle of advertising set

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gap_set_periodic_adv_sync_trans_params (esp_bd_addr_t addr, const esp_ble_gap_past_params_t *params)
```
This function is used to set periodic advertising sync transfer params.

**Parameters**
- **addr** - [in]: Peer device address
- **params** - [in]: Params of periodic advertising sync transfer

**Returns**
- ESP_OK: success
- other: failed

**Unions**

```c
union esp_ble_key_value_t
#include <esp_gap_ble_api.h> union type of the security key value
```

**Public Members**
**esp_ble_penc_keys_t penc_key**
received peer encryption key

**esp_ble_pcsrk_keys_t pcsrk_key**
received peer device SRK

**esp_ble_pid_keys_t pid_key**
peer device ID key

**esp_ble_lenc_keys_t lenc_key**
local encryption reproduction keys LTK = d1(ER,DIV,0)

**esp_ble_lcsrk_keys lcsrk_key**
local device CSRK = d1(ER,DIV,1)

union **esp_ble_sec_t**

`#include <esp_gap_ble_api.h>` union associated with BLE security

### Public Members

**esp_ble_sec_key_notif_t key_notif**
passkey notification

**esp_ble_sec_req_t ble_req**
BLE SMP related request

**esp_ble_key_t ble_key**
BLE SMP keys used when pairing

**esp_ble_local_id_keys_t ble_id_keys**
BLE IR event

**esp_ble_local_oob_data_t oob_data**
BLE SMP secure connection OOB data

**esp_ble_auth_cmpl_t auth_cmpl**
Authentication complete indication.

union **esp_ble_gap_cb_param_t**

`#include <esp_gap_ble_api.h>` Gap callback parameters union.

### Public Members

Structure **esp_ble_gap_cb_param_t::ble_get_dev_name_cmplEvtParam get_dev_name_cmpl**
Event parameter of ESP_GAP_BLE_GET_DEV_NAME_COMPLETE_EVT

Structure **esp_ble_gap_cb_param_t::ble_adv_data_cmplEvtParam adv_data_cmpl**
Event parameter of ESP_GAP_BLE_ADV_DATA_SET_COMPLETE_EVT
struct esp_ble_gap_cb_param_t::ble_scan_rsp_data_cmpl_evt_param scan_rsp_data_cmpl
    Event parameter of ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_scan_param_cmpl_evt_param scan_param_cmpl
    Event parameter of ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_scan_result_evt_param scan_rst
    Event parameter of ESP_GAP_BLE_SCAN_RESULT_EVT

struct esp_ble_gap_cb_param_t::ble_adv_data_raw_cmpl_evt_param adv_data_raw_cmpl
    Event parameter of ESP_GAP_BLE_ADV_DATA_RAW_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_scan_rsp_data_raw_cmpl_evt_param scan_rsp_data_raw_cmpl
    Event parameter of ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_adv_start_cmpl_evt_param adv_start_cmpl
    Event parameter of ESP_GAP_BLE_ADV_START_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_scan_start_cmpl_evt_param scan_start_cmpl
    Event parameter of ESP_GAP_BLE_SCAN_START_COMPLETE_EVT

esp_ble_sec_t ble_security
    ble gap security union type

struct esp_ble_gap_cb_param_t::ble_scan_stop_cmpl_evt_param scan_stop_cmpl
    Event parameter of ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_adv_stop_cmpl_evt_param adv_stop_cmpl
    Event parameter of ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_rand_cmpl_evt_param set_rand_addr_cmpl
    Event parameter of ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT

struct esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param update_conn_params
    Event parameter of ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT

struct esp_ble_gap_cb_param_t::ble_pkt_data_length_cmpl_evt_param pkt_data_length_cmpl
    Event parameter of ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_local_privacy_cmpl_evt_param local_privacy_cmpl
    Event parameter of ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_remove_bond_dev_cmpl_evt_param remove_bond_dev_cmpl
    Event parameter of ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_clear_bond_dev_cmpl_evt_param clear_bond_dev_cmpl
    Event parameter of ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT
struct esp_ble_gap_cb_param_t::ble_get_bond_dev_cmpl_evt_param get_bond_dev_cmpl
    Event parameter of ESP_GAP_BLE_GET_BOND_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_read_rssi_cmpl_evt_param read_rssi_cmpl
    Event parameter of ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_update_whitelist_cmpl_evt_param update_whitelist_cmpl
    Event parameter of ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param update_duplicate_exceptional_list_cmpl
    Event parameter of ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_channels_evt_param ble_set_channels
    Event parameter of ESP_GAP_BLE_SET_CHANNELS_EVT

struct esp_ble_gap_cb_param_t::ble_read_phy_cmpl_evt_param read_phy
    Event parameter of ESP_GAP_BLE_READ_PHY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_perf_def_phy_cmpl_evt_param set_perf_def_phy
    Event parameter of ESP_GAP_BLE_SET_PREFERRED_DEFAULT_PHY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_perf_phy_cmpl_evt_param set_perf_phy
    Event parameter of ESP_GAP_BLE_SET_PREFERRED_PHY_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_set_rand_addr_cmpl_evt_param ext_adv_set_rand_addr
    Event parameter of ESP_GAP_BLE_EXT_ADV_SET_RAND_ADDR_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_set_params_cmpl_evt_param ext_adv_set_params
    Event parameter of ESP_GAP_BLE_EXT_ADV_SET_PARAMS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_data_set_cmpl_evt_param ext_adv_data_set
    Event parameter of ESP_GAP_BLE_EXT_ADV_DATA_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_scan_rsp_set_cmpl_evt_param scan_rsp_set
    Event parameter of ESP_GAP_BLE_EXT_SCAN_RSP_DATA_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_start_cmpl_evt_param ext_adv_start
    Event parameter of ESP_GAP_BLE_EXT_ADV_START_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_stop_cmpl_evt_param ext_adv_stop
    Event parameter of ESP_GAP_BLE_EXT_ADV_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_set_remove_cmpl_evt_param ext_adv_remove
    Event parameter of ESP_GAP_BLE_EXT_ADV_SET_REMOVE_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_set_clear_cmpl_evt_param ext_adv_clear
    Event parameter of ESP_GAP_BLE_EXT_ADV_SET_CLEAR_COMPLETE_EVT
struct esp_ble_gap_cb_param_t::ble_periodic_adv_set_params_period_adv_set_params
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SET_PARAMS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_data_set_cmpl_param_period_adv_data_set
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_DATA_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_start_cmpl_param_period_adv_start
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_START_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_stop_cmpl_param_period_adv_stop
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_period_adv_create_sync_cmpl_param_period_adv_create_sync
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_CREATE_SYNC_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_period_adv_sync_cancel_cmpl_param_period_adv_sync_cancel
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SYNC_CANCEL_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_period_adv_sync_terminate_cmpl_param_period_adv_sync_term
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SYNC_TERMINATE_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_period_adv_add_dev_cmpl_param_period_adv_add_dev
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_ADD_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_period_adv_remove_dev_cmpl_param_period_adv_remove_dev
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_REMOVE_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_period_adv_clear_dev_cmpl_param_period_adv_clear_dev
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_CLEAR_DEV_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_ext_scan_params_cmpl_param_set_ext_scan_params
    Event parameter of ESP_GAP_BLE_SET_EXT_SCAN_PARAMS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_scan_params_set_cmpl_param_ext_scan_start
    Event parameter of ESP_GAP_BLE_EXT_SCAN_START_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_scan_stop_cmpl_param_ext_scan_stop
    Event parameter of ESP_GAP_BLE_EXT_SCAN_STOP_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_conn_params_set_cmpl_param_ext_conn_params_set
    Event parameter of ESP_GAP_BLE_PREFER_EXT_CONN_PARAMS_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_adv_terminate_param_adv_terminate
    Event parameter of ESP_GAP_BLE_ADV_TERMINATED_EVT

struct esp_ble_gap_cb_param_t::ble_scan_req_received_param_scan_req_received
    Event parameter of ESP_GAP_BLE_SCAN_REQ_RECEIVED_EVT
struct esp_ble_gap_cb_param_t::ble_channel_sel_alg_param channel_sel_alg
    Event parameter of ESP_GAP_BLE_CHANNEL_SELECT_ALGORITHM_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_sync_lost_param periodic_adv_sync_lost
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SYNC_LOST_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_sync_estab_param periodic_adv_sync_estab
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SYNC_ESTAB_EVT

struct esp_ble_gap_cb_param_t::ble_phy_update_cmpl_param phy_update
    Event parameter of ESP_GAP_BLE_PHY_UPDATE_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_ext_adv_report_param ext_adv_report
    Event parameter of ESP_GAP_BLE_EXT_ADV_REPORT_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_report_param period_adv_report
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_REPORT_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_recv_enable_cmpl_param period_adv_recv_enable
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_RECV_ENABLE_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_sync_trans_cmpl_param period_adv_sync_trans
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SYNC_TRANS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_set_info_trans_cmpl_param period_adv_set_info_trans
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SET_INFO_TRANS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_set_past_params_cmpl_param set_past_params
    Event parameter of ESP_GAP_BLE_SET_PAST_PARAMS_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_periodic_adv_sync_trans_recv_param past_received
    Event parameter of ESP_GAP_BLE_PERIODIC_ADV_SYNC_TRANS_RECV_EVT

struct ble_adv_data_cmpl_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_ADV_DATA_SET_COMPLETE_EVT.

Public Members

esp_bt_status_t status
    Indicate the set advertising data operation success status

struct ble_adv_data_raw_cmpl_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_ADV_DATA_RAW_SET_COMPLETE_EVT.
Public Members

`esp_bt_status_t status`
Indicate the set raw advertising data operation success status

struct `ble_adv_start_cmpl_evt_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_ADV_START_COMPLETE_EVT.

Public Members

`esp_bt_status_t status`
Indicate advertising start operation success status

struct `ble_adv_stop_cmpl_evt_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT.

Public Members

`esp_bt_status_t status`
Indicate adv stop operation success status

struct `ble_adv_terminate_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_ADV_TERMINATED_EVT.

Public Members

`uint8_t status`
Indicate adv terminate status

`uint8_t adv_instance`
extend advertising handle

`uint16_t conn_idx`
connection index

`uint8_t completed_event`
the number of completed extend advertising events

struct `ble_channel_sel_alg_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_CHANNEL_SELECT_ALGORITHM_EVT.

Public Members

`uint16_t conn_handle`
connection handle
uint8_t channel_sel_alg

channel selection algorithm

struct ble_clear_bond_dev_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate the clear bond device operation success status

struct ble_ext_adv_data_set_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_DATA_SET_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate extend advertising data set status

struct ble_ext_adv_report_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_REPORT_EVT.

Public Members

esp_ble_gap_ext_adv_repnot_t params
extend advertising report parameters

struct ble_ext_adv_scan_rsp_set_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_SCAN_RSP_DATA_SET_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate extend advertising scan response data set status

struct ble_ext_adv_set_clear_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_SET_CLEAR_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate advertising stop operation success status

struct ble_ext_adv_set_params_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_SET_PARAMS_COMPLETE_EVT.
Public Members

`esp_bt_status_t status`
Indicate extend advertising parameters set status

```c
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_EXT_ADV_SET_RAND_ADDR_COMPLETE_EVT.
```

Public Members

`esp_bt_status_t status`
Indicate extend advertising random address set status

```c
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_EXT_ADV_SET_REMOVE_COMPLETE_EVT.
```

Public Members

`esp_bt_status_t status`
Indicate advertising stop operation success status

```c
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_EXT_ADV_START_COMPLETE_EVT.
```

Public Members

`esp_bt_status_t status`
Indicate advertising stop operation success status

```c
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_EXT_ADV_STOP_COMPLETE_EVT.
```

Public Members

`esp_bt_status_t status`
Indicate extend connection parameters set status

```c
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PREFER_EXT_CONN_PARAMS_SET_COMPLETE_EVT.
```
struct **ble_ext_scan_start_cmpl_param**

```
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_SCAN_START_COMPLETE_EVT.
```

**Public Members**

```
esp_bt_status_t status
```

Indicate extend advertising start status

struct **ble_ext_scan_stop_cmpl_param**

```
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_SCAN_STOP_COMPLETE_EVT.
```

**Public Members**

```
esp_bt_status_t status
```

Indicate extend advertising stop status

struct **ble_get_bond_dev_cmpl_evt_param**

```
#include <esp_gap_ble_api.h> ESP_GAP_BLE_GET_BOND_DEV_COMPLETE_EVT.
```

**Public Members**

```
esp_bt_status_t status
```

Indicate the get bond device operation success status

```
uint8_t dev_num
```

Indicate the get number device in the bond list

```
esp_ble_bond_dev_t *bond_dev
```

the pointer to the bond device Structure

struct **ble_get_dev_name_cmpl_evt_param**

```
#include <esp_gap_ble_api.h> ESP_GAP_BLE_GET_DEV_NAME_COMPLETE_EVT.
```

**Public Members**

```
esp_bt_status_t status
```

Indicate the get device name success status

```
char *name
```

Name of bluetooth device

struct **ble_local_privacy_cmpl_evt_param**

```
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT.
```
Chapter 2. API Reference

Public Members

```c
esp_bt_status_t status
```
Indicate the set local privacy operation success status

```c
struct ble_period_adv_add_dev_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_ADD_DEV_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising device list add status

```c
struct ble_period_adv_clear_dev_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_CLEAR_DEV_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising device list clean status

```c
struct ble_period_adv_create_sync_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_CREATE_SYNC_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising create sync status

```c
struct ble_period_adv_remove_dev_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_REMOVE_DEV_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising device list remove status

```c
struct ble_period_adv_sync_cancel_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SYNC_CANCEL_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising sync cancel status
struct `ble_period_adv_sync_term_cmpl_param`

```
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PERIODIC_ADV_SYNC_TERM_COMPLETE_EVT.
```

**Public Members**

`esp_bt_status_t status`

Indicate periodic advertising sync terminate status

struct `ble_period_adv_data_set_cmpl_param`

```
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PERIODIC_ADV_DATA_SET_COMPLETE_EVT.
```

**Public Members**

`esp_bt_status_t status`

Indicate periodic advertising data set status

struct `ble_period_adv_recv_enable_cmpl_param`

```
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PERIODIC_ADV_RECV_ENABLE_COMPLETE_EVT.
```

**Public Members**

`esp_bt_status_t status`

Set periodic advertising receive enable status

struct `ble_period_adv_report_param`

```
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PERIODIC_ADV_REPORT_EVT.
```

**Public Members**

`esp_ble_gap_periodic_adv_report_t params`

Periodic advertising report parameters

struct `ble_period_adv_set_info_trans_cmpl_param`

```
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PERIODIC_ADV_SET_INFO_TRANS_COMPLETE_EVT.
```

**Public Members**

`esp_bt_status_t status`

Periodic advertising set info transfer status

```
esp_bd_addr_t bda
```

The remote device address

struct `ble_period_adv_set_params_cmpl_param`

```
#include <esp_gap_ble_api.h>
ESP_GAP_BLE_PERIODIC_ADV_SET_PARAMS_COMPLETE_EVT.
```
Chapter 2. API Reference

Public Members

```c
esp_bt_status_t status

Indicate periodic advertising parameters set status
```

`struct ble_periodic_adv_start_cmpl_param`

```c
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_START_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status

Indicate periodic advertising start status
```

`struct ble_periodic_adv_stop_cmpl_param`

```c
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_STOP_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status

Indicate periodic advertising stop status
```

`struct ble_periodic_adv_sync_estab_param`

```c
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SYNC_ESTAB_EVT.
```

Public Members

```c
uint8_t status

periodic advertising sync status
```

```c
uint16_t sync_handle

periodic advertising sync handle
```

```c
uint8_t sid

periodic advertising sid
```

```c
esp_ble_addr_type_t adv_addr_type

periodic advertising address type
```

```c
esp_bd_addr_t adv_addr

periodic advertising address
```

```c
esp_ble_gap_phy_t adv_phy

periodic advertising phy type
```

```c
uint16_t period_adv_interval

periodic advertising interval
```
```c
uint8_t adv_clk_accuracy
    periodic advertising clock accuracy

struct ble_periodic_adv_sync_lost_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SYNC_LOST_EVT.

Public Members

uint16_t sync_handle
    sync handle

struct ble_periodic_adv_sync_trans_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SYNC_TRANS_COMPLETE_EVT.

Public Members

esp_bt_status_t status
    Periodic advertising sync transfer status

esp_bd_addr_t bda
    The remote device address

struct ble_periodic_adv_sync_trans_recv_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SYNC_TRANS_RECV_EVT.

Public Members

esp_bt_status_t status
    Periodic advertising sync transfer received status

esp_bd_addr_t bda
    The remote device address

uint16_t service_data
    The value provided by the peer device

uint16_t sync_handle
    Periodic advertising sync handle

uint8_t adv_sid
    Periodic advertising set id

uint8_t adv_addr_type
    Periodic advertiser address type
```
**Chapter 2. API Reference**

```c
esp_bd_addr_t adv_addr
   Periodic advertiser address

esp_ble_gap_phy_t adv_phy
   Periodic advertising PHY

uint16_t adv_interval
   Periodic advertising interval

uint8_t adv_clk_accuracy
   Periodic advertising clock accuracy
```

```c
struct ble_phy_update_cmpl_param
   #include <esp_gap_ble_api.h> ESP_GAP_BLE_PHY_UPDATE_COMPLETE_EVT.

   Public Members

   esp_bt_status_t status
      phy update status

   esp_bd_addr_t bda
      address

   esp_ble_gap_phy_t tx_phy
      tx phy type

   esp_ble_gap_phy_t rx_phy
      rx phy type
```

```c
struct ble_pkt_data_length_cmplEvt_param
   #include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT.

   Public Members

   esp_bt_status_t status
      Indicate the set pkt data length operation success status

   esp_ble_pkt_data_length_params_t params
      pkt data length value
```

```c
struct ble_read_phy_cmplEvt_param
   #include <esp_gap_ble_api.h> ESP_GAP_BLE_READ_PHY_COMPLETE_EVT.

   Public Members
```


```c
struct ble_read_rssi_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT.
```

**Public Members**

```c
esp_bt_status_t status
Indicate the read adv tx power operation success status
```

```c
int8_t rssi
The ble remote device rssi value, the range is from -127 to 20, the unit is dbm, if the RSSI cannot be read, the RSSI metric shall be set to 127.
```

```c
esp_bd_addr_t remote_addr
The remote device address
```

```c
struct ble_remove_bond_dev_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT.
```

**Public Members**

```c
esp_bt_status_t status
Indicate the remove bond device operation success status
```

```c
esp_bd_addr_t bd_addr
The device address which has been remove from the bond list
```

```c
struct ble_scan_param_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT.
```

**Public Members**

```c
esp_bt_status_t status
Indicate the set scan param operation success status
```

```c
struct ble_scan_req_received_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_REQ_RECEIVED_EVT.
```
**Public Members**

```c
uint8_t adv_instance
    extend advertising handle

esp_ble_addr_type_t scan_addr_type
    scanner address type

esp_bd_addr_t scan_addr
    scanner address
```

```c
def struct ble_scan_result_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_RESULT_EVT.

Public Members
```

```c
esp_gap_searchEvt_t search_evt
    Search event type

esp_bd_addr_t bda
    Bluetooth device address which has been searched

esp_bt_dev_type_t dev_type
    Device type

esp_ble_addr_type_t ble_addr_type
    Blc device address type

esp_ble_evt_type_t ble_evt_type
    Ble scan result event type

int rssi
    Searched device’s RSSI

uint8_t ble_adv[ESP_BLE_ADV_DATA_LEN_MAX +
    ESP_BLE_SCAN_RSP_DATA_LEN_MAX]
    Received EIR

int flag
    Advertising data flag bit

int num_resps
    Scan result number

uint8_t adv_data_len
    Adv data length
```
Chapter 2. API Reference

typedef uint8_t scan_rsp_len
    Scan response length

typedef uint32_t num_dis
    The number of discard packets

struct ble_scan_rsp_data_cmpl_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT.

    Public Members

        esp_bt_status_t status
            Indicate the set scan response data operation success status

struct ble_scan_rsp_data_raw_cmpl_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT.

    Public Members

        esp_bt_status_t status
            Indicate the set raw advertising data operation success status

struct ble_scan_start_cmpl_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_START_COMPLETE_EVT.

    Public Members

        esp_bt_status_t status
            Indicate scan start operation success status

struct ble_scan_stop_cmpl_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT.

    Public Members

        esp_bt_status_t status
            Indicate scan stop operation success status

struct ble_set_channels_evt_param
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_CHANNELS_EVT.

    Public Members

        esp_bt_status_t status
            BLE set channel status
struct ble_set_ext_scan_params_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_EXT_SCAN_PARAMS_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate extend advertising parameters set status

struct ble_set_past_params_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PAST_PARAMS_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Set periodic advertising sync transfer params status

esp_bd_addr_t bda
The remote device address

struct ble_set_perf_def_phy_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PREFERRED_DEFAULT_PHY_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate perf default phy set status

struct ble_set_perf_phy_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PREFERRED_PHY_COMPLETE_EVT.

Public Members

esp_bt_status_t status
Indicate perf phy set status

struct ble_set_rand_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT.

Public Members

esp_bt_status_t status
Indicate set static rand address operation success status

struct ble_update_conn_params_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT.
**Public Members**

`esp_bt_status_t status`
Indicate update connection parameters success status

`esp_bd_addr_t bda`
Bluetooh device address

`uint16_t min_int`
Min connection interval

`uint16_t max_int`
Max connection interval

`uint16_t latency`
Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3

`uint16_t conn_int`
Current connection interval

`uint16_t timeout`
Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80 Time = N * 10 msec

struct `ble_update_duplicate_exceptional_list_cmpl_evt_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT.

**Public Members**

`esp_bt_status_t status`
Indicate update duplicatescan exceptional list operations success status

`uint8_t subcode`
Define in esp_bt_duplicate_exceptional_subcode_type_t

`uint16_t length`
The length of device_info

`esp_duplicate_info_t device_info`
Device information, when subcode is ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_CLEAN, the value is invalid

struct `ble_update_whitelist_cmpl_evt_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT.

**Public Members**
Chapter 2. API Reference

*esp_bt_status_t* `status`
Indicate the add or remove whitelist operation success status

*esp_ble_wl_operation_t* `wl_operation`
The value is ESP_BLE_WHITELIST_ADD if add address to whitelist operation success, ESP_BLE_WHITELIST_REMOVE if remove address from the whitelist operation success

**Structures**

```c
struct esp_ble_adv_params_t
    Advertising parameters.
```

**Public Members**

```c
uint16_t adv_int_min
    Minimum advertising interval for undirected and low duty cycle directed advertising. Range: 0x0020 to 0x4000 Default: N = 0x0800 (1.28 second) Time = N * 0.625 msec Time Range: 20 ms to 10.24 sec
```

```c
uint16_t adv_int_max
    Maximum advertising interval for undirected and low duty cycle directed advertising. Range: 0x0020 to 0x4000 Default: N = 0x0800 (1.28 second) Time = N * 0.625 msec Time Range: 20 ms to 10.24 sec
```

```c
esp_ble_adv_type_t adv_type
    Advertising type
```

```c
esp_ble_addr_type_t own_addr_type
    Owner bluetooth device address type
```

```c
esp_bd_addr_t peer_addr
    Peer device bluetooth device address
```

```c
esp_ble_addr_type_t peer_addr_type
    Peer device bluetooth device address type, only support public address type and random address type
```

```c
esp_ble_adv_channel_t channel_map
    Advertising channel map
```

```c
esp_ble_adv_filter_t adv_filter_policy
    Advertising filter policy
```

```c
struct esp_ble_adv_data_t
    Advertising data content, according to “Supplement to the Bluetooth Core Specification”.
```

**Public Members**

```c
bool set_scan_rsp
    Set this advertising data as scan response or not
```
bool include_name
   Advertising data include device name or not

bool include_txpower
   Advertising data include TX power

int min_interval
   Advertising data show slave preferred connection min interval. The connection interval in the following
   manner: connIntervalmin = Conn_INTERVAL_MIN * 1.25 ms Conn_INTERVAL_MIN range: 0x0006 to 0xC80
   Value of 0xFFFF indicates no specific minimum. Values not defined above are reserved for future use.

int max_interval
   Advertising data show slave preferred connection max interval. The connection interval in the follow-
   ing manner: connIntervalmax = Conn_INTERVAL_MAX * 1.25 ms Conn_INTERVAL_MAX range: 0x0006 to
   0xC80 Conn_INTERVAL_MAX shall be equal to or greater than the Conn_INTERVAL_MIN. Value of 0xFFFF
   indicates no specific maximum. Values not defined above are reserved for future use.

int appearance
   External appearance of device

uint16_t manufacturer_len
   Manufacturer data length

uint8_t *p_manufacturer_data
   Manufacturer data point

uint16_t service_data_len
   Service data length

uint8_t *p_service_data
   Service data point

uint16_t service_uuid_len
   Service uuid length

uint8_t *p_service_uuid
   Service uuid array point

uint8_t flag
   Advertising flag of discovery mode, see BLE_ADV_DATA_FLAG detail

struct esp_ble_scan_params_t
   Ble scan parameters.

Public Members

   esp_ble_scan_type_t scan_type
      Scan type
**esp_ble_addr_type_t own_addr_type**

Owner address type

**esp_ble_scan_filter_t scan_filter_policy**

Scan filter policy

uint16_t *scan_interval*

Scan interval. This is defined as the time interval from when the Controller started its last LE scan until it begins the subsequent LE scan. Range: 0x0004 to 0x4000 Default: 0x0010 (10 ms) Time = N * 0.625 msec Time Range: 2.5 msec to 10.24 seconds

uint16_t *scan_window*

Scan window. The duration of the LE scan. LE_Scan_Window shall be less than or equal to LE_Scan_Interval Range: 0x0004 to 0x4000 Default: 0x0010 (10 ms) Time = N * 0.625 msec Time Range: 2.5 msec to 10240 msec

**esp_ble_scan_duplicate_t scan_duplicate**

The Scan Duplicates parameter controls whether the Link Layer should filter out duplicate advertising reports (BLE_SCAN_DUPLICATE_ENABLE) to the Host, or if the Link Layer should generate advertising reports for each packet received

**struct esp_gap_conn_params_t**

connection parameters information

**Public Members**

uint16_t *interval*

connection interval

uint16_t *latency*

Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3

uint16_t *timeout*

Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80 Time = N * 10 msec Time Range: 100 msec to 32 seconds

**struct esp_ble_conn_update_params_t**

Connection update parameters.

**Public Members**

**esp_bd_addr_t bda**

Bluetooth device address

uint16_t *min_int*

Min connection interval
Chapter 2. API Reference

```c
uint16_t max_int
Max connection interval

uint16_t latency
Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3

uint16_t timeout
Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80
Time = N * 10 msec Time Range: 100 msec to 32 seconds
```

```c
struct esp_ble_pkt_data_length_params_t
BLE pkt date length keys.

Public Members

uint16_t rx_len
pkt rx data length value

uint16_t tx_len
pkt tx data length value
```

```c
struct esp_ble_penc_keys_t
BLE encryption keys.

Public Members

esp_bt_octet16_t ltk
The long term key

esp_bt_octet8_t rand
The random number

uint16_t ediv
The ediv value

uint8_t sec_level
The security level of the security link

uint8_t key_size
The key size(7~16) of the security link
```

```c
struct esp_ble_pcsrk_keys_t
BLE CSRK keys.

Public Members
```
uint32_t counter
  The counter

esp_bt_octet16_t csrk
  The csrk key

uint8_t sec_level
  The security level

struct esp_ble_pid_keys_t
  BLE pid keys.

  **Public Members**

  esp_bt_octet16_t irk
    The irk value

  esp_ble_addr_type_t addr_type
    The address type

  esp_bd_addr_t static_addr
    The static address

struct esp_ble_lenc_keys_t
  BLEEncryption reproduction keys.

  **Public Members**

  esp_bt_octet16_t ltk
    The long term key

  uint16_t div
    The div value

  uint8_t key_size
    The key size of the security link

  uint8_t sec_level
    The security level of the security link

struct esp_ble_lcsrk_keys
  BLE SRK keys.

  **Public Members**
uint32_t counter
    The counter value

uint16_t div
    The div value

uint8_t sec_level
    The security level of the security link

esp_bt_octet16_t csrk
    The csrk key value

struct esp_ble_sec_keynotif_t
    Structure associated with ESP_KEY_NOTIF_EVT.

**Public Members**

esp_bd_addr_t bd_addr
    peer address

uint32_t passkey
    the numeric value for comparison. If just_works, do not show this number to UI

struct esp_ble_sec_req_t
    Structure of the security request.

**Public Members**

esp_bd_addr_t bd_addr
    peer address

struct esp_ble_bond_key_info_t
    struct type of the bond key information value

**Public Members**

esp_ble_key_mask_t key_mask
    the key mask to indicate which key is present

esp_ble_penc_keys_t penc_key
    received peer encryption key

esp_ble_pcsrk_keys_t pcsrk_key
    received peer device SRK
```
.esp_ble_pid_keys_t pid_key
peer device ID key

struct esp_ble_bond_dev_t
struct type of the bond device value

Public Members

.esp_bd_addr_t bd_addr
peer address

.esp_ble_bond_key_info_t bond_key
the bond key information

struct esp_ble_key_t
union type of the security key value

Public Members

.esp_bd_addr_t bd_addr
peer address

.esp_ble_key_type_t key_type
key type of the security link

.esp_ble_key_value_t p_key_value
the pointer to the key value

struct esp_ble_local_id_keys_t
structure type of the ble local id keys value

Public Members

.esp_bt_octet16_t ir
the 16 bits of the ir value

.esp_bt_octet16_t irk
the 16 bits of the ir key value

.esp_bt_octet16_t dhk
the 16 bits of the dh key value

struct esp_ble_local_oob_data_t
structure type of the ble local oob data value
```
Public Members

`esp_bt_octet16_t oob_c`
the 128 bits of confirmation value

`esp_bt_octet16_t oob_r`
the 128 bits of randomizer value

```c
struct esp_ble_auth_cmpl_t
Structure associated with ESP_AUTH_CMPL_EVT.
```

Public Members

`esp_bd_addr_t bd_addr`
BD address peer device.

`bool key_present`
Valid link key value in key element

`esp_link_key key`
Link key associated with peer device.

`uint8_t key_type`
The type of Link Key

`bool success`
TRUE of authentication succeeded, FALSE if failed.

`uint8_t fail_reason`
The HCI reason/error code for when success=FALSE

`esp_ble_addr_type_t addr_type`
Peer device address type

`esp_bt_dev_type_t dev_type`
Device type

`esp_ble_auth_req_t auth_mode`
authentication mode

```c
struct esp_ble_gap_ext_adv_params_t
ext adv parameters
```

Public Members

`esp_ble_ext_adv_type_mask_t type`
ext adv type
uint32_t interval_min
   ext adv minimum interval

uint32_t interval_max
   ext adv maximum interval

esp_ble_adv_channel_t channel_map
   ext adv channel map

esp_ble_addr_type_t own_addr_type
   ext adv own address type

esp_ble_addr_type_t peer_addr_type
   ext adv peer address type

esp_bd_addr_t peer_addr
   ext adv peer address

esp_ble_adv_filter_t filter_policy
   ext adv filter policy

int8_t tx_power
   ext adv tx power

esp_ble_gap_pri_phy_t primary_phy
   ext adv primary phy

uint8_t max_skip
   ext adv maximum skip

esp_ble_gap_phy_t secondary_phy
   ext adv secondary phy

uint8_t sid
   ext adv sid

bool scan_reqnotif
   ext adv scan request event notify

struct esp_ble_ext_scan_cfg_t
   ext scan config

Public Members

esp_ble_scan_type_t scan_type
   ext scan type
uint16_t `scan_interval`
    ext scan interval

uint16_t `scan_window`
    ext scan window

struct `esp_ble_ext_scan_params_t`
    ext scan parameters

**Public Members**

`esp_ble_addr_type_t own_addr_type`
    ext scan own address type

`esp_ble_scan_filter_t filter_policy`
    ext scan filter policy

`esp_ble_scan_duplicate_t scan_duplicate`
    ext scan duplicate scan

`esp_ble_ext_scan_cfg_mask_t cfg_mask`
    ext scan config mask

`esp_ble_ext_scan_cfg_t uncoded_cfg`
    ext scan uncoded config parameters

`esp_ble_ext_scan_cfg_t coded_cfg`
    ext scan coded config parameters

struct `esp_ble_gap_conn_params_t`
    create extend connection parameters

**Public Members**

uint16_t `scan_interval`
    init scan interval

uint16_t `scan_window`
    init scan window

uint16_t `interval_min`
    minimum interval

uint16_t `interval_max`
    maximum interval
uint16_t latency
   ext scan type

uint16_t supervision_timeout
   connection supervision timeout

uint16_t min_ce_len
   minimum ce length

uint16_t max_ce_len
   maximum ce length

struct esp_ble_gap_ext_adv_t
   extend adv enable parameters

Public Members

uint8_t instance
   advertising handle

int duration
   advertising duration

int max_events
   maximum number of extended advertising events

struct esp_ble_gap_periodic_adv_params_t
   periodic adv parameters

Public Members

uint16_t interval_min
   periodic advertising minimum interval

uint16_t interval_max
   periodic advertising maximum interval

uint8_t properties
   periodic advertising properties

struct esp_ble_gap_periodic_adv_sync_params_t
   periodic adv sync parameters

Public Members
\textit{esp\_ble\_gap\_sync\_t filter\_policy}

periodic advertising sync filter policy

uint8_t \texttt{sid}

periodic advertising sid

\textit{esp\_ble\_addr\_type\_t addr\_type}

periodic advertising address type

\textit{esp\_bd\_addr\_t addr}

periodic advertising address

uint16_t \texttt{skip}

the maximum number of periodic advertising events that can be skipped

uint16_t \texttt{sync\_timeout}

synchronization timeout

\textbf{Public Members}

\textit{esp\_ble\_gap\_adv\_type\_t event\_type}

extend advertising type

uint8_t \texttt{addr\_type}

extend advertising address type

\textit{esp\_bd\_addr\_t addr}

extend advertising address

\textit{esp\_ble\_gap\_pri\_phy\_t primary\_phy}

extend advertising primary phy

\textit{esp\_ble\_gap\_phy\_t secondly\_phy}

extend advertising secondary phy

uint8_t \texttt{sid}

extend advertising sid

uint8_t \texttt{tx\_power}

extend advertising tx power

int8_t \texttt{rssi}

extend advertising rssi
uint16_t per_adv_interval
   periodic advertising interval

uint8_t dir_addr_type
   direct address type

esp_bd_addr_t dir_addr
   direct address

esp_ble_gap_ext_adv_data_status_t data_status
   data type

uint8_t adv_data_len
   extend advertising data length

uint8_t adv_data[251]
   extend advertising data

struct esp_ble_gap_periodic_adv_report_t
   periodic adv report parameters

Public Members

uint16_t sync_handle
   periodic advertising train handle

uint8_t tx_power
   periodic advertising tx power

int8_t rssi
   periodic advertising rssi

esp_ble_gap_ext_adv_data_status_t data_status
   periodic advertising data type

uint8_t data_length
   periodic advertising data length

uint8_t data[251]
   periodic advertising data

struct esp_ble_gap_periodic_adv_sync_estab_t
   perodic adv sync establish parameters

Public Members
Chapter 2. API Reference

uint8_t status
    periodic advertising sync status

uint16_t sync_handle
    periodic advertising train handle

uint8_t sid
    periodic advertising sid

esp_ble_addr_type_t addr_type
    periodic advertising address type

esp_bd_addr_t adv_addr
    periodic advertising address

esp_ble_gap_phy_t adv_phy
    periodic advertising adv phy type

uint16_t period_adv_interval
    periodic advertising interval

uint8_t adv_clk_accuracy
    periodic advertising clock accuracy

struct esp_ble_gap_past_params_t
    periodic adv sync transfer parameters

**Public Members**

esp_ble_gap_past_mode_t mode
    periodic advertising sync transfer mode

uint16_t skip
    the number of periodic advertising packets that can be skipped

uint16_t sync_timeout
    synchronization timeout for the periodic advertising train

uint8_t cte_type
    periodic advertising sync transfer CET type

**Macros**

ESP_BLE_ADV_FLAG_LIMIT_DISC
    BLE_ADV_DATA_FLAG data flag bit definition used for advertising data flag.

ESP_BLE_ADV_FLAG_GEN_DISC

ESP_BLE_ADV_FLAG_BREDR_NOT_SPT

ESP_BLE_ADV_FLAG_DMT_CONTROLLER_SPT

ESP_BLE_ADV_FLAG_DMT_HOST_SPT

ESP_BLE_ADV_FLAG_NON_LIMIT_DISC

ESP_LE_KEY_NONE
relate to BTM_LE_KEY_xxx in stack/btm_api.h
No encryption key

ESP_LE_KEY_PENC
encryption key, encryption information of peer device

ESP_LE_KEY_PID
identity key of the peer device

ESP_LE_KEY_PCSRK
peer SRK

ESP_LE_KEY_PLK
Link key

ESP_LE_KEY_LLK
peer link key

ESP_LE_KEY_LENC
master role security information: div

ESP_LE_KEY_LID
master device ID key

ESP_LE_KEY_LCSRK
local CSRK has been deliver to peer

ESP_LE_AUTH_NO_BOND
relate to BTM_LE_AUTH_xxx in stack/btm_api.h
0 no bonding

ESP_LE_AUTH_BOND
1 << 0 device in the bonding with peer

ESP_LE_AUTH_REQ_MITM
1 << 2 man in the middle attack

ESP_LE_AUTH_REQ_BOND_MITM
0101 banding with man in the middle attack
ESP_LE_AUTH_REQ_SC_ONLY
1 << 3 secure connection

ESP_LE_AUTH_REQ_SC_BOND
1001 secure connection with band

ESP_LE_AUTH_REQ_SC_MITM
1100 secure conn with MITM

ESP_LE_AUTH_REQ_SC_MITM_BOND
1101 SC with MITM and Bonding

ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_DISABLE
authentication disable

ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_ENABLE
authentication enable

ESP_BLE_OOB_DISABLE
disbale the out of bond

ESP_BLE_OOB_ENABLE
enable the out of bond

ESP_IO_CAP_OUT
relate to BTM_IO_CAP_xxx in stack/btm_api.h
DisplayOnly

ESP_IO_CAP_IO
DisplayYesNo

ESP_IO_CAP_IN
KeyboardOnly

ESP_IO_CAP_NONE
NoInputNoOutput

ESP_IO_CAP_KBDISP
Keyboard display

ESP_BLE_APPEARANCE_UNKNOWN
relate to BTM_BLE_APPEARANCE_UNKNOWN in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_PHONE
relate to BTM_BLE_APPEARANCE_GENERIC_PHONE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_COMPUTER
relate to BTM_BLE_APPEARANCE_GENERIC_COMPUTER in stack/btm_ble_api.h
ESPEBLE_APPEARANCE_GENERIC_WATCH
relate to BTM_BLE_APPEARANCE_GENERIC_WATCH in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_SPORTS_WATCH
relate to BTM_BLE_APPEARANCE_SPORTS_WATCH in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_CLOCK
relate to BTM_BLE_APPEARANCE_GENERIC_CLOCK in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_DISPLAY
relate to BTM_BLE_APPEARANCE_GENERIC_DISPLAY in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_REMOTE
relate to BTM_BLE_APPEARANCE_GENERIC_REMOTE in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_EYEGGLASSES
relate to BTM_BLE_APPEARANCE_GENERIC_EYEGGLASSES in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_TAG
relate to BTM_BLE_APPEARANCE_GENERIC_TAG in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_KEYRING
relate to BTM_BLE_APPEARANCE_GENERIC_KEYRING in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_MEDIA_PLAYER
relate to BTM_BLE_APPEARANCE_GENERIC_MEDIA_PLAYER in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_BARCODE_SCANNER
relate to BTM_BLE_APPEARANCE_GENERIC_BARCODE_SCANNER in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_THERMOMETER
relate to BTM_BLE_APPEARANCE_GENERIC_THERMOMETER in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_THERMOMETER_EAR
relate to BTM_BLE_APPEARANCE_THERMOMETER_EAR in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_HEART_RATE
relate to BTM_BLE_APPEARANCE_GENERIC_HEART_RATE in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_HEART_RATE_BELT
relate to BTM_BLE_APPEARANCE_HEART_RATE_BELT in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_GENERIC_BLOOD_PRESSURE
relate to BTM_BLE_APPEARANCE_GENERIC_BLOOD_PRESSURE in stack/btm_ble_api.h

ESPEBLE_APPEARANCE_BLOOD_PRESSURE_ARM
relate to BTM_BLE_APPEARANCE_BLOOD_PRESSURE_ARM in stack/btm_ble_api.h
Chapter 2. API Reference

ESP_BLE_APPEARANCE_BLOOD_PRESSURE_WRIST
relate to BTM_BLE_APPEARANCE_BLOOD_PRESSURE_WRIST in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_HID
relate to BTM_BLE_APPEARANCE_GENERIC_HID in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_KEYBOARD
relate to BTM_BLE_APPEARANCE_HID_KEYBOARD in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_MOUSE
relate to BTM_BLE_APPEARANCE_HID_MOUSE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_JOYSTICK
relate to BTM_BLE_APPEARANCE_HID_JOYSTICK in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_GAMEPAD
relate to BTM_BLE_APPEARANCE_HID_GAMEPAD in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_DIGITIZER_TABLET
relate to BTM_BLE_APPEARANCE_HID_DIGITIZER_TABLET in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_CARD_READER
relate to BTM_BLE_APPEARANCE_HID_CARD_READER in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_DIGITAL_PEN
relate to BTM_BLE_APPEARANCE_HID_DIGITAL_PEN in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_HID_BARCODE_SCANNER
relate to BTM_BLE_APPEARANCE_HID_BARCODE_SCANNER in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_GLUCOSE
relate to BTM_BLE_APPEARANCE_GENERIC_GLUCOSE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_WALKING
relate to BTM_BLE_APPEARANCE_GENERIC_WALKING in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_WALKING_IN_SHOE
relate to BTM_BLE_APPEARANCE_WALKING_IN_SHOE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_WALKING_ON_SHOE
relate to BTM_BLE_APPEARANCE_WALKING_ON_SHOE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_WALKING_ON_HIP
relate to BTM_BLE_APPEARANCE_WALKING_ON_HIP in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_CYCLING
relate to BTM_BLE_APPEARANCE GENERIC_CYCLING in stack/btm_ble_api.h
ESP_BLE_APPEARANCE_CYCLING_COMPUTER
    relate to BTM_BLE_APPEARANCE_CYCLING_COMPUTER in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_CYCLING_SPEED
    relate to BTM_BLE_APPEARANCE_CYCLING_SPEED in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_CYCLING_CADENCE
    relate to BTM_BLE_APPEARANCE_CYCLING_CADENCE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_CYCLING_POWER
    relate to BTM_BLE_APPEARANCE_CYCLING_POWER in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_CYCLING_SPEED_CADENCE
    relate to BTM_BLE_APPEARANCE_CYCLING_SPEED_CADENCE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_PULSE_OXIMETER
    relate to BTM_BLE_APPEARANCE_GENERIC_PULSE_OXIMETER in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_PULSE_OXIMETER_FINGERTIP
    relate to BTM_BLE_APPEARANCE_PULSE_OXIMETER_FINGERTIP in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_PULSE_OXIMETER_WRIST
    relate to BTM_BLE_APPEARANCE_PULSE_OXIMETER_WRIST in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_WEIGHT
    relate to BTM_BLE_APPEARANCE_GENERIC_WEIGHT in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_PERSONAL_MOBILITY_DEVICE
    relate to BTM_BLE_APPEARANCE_GENERIC_PERSONAL_MOBILITY_DEVICE in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_POWERED_WHEELCHAIR
    relate to BTM_BLE_APPEARANCE_POWERED_WHEELCHAIR in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_MOBILITY_SCOOTER
    relate to BTM_BLE_APPEARANCE_MOBILITY_SCOOTER in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_CONTINUOUS_GLUCOSE_MONITOR
    relate to BTM_BLE_APPEARANCE_GENERIC_CONTINUOUS_GLUCOSE_MONITOR in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_INSULIN_PUMP
    relate to BTM_BLE_APPEARANCE_GENERIC_INSULIN_PUMP in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_INSULIN_PUMP_DURABLE_PUMP
    relate to BTM_BLE_APPEARANCE_INSULIN_PUMP_DURABLE_PUMP in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_INSULIN_PUMP_PATCH_PUMP
    relate to BTM_BLE_APPEARANCE_INSULIN_PUMP_PATCH_PUMP in stack/btm_ble_api.h
Chapter 2. API Reference

ESP_BLE_APPEARANCE_INSULIN_PEN
relate to BTM_BLE_APPEARANCE_INSULIN_PEN in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_MEDICATION_DELIVERY
relate to BTM_BLE_APPEARANCE_GENERIC_MEDICATION_DELIVERY in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_GENERIC_OUTDOOR_SPORTS
relate to BTM_BLE_APPEARANCE_GENERIC_OUTDOOR_SPORTS in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION
relate to BTM_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_AND_NAV
relate to BTM_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_AND_NAV in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD
relate to BTM_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD in stack/btm_ble_api.h

ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD_AND_NAV
relate to BTM_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD_AND_NAV in stack/btm_ble_api.h

ESP_GAP_BLE_CHANNELS_LEN
channel length

ESP_GAP_BLE_ADD_WHITELIST_COMPLETE_EVT
This is the old name, just for backwards compatibility.

ESP_BLE_ADV_DATA_LEN_MAX
Advertising data maximum length.

ESP_BLESCAN_RSP_DATA_LEN_MAX
Scan response data maximum length.

BLE_BIT (n)

ESP_BLE_GAP_SET_EXT_ADV_PROP_NONCONN_NONSCANNABLE_UNDIRECTED
Non-Connectable and Non-Scannable Undirected advertising

ESP_BLE_GAP_SET_EXT_ADV_PROP_CONNECTABLE
Connectable advertising

ESP_BLE_GAP_SET_EXT_ADV_PROP_SCANNABLE
Scannable advertising

ESP_BLE_GAP_SET_EXT_ADV_PROP_DIRECTED
Directed advertising
Chapter 2. API Reference

**ESP_BLE_GAP_SET_EXT_ADV_PROP_HD_DIRECTED**
High Duty Cycle Directed Connectable advertising (<= 3.75 ms Advertising Interval)

**ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY**
Use legacy advertising PDUs

**ESP_BLE_GAP_SET_EXT_ADV_PROP_ANON_ADV**
Omit advertiser’s address from all PDUs (“anonymous advertising”)

**ESP_BLE_GAP_SET_EXT_ADV_PROP_INCLUDE_TX_PWR**
Include TxPower in the extended header of the advertising PDU

**ESP_BLE_GAP_SET_EXT_ADV_PROP_MASK**
Reserved for future use If extended advertising PDU types are being used (bit 4 = 0) then: The advertisement shall not be both connectable and scannable. High duty cycle directed connectable advertising (<= 3.75 ms advertising interval) shall not be used (bit 3 = 0) ADV_IND

**ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_IND**
ADV_DIRECT_IND (low duty cycle)

**ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_LD_DIR**
ADV_DIRECT_IND (high duty cycle)

**ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_HD_DIR**
ADV_SCAN_IND

**ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_SCAN**
ADV_NONCONN_IND

**ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_NONCONN**

**ESP_BLE_GAP_PHY_1M**
Secondary Advertisement PHY is LE1M

**ESP_BLE_GAP_PHY_2M**
Secondary Advertisement PHY is LE2M

**ESP_BLE_GAP_PHY_CODED**
Secondary Advertisement PHY is LE Coded

**ESP_BLE_GAP_NO_PREFER_TRANSMIT_PHY**
No Prefer TX PHY supported by controller

**ESP_BLE_GAP_NO_PREFER_RECEIVE_PHY**
No Prefer RX PHY supported by controller

**ESP_BLE_GAP_PRI_PHY_1M**
Primary phy only support 1M and LE coded phy.
Primary Phy is LE1M
ESP_BLE_GAP_PRI_PHY_CODED
Primary Phy is LE CODED

ESP_BLE_GAP_PHY_1M_PREF_MASK
The Host prefers use the LE1M transmitter or receiver PHY

ESP_BLE_GAP_PHY_2M_PREF_MASK
The Host prefers use the LE2M transmitter or receiver PHY

ESP_BLE_GAP_PHY_CODED_PREF_MASK
The Host prefers use the LE CODED transmitter or receiver PHY

ESP_BLE_GAP_PHY_OPTIONS_NO_PREF
The Host has no preferred coding when transmitting on the LE Coded PHY

ESP_BLE_GAP_PHY_OPTIONS_PREF_S2_CODING
The Host prefers that S=2 coding be used when transmitting on the LE Coded PHY

ESP_BLE_GAP_PHY_OPTIONS_PREF_S8_CODING
The Host prefers that S=8 coding be used when transmitting on the LE Coded PHY

ESP_BLE_GAP_EXT_SCAN_CFG_UNCODE_MASK
Scan Advertisements on the LE1M PHY

ESP_BLE_GAP_EXT_SCAN_CFG_CODE_MASK
Scan advertisements on the LE coded PHY

ESP_BLE_GAP_EXT_ADV_DATA_COMPLETE
Advertising data.
extended advertising data complete

ESP_BLE_GAP_EXT_ADV_DATA_INCOMPLETE
extended advertising data incomplete

ESP_BLE_GAP_EXT_ADV_DATA_TRUNCATED
extended advertising data truncated mode

ESP_BLE_GAP_SYNC_POLICY_BY_ADV_INFO
Advertising SYNC policy.
sync policy by advertising info

ESP_BLE_GAP_SYNC_POLICY_BY_PERIODIC_LIST
periodic advertising sync policy

ESP_BLE_ADV_REPORT_EXT_ADV_IND
Advertising report.
advertising report with extended advertising indication type
Chapter 2. API Reference

ESP_BLE_ADV_REPORT_EXT_SCAN_IND
advertising report with extended scan indication type

ESP_BLE_ADV_REPORT_EXT_DIRECT_ADV
advertising report with extended direct advertising indication type

ESP_BLE_ADV_REPORT_EXT_SCAN_RSP
advertising report with extended scan response indication type Bluetooth 5.0, Vol 2, Part E, 7.7.65.13

ESP_BLE_LEGACY_ADV_TYPE_IND
advertising report with legacy advertising indication type

ESP_BLE_LEGACY_ADV_TYPE_DIRECT_IND
advertising report with legacy direct indication type

ESP_BLE_LEGACY_ADV_TYPE_SCAN_IND
advertising report with legacy scan indication type

ESP_BLE_LEGACY_ADV_TYPE_NONCON_IND
advertising report with legacy non connectable indication type

ESP_BLE_LEGACY_ADV_TYPE_SCAN_RSP_TO_ADV_IND
advertising report with legacy scan response indication type

ESP_BLE_LEGACY_ADV_TYPE_SCAN_RSP_TO_ADV_SCAN_IND
advertising report with legacy advertising with scan response indication type

EXT_ADV_TX_PWR_NO_PREFERENCE
Extend advertising tx power, range: [-127, +126] dBm.
host has no preference for tx power

ESP_BLE_GAP_PAST_MODE_NO_SYNC_EVT
Periodic advertising sync trans mode.
No attempt is made to sync and no periodic adv sync transfer received event

ESP_BLE_GAP_PAST_MODE_NO_REPORT_EVT
An periodic adv sync transfer received event and no periodic adv report events

ESP_BLE_GAP_PAST_MODE_DUP_FILTER_DISABLED
Periodic adv report events will be enabled with duplicate filtering disabled

ESP_BLE_GAP_PAST_MODE_DUP_FILTER_ENABLED
Periodic adv report events will be enabled with duplicate filtering enabled

Type Definitions

typedef uint8_t esp_ble_key_type_t
typedef uint8_t esp_ble_auth_req_t
combination of the above bit pattern

typedef uint8_t esp_ble_io_cap_t
combination of the io capability

typedef uint8_t esp_gap_ble_channels[ESP_GAP_BLE_CHANNELS_LEN]

typedef uint8_t esp_duplicate_info_t[ESP_BD_ADDR_LEN]

typedef uint16_t esp_ble_ext_adv_type_mask_t

typedef uint8_t esp_ble_gap_phy_t

typedef uint8_t esp_ble_gap_all_phys_t

typedef uint8_t esp_ble_gap_pri_phy_t

typedef uint8_t esp_ble_gap_phy_mask_t

typedef uint16_t esp_ble_gap_prefer_phy_options_t

typedef uint8_t esp_ble_ext_scan_cfg_mask_t

typedef uint8_t esp_ble_gap_ext_adv_data_status_t

typedef uint8_t esp_ble_gap_sync_t

typedef uint8_t esp_ble_gap_adv_type_t

typedef uint8_t esp_ble_gap_past_mode_t

typedef void (*esp_gap_ble_cb_t)(esp_gap_ble_cb_event_t event, esp_gap_ble_cb_param_t *param)
GAP callback function type.

Param event : Event type
Param param : Point to callback parameter, currently is union type

Enumerations

enum esp_gap_ble_cb_event_t
GAP BLE callback event type.

Values:

enumerator ESP_GAP_BLE_ADV_DATA_SET_COMPLETE_EVT
When advertising data set complete, the event comes
enumerator **ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT**
When scan response data set complete, the event comes

enumerator **ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT**
When scan parameters set complete, the event comes

enumerator **ESP_GAP_BLE_SCAN_RESULT_EVT**
When one scan result ready, the event comes each time

enumerator **ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT**
When raw scan response data set complete, the event comes

enumerator **ESP_GAP_BLE_ADV_DATA_RAW_SET_COMPLETE_EVT**
When raw advertising data set complete, the event comes

enumerator **ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT**
When raw scan response data set complete, the event comes

enumerator **ESP_GAP_BLE_ADV_START_COMPLETE_EVT**
When start advertising complete, the event comes

enumerator **ESP_GAP_BLE_SCAN_START_COMPLETE_EVT**
When start scan complete, the event comes

enumerator **ESP_GAP_BLE_AUTH_CMPL_EVT**
Authentication complete indication.

enumerator **ESP_GAP_BLE_KEY_EVT**
BLE key event for peer device keys

enumerator **ESP_GAP_BLE_SEC_REQ_EVT**
BLE security request

enumerator **ESP_GAP_BLE_PASSKEY_NOTIF_EVT**
passkey notification event

enumerator **ESP_GAP_BLE_PASSKEY_REQ_EVT**
passkey request event

enumerator **ESP_GAP_BLE_OOB_REQ_EVT**
OOB request event

enumerator **ESP_GAP_BLE_LOCAL_IR_EVT**
BLE local IR (identity Root 128-bit random static value used to generate Long Term Key) event

enumerator **ESP_GAP_BLE_LOCAL_ER_EVT**
BLE local ER (Encryption Root value used to generate identity resolving key) event

enumerator **ESP_GAP_BLE_NC_REQ_EVT**
Numeric Comparison request event
enumerator **ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT**  
    When stop adv complete, the event comes

enumerator **ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT**  
    When stop scan complete, the event comes

enumerator **ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT**  
    When set the static rand address complete, the event comes

enumerator **ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT**  
    When update connection parameters complete, the event comes

enumerator **ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT**  
    When set pkt length complete, the event comes

enumerator **ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT**  
    When Enable/disable privacy on the local device complete, the event comes

enumerator **ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT**  
    When remove the bond device complete, the event comes

enumerator **ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT**  
    When clear the bond device clear complete, the event comes

enumerator **ESP_GAP_BLE_GET_BOND_DEV_COMPLETE_EVT**  
    When get the bond device list complete, the event comes

enumerator **ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT**  
    When read the rssi complete, the event comes

enumerator **ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT**  
    When add or remove whitelist complete, the event comes

enumerator **ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT**  
    When update duplicate exceptional list complete, the event comes

enumerator **ESP_GAP_BLE_SET_CHANNELS_EVT**  
    When setting BLE channels complete, the event comes

enumerator **ESP_GAP_BLE_READ_PHY_COMPLETE_EVT**  
    when reading phy complete, this event comes

enumerator **ESP_GAP_BLE_SET.PREFERRED_DEFAULT_PHY_COMPLETE_EVT**  
    when preferred default phy complete, this event comes

enumerator **ESP_GAP_BLE_SET.PREFERRED_PHY_COMPLETE_EVT**  
    when preferred phy complete, this event comes
enumerator **ESP_GAP_BLE_EXT_ADV_SET_RAND_ADDR_COMPLETE_EVT**
when extended set random address complete, the event comes

enumerator **ESP_GAP_BLE_EXT_ADV_SET_PARAMS_COMPLETE_EVT**
when extended advertising parameter complete, the event comes

enumerator **ESP_GAP_BLE_EXT_ADV_DATA_SET_COMPLETE_EVT**
when extended advertising data complete, the event comes

enumerator **ESP_GAP_BLE_EXT_SCAN_RSP_DATA_SET_COMPLETE_EVT**
when extended scan response data complete, the event comes

enumerator **ESP_GAP_BLE_EXT_ADV_START_COMPLETE_EVT**
when extended advertising start complete, the event comes

enumerator **ESP_GAP_BLE_EXT_ADV_STOP_COMPLETE_EVT**
when extended advertising stop complete, the event comes

enumerator **ESP_GAP_BLE_EXT_ADV_SET_REMOVE_COMPLETE_EVT**
when extended advertising set remove complete, the event comes

enumerator **ESP_GAP_BLE_EXT_ADV_SET_CLEAR_COMPLETE_EVT**
when extended advertising set clear complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_SET_PARAMS_COMPLETE_EVT**
when periodic advertising parameter complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_DATA_SET_COMPLETE_EVT**
when periodic advertising data complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_START_COMPLETE_EVT**
when periodic advertising start complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_STOP_COMPLETE_EVT**
when periodic advertising stop complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_CREATE_SYNC_COMPLETE_EVT**
when periodic advertising create sync complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_SYNC_CANCEL_COMPLETE_EVT**
when extended advertising sync cancel complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_SYNC_TERMINATE_COMPLETE_EVT**
when extended advertising sync terminate complete, the event comes

enumerator **ESP_GAP_BLE_PERIODIC_ADV_ADD_DEV_COMPLETE_EVT**
when extended advertising add device complete, the event comes
enumerator ESP_GAP_BLE_PERIODIC_ADV_REMOVE_DEV_COMPLETE_EVT
when extended advertising remove device complete, the event comes

enumerator ESP_GAP_BLE_PERIODIC_ADV_CLEAR_DEV_COMPLETE_EVT
when extended advertising clear device, the event comes

enumerator ESP_GAP_BLE_SET_EXT_SCAN_PARAMS_COMPLETE_EVT
when extended scan parameter complete, the event comes

enumerator ESP_GAP_BLE_EXT_SCAN_START_COMPLETE_EVT
when extended scan start complete, the event comes

enumerator ESP_GAP_BLE_EXT_SCAN_STOP_COMPLETE_EVT
when extended scan stop complete, the event comes

enumerator ESP_GAP_BLE_PREFER_EXT_CONN_PARAMS_SET_COMPLETE_EVT
when extended prefer connection parameter set complete, the event comes

enumerator ESP_GAP_BLE_PHY_UPDATE_COMPLETE_EVT
when ble phy update complete, the event comes

enumerator ESP_GAP_BLE_EXT_ADV_REPORT_EVT
when extended advertising report complete, the event comes

enumerator ESP_GAP_BLE_SCAN_TIMEOUT_EVT
when scan timeout complete, the event comes

enumerator ESP_GAP_BLE_ADV_TERMINATED_EVT
when advertising terminate data complete, the event comes

enumerator ESP_GAP_BLE_SCAN_REQ_RECEIVED_EVT
when scan req received complete, the event comes

enumerator ESP_GAP_BLE_CHANNEL_SELECT_ALGORITHM_EVT
when channel select algorithm complete, the event comes

enumerator ESP_GAP_BLE_PERIODIC_ADV_REPORT_EVT
when periodic report advertising complete, the event comes

enumerator ESP_GAP_BLE_PERIODIC_ADV_SYNC_LOST_EVT
when periodic advertising sync lost complete, the event comes

enumerator ESP_GAP_BLE_PERIODIC_ADV_SYNC_ESTAB_EVT
when periodic advertising sync establish complete, the event comes

enumerator ESP_GAP_BLE_SC_OOB_REQ_EVT
Secure Connection OOB request event
enumerator `ESP_GAP_BLE_SC_CR_LOC_OOB_EVT`
Secure Connection create OOB data complete event

enumerator `ESP_GAP_BLE_GET_DEV_NAME_COMPLETE_EVT`
When getting BT device name complete, the event comes

enumerator `ESP_GAP_BLE_PERIODIC_ADV_RECV_ENABLE_COMPLETE_EVT`
when set periodic advertising receive enable complete, the event comes

enumerator `ESP_GAP_BLE_PERIODIC_ADV_SYNC_TRANS_COMPLETE_EVT`
when periodic advertising sync transfer complete, the event comes

enumerator `ESP_GAP_BLE_PERIODIC_ADV_SET_INFO_TRANS_COMPLETE_EVT`
when periodic advertising set info transfer complete, the event comes

enumerator `ESP_GAP_BLE_SET_PAST_PARAMS_COMPLETE_EVT`
when set periodic advertising sync transfer params complete, the event comes

enumerator `ESP_GAP_BLE_PERIODIC_ADV_SYNC_TRANS_RECV_EVT`
when periodic advertising sync transfer received, the event comes

enumerator `ESP_GAP_BLE_EVT_MAX`
when maximum advertising event complete, the event comes

enum `esp_ble_adv_data_type`
The type of advertising data (not adv_type)

Values:

enumerator `ESP_BLE_AD_TYPE_FLAG`

enumerator `ESP_BLE_AD_TYPE_16SRV_PART`

enumerator `ESP_BLE_AD_TYPE_16SRV_CMPL`

enumerator `ESP_BLE_AD_TYPE_32SRV_PART`

enumerator `ESP_BLE_AD_TYPE_32SRV_CMPL`

enumerator `ESP_BLE_AD_TYPE_128SRV_PART`

enumerator `ESP_BLE_AD_TYPE_128SRV_CMPL`

enumerator `ESP_BLE_AD_TYPE_NAME_SHORT`

enumerator `ESP_BLE_AD_TYPE_NAME_CMPL`

enumerator `ESP_BLE_AD_TYPE_TX_PWR`
enumerator ESP_BLE_AD_TYPE_DEV_CLASS
enumerator ESP_BLE_AD_TYPE_SM_TK
enumerator ESP_BLE_AD_TYPE_SM_OOB_FLAG
enumerator ESP_BLE_AD_TYPE_INT_RANGE
enumerator ESP_BLE_AD_TYPE_SOL_SRV_UUID
enumerator ESP_BLE_AD_TYPE_128_SOL_SRV_UUID
enumerator ESP_BLE_AD_TYPE_SERVICE_DATA
enumerator ESP_BLE_AD_TYPE_PUBLIC_TARGET
enumerator ESP_BLE_AD_TYPE_RANDOM_TARGET
enumerator ESP_BLE_AD_TYPE_APPEARANCE
enumerator ESP_BLE_AD_TYPE_ADV_INT
enumerator ESP_BLE_AD_TYPE_LE_DEV_ADDR
enumerator ESP_BLE_AD_TYPE_LE_ROLE
enumerator ESP_BLE_AD_TYPE_SPAIR_C256
enumerator ESP_BLE_AD_TYPE_SPAIR_R256
enumerator ESP_BLE_AD_TYPE_32_SOL_SRV_UUID
enumerator ESP_BLE_AD_TYPE_32SERVICE_DATA
enumerator ESP_BLE_AD_TYPE_128SERVICE_DATA
enumerator ESP_BLE_AD_TYPE_LE_SECURE_CONFIRM
enumerator ESP_BLE_AD_TYPE_LE_SECURE_RANDOM
enumerator ESP_BLE_AD_TYPE_URI
enumerator ESP_BLE_AD_TYPE_INDOOR_POSITION
enumerator ESP_BLE_AD_TYPE_TRANS_DISC_DATA
enumerator ESP_BLE_AD_TYPE_LE_SUPPORT_FEATURE
enumerator ESP_BLE_AD_TYPE_CHAN_MAP_UPDATE
enumerator ESP_BLE_AD_MANUFACTURER_SPECIFIC_TYPE

enum esp_ble_adv_type_t
   Advertising mode.
   
   Values:
   
   enumerator ADV_TYPE_IND
   enumerator ADV_TYPE_DIRECT_IND_HIGH
   enumerator ADV_TYPE_SCAN_IND
   enumerator ADV_TYPE_NONCONN_IND
   enumerator ADV_TYPE_DIRECT_IND_LOW

enum esp_ble_adv_channel_t
   Advertising channel mask.
   
   Values:
   
   enumerator ADV_CHNL_37
   enumerator ADV_CHNL_38
   enumerator ADV_CHNL_39
   enumerator ADV_CHNL_ALL

enum esp_ble_adv_filter_t
   Values:
   
   enumerator ADV_FILTER_ALLOW_SCAN_ANY_CON_ANY
      Allow both scan and connection requests from anyone.
   
   enumerator ADV_FILTER_ALLOW_SCAN_WLST_CON_ANY
      Allow both scan req from White List devices only and connection req from anyone.
   
   enumerator ADV_FILTER_ALLOW_SCAN_ANY_CON_WLST
      Allow both scan req from anyone and connection req from White List devices only.
   
   enumerator ADV_FILTER_ALLOW_SCAN_WLST_CON_WLST
      Allow scan and connection requests from White List devices only.
enum esp_ble_sec_act_t

Values:

enumerator ESP_BLE_SEC_ENCRYPT
relate to BTA_DM_BLE_SEC_ENCRYPT in bta/bta_api.h. If the device has already bonded, the stack will used Long Term Key (LTK) to encrypt with the remote device directly. Else if the device hasn’t bonded, the stack will used the default authentication request used the esp_ble_gap_set_security_param function set by the user.

enumerator ESP_BLE_SEC_ENCRYPT_NO_MITM
relate to BTA_DM_BLE_SEC_ENCRYPT_NO_MITM in bta/bta_api.h. If the device has been already bonded, the stack will check the LTK (Long Term Key) Whether the authentication request has been met, and if met, use the LTK to encrypt with the remote device directly, else re-pair with the remote device. Else if the device hasn’t been bonded, the stack will use NO MITM authentication request in the current link instead of using the authreq in the esp_ble_gap_set_security_param function set by the user.

enumerator ESP_BLE_SEC_ENCRYPT_MITM
relate to BTA_DM_BLE_SEC_ENCRYPT_MITM in bta/bta_api.h. If the device has been already bonded, the stack will check the LTK (Long Term Key) whether the authentication request has been met, and if met, use the LTK to encrypt with the remote device directly, else re-pair with the remote device. Else if the device hasn’t been bonded, the stack will use MITM authentication request in the current link instead of using the authreq in the esp_ble_gap_set_security_param function set by the user.

enum esp_ble_sm_param_t

Values:

enumerator ESP_BLE_SM_PASSKEY
Authentication requirements of local device

enumerator ESP_BLE_SM_AUTHEN_REQ_MODE
The IO capability of local device

enumerator ESP_BLE_SM_IOCAP_MODE
Initiator Key Distribution/Generation

enumerator ESP_BLE_SM_SET_INIT_KEY
Responder Key Distribution/Generation

enumerator ESP_BLE_SM_SET_RSP_KEY
Maximum Encryption key size to support

enumerator ESP_BLE_SM_MAX_KEY_SIZE
Minimum Encryption key size requirement from Peer

enumerator ESP_BLE_SM_MIN_KEY_SIZE
Set static Passkey

enumerator ESP_BLE_SM_SET_STATIC_PASSKEY
Reset static Passkey
enumerator **ESP_BLE_SM_CLEAR_STATIC_PASSKEY**
Accept only specified SMP Authentication requirement

enumerator **ESP_BLE_SM_ONLY_ACCEPT_SPECIFIED_SEC_AUTH**
Enable/Disable OOB support

enumerator **ESP_BLE_SM_OOB_SUPPORT**
App encryption key size

enumerator **ESP_BLE_APP_ENC_KEY_SIZE**
authentication max param

enumerator **ESP_BLE_SM_MAX_PARAM**

**enum esp_ble_scan_type_t**
Ble scan type.

*Values:*

enumerator **BLE_SCAN_TYPE_PASSIVE**
Passive scan

enumerator **BLE_SCAN_TYPE_ACTIVE**
Active scan

**enum esp_ble_scan_filter_t**
Ble scan filter type.

*Values:*

enumerator **BLE_SCAN_FILTER_ALLOW_ALL**
Accept all:
  1. advertisement packets except directed advertising packets not addressed to this device (default).

enumerator **BLE_SCAN_FILTER_ALLOW_ONLY_WLST**
Accept only:
  1. advertisement packets from devices where the advertiser’s address is in the White list.
  2. Directed advertising packets which are not addressed for this device shall be ignored.

enumerator **BLE_SCAN_FILTER_ALLOW_UND_RPA_DIR**
Accept all:
  1. undirected advertisement packets, and
  2. directed advertising packets where the initiator address is a resolvable private address, and
  3. directed advertising packets addressed to this device.

enumerator **BLE_SCAN_FILTER_ALLOW_WLIST_RPA_DIR**
Accept all:
  1. advertisement packets from devices where the advertiser’s address is in the White list, and
  2. directed advertising packets where the initiator address is a resolvable private address, and
  3. directed advertising packets addressed to this device.
enum esp_ble_scan_duplicate_t

Ble scan duplicate type.

Values:

enumerator BLE_SCAN_DUPLICATE_DISABLE
    the Link Layer should generate advertising reports to the host for each packet received

evernator BLE_SCAN_DUPLICATE_ENABLE
    the Link Layer should filter out duplicate advertising reports to the Host

evernator BLE_SCAN_DUPLICATE_MAX
    0x02 −0xFF, Reserved for future use

enum esp_gap_search_evt_t

Sub Event of ESP_GAP_BLE_SCAN_RESULT_EVT.

Values:

enumerator ESP_GAP_SEARCH_INQ_RES_EVT
    Inquiry result for a peer device.

evernator ESP_GAP_SEARCH_INQ_CMPL_EVT
    Inquiry complete.

evernator ESP_GAP_SEARCH_DISC_RES_EVT
    Discovery result for a peer device.

evernator ESP_GAP_SEARCH_DISC_BLE_RES_EVT
    Discovery result for BLE GATT based service on a peer device.

evernator ESP_GAP_SEARCH_DISC_CMPL_EVT
    Discovery complete.

evernator ESP_GAP_SEARCH_DI_DISC_CMPL_EVT
    Discovery complete.

evernator ESP_GAP_SEARCH_SEARCH_CANCEL_CMPL_EVT
    Search cancelled

evernator ESP_GAP_SEARCH_INQ_DISCARD_NUM_EVT
    The number of pkt discarded by flow control

enum esp_ble_evt_type_t

Ble scan result event type, to indicate the result is scan response or advertising data or other.

Values:

enumerator ESP_BLE_EVT_CONN_ADV
    Connectable undirected advertising (ADV_IND)
enumerator **ESP_BLE_EVT_CONN_DIR_ADV**
   Connectable directed advertising (ADV_DIRECT_IND)

enumerator **ESP_BLE_EVT_DISC_ADV**
   Scannable undirected advertising (ADV_SCAN_IND)

enumerator **ESP_BLE_EVT_NON_CONN_ADV**
   Non connectable undirected advertising (ADV_NONCONN_IND)

enumerator **ESP_BLE_EVT_SCAN_RSP**
   Scan Response (SCAN_RSP)

enum **esp_ble_wl_operation_t**

   *Values:*

   enumerator **ESP_BLE_WHITELIST_REMOVE**
      remove mac from whitelist

   enumerator **ESP_BLE_WHITELIST_ADD**
      add address to whitelist

   enumerator **ESP_BLE_WHITELIST_CLEAR**
      clear all device in whitelist

enum **esp_bt_duplicate_exceptional_subcode_type_t**

   *Values:*

   enumerator **ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_ADD**
      Add device info into duplicate scan exceptional list

   enumerator **ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_REMOVE**
      Remove device info from duplicate scan exceptional list

   enumerator **ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_CLEAN**
      Clean duplicate scan exceptional list

enum **esp_ble_duplicate_exceptional_info_type_t**

   *Values:*

   enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_ADV_ADDR**
      BLE advertising address, device info will be added into ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ADDR_LIST

   enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_MESH_LINK_ID**
      BLE mesh link ID, it is for BLE mesh, device info will be added into ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_LINK_ID_LIST

   enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_MESH_BEACON_TYPE**
      BLE mesh beacon AD type, the format is | Len | 0x2B | Beacon Type | Beacon Data |
enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_MESH_PROV_SRV_ADV**

BLE mesh provisioning service uuid, the format is |0x02|0x01|flags|0x03|0x03|0x1827| ... \*.

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_MESH_PROXY_SRV_ADV**

BLE mesh adv with proxy service uuid, the format is |0x02|0x01|flags|0x03|0x03|0x1828| ... \*.

**enum esp_duplicate_scan_exceptional_list_type_t**

**Values:**

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ADDR_LIST**

duplicate scan exceptional addr list

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_LINK_ID_LIST**

duplicate scan exceptional mesh link ID list

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_BEACON_TYPE_LIST**

duplicate scan exceptional mesh beacon type list

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_PROV_SRV_ADV_LIST**

duplicate scan exceptional mesh adv with provisioning service uuid

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_PROXY_SRV_ADV_LIST**

duplicate scan exceptional mesh adv with provisioning service uuid

enumerator **ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ALL_LIST**

duplicate scan exceptional all list

**GATT DEFINES**

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_gatt_defs.h

**Unions**

union **esp_gatt_rsp_t**

#include <esp_gatt_defs.h> GATT remote read request response type.

**Public Members**

```c
esp_gatt_value_t attr_value
```

Gatt attribute structure

```c
uint16_t handle
```

Gatt attribute handle
Structures

struct esp_gatt_id_t
    Gatt id, include uuid and instance id.

    Public Members

    esp_bt_uuid_t uuid
        UUID

    uint8_t inst_id
        Instance id

struct esp_gatt_srvc_id_t
    Gatt service id, include id (uuid and instance id) and primary flag.

    Public Members

    esp_gatt_id_t id
        Gatt id, include uuid and instance

    bool is_primary
        This service is primary or not

struct esp_attr_desc_t
    Attribute description (used to create database)

    Public Members

    uint16_t uuid_length
        UUID length

    uint8_t *uuid_p
        UUID value

    uint16_t perm
        Attribute permission

    uint16_t max_length
        Maximum length of the element

    uint16_t length
        Current length of the element

    uint8_t *value
        Element value array

struct esp_attr_control_t
    attribute auto response flag
Public Members

uint8_t auto_rsp
if auto_rsp set to ESP_GATT_RSP_BY_APP, means the response of Write/Read operation will by replied by application. if auto_rsp set to ESP_GATT_AUTO_RSP, means the response of Write/Read operation will be replied by GATT stack automatically.

struct esp_gatts_attr_db_t
attribute type added to the gatt server database

Public Members

esp_attr_control_t attr_control
The attribute control type

esp_attr_desc_t att_desc
The attribute type

struct esp_attr_value_t
set the attribute value type

Public Members

uint16_t attr_max_len
attribute max value length

uint16_t attr_len
attribute current value length

uint8_t *attr_value
the pointer to attribute value

struct esp_gatts_incl_svc_desc_t
Gatt includeservice entry element.

Public Members

uint16_t start_hdl
Gatt start handle value of included service

uint16_t end_hdl
Gatt end handle value of included service

uint16_t uuid
Gatt attribute value UUID of included service

struct esp_gatts_incl128_svc_desc_t
Gatt include 128 bit service entry element.
**Public Members**

```c
uint16_t start_hdl
    Gatt start handle value of included 128 bit service
```

```c
uint16_t end_hdl
    Gatt end handle value of included 128 bit service
```

```c
struct esp_gatt_value_t
    Gatt attribute value.
```

**Public Members**

```c
uint8_t value[ESP_GATT_MAX_ATTR_LEN]
    Gatt attribute value
```

```c
uint16_t handle
    Gatt attribute handle
```

```c
uint16_t offset
    Gatt attribute value offset
```

```c
uint16_t len
    Gatt attribute value length
```

```c
uint8_t auth_req
    Gatt authentication request
```

```c
struct esp_gatt_conn_params_t
    Connection parameters information.
```

**Public Members**

```c
uint16_t interval
    connection interval
```

```c
uint16_t latency
    Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3
```

```c
uint16_t timeout
    Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80
    Time = N * 10 msec Time Range: 100 msec to 32 seconds
```

```c
struct esp_gattc_multi_t
    read multiple attribute
```
Public Members

uint8_t num_attr
The number of the attribute

uint16_t handles[ESP_GATT_MAX_READ_MULTI_HANDLES]
The handles list

struct esp_gattc_db_elem_t
data base attribute element

Public Members

esp_gatt_db_attr_type_t type
The attribute type

uint16_t attribute_handle
The attribute handle, it’s valid for all of the type

uint16_t start_handle
The service start handle, it’s valid only when the type = ESP_GATT_DB_PRIMARY_SERVICE or ESP_GATT_DB_SECONDARY_SERVICE

uint16_t end_handle
The service end handle, it’s valid only when the type = ESP_GATT_DB_PRIMARY_SERVICE or ESP_GATT_DB_SECONDARY_SERVICE

esp_gatt_char_prop_t properties
The characteristic properties, it’s valid only when the type = ESP_GATT_DB_CHARACTERISTIC

esp_bt_uuid_t uuid
The attribute uuid, it’s valid for all of the type

struct esp_gattc_service_elem_tservice element

Public Members

bool is_primary
The service flag, true if the service is primary service, else is secondary service

uint16_t start_handle
The start handle of the service

uint16_t end_handle
The end handle of the service
**Chapter 2. API Reference**

```c
struct esp_gattc_char_elem_t
characteristic element

Public Members

uint16_t char_handle
    The characteristic handle

uint16_t uuid
    The characteristic uuid

struct esp_gattc_descr_elem_t
descriptor element

Public Members

uint16_t handle
    The characteristic descriptor handle

uint16_t uuid
    The characteristic descriptor uuid

struct esp_gattc_incl_svc_elem_t
include service element

Public Members

uint16_t handle
    The include service current attribute handle

uint16_t incl_srvc_s_handle
    The start handle of the service which has been included

uint16_t incl_srvc_e_handle
    The end handle of the service which has been included

uint16_t uuid
    The include service uuid
```
Chapter 2. API Reference

Macros

ESP_GATT_UUID_IMMEDIATE_ALERT_SVC
  All “ESP_GATT_UUID_xxx” is attribute types

ESP_GATT_UUID_LINK_LOSS_SVC

ESP_GATT_UUID_TX_POWER_SVC

ESP_GATT_UUID_CURRENT_TIME_SVC

ESP_GATT_UUID_REF_TIME_UPDATE_SVC

ESP_GATT_UUID_NEXT_DST_CHANGE_SVC

ESP_GATT_UUID_GLUCOSE_SVC

ESP_GATT_UUID_HEALTH_THERMOM_SVC

ESP_GATT_UUID_DEVICE_INFO_SVC

ESP_GATT_UUID_HEART_RATE_SVC

ESP_GATT_UUID_PHONE_ALERT_STATUS_SVC

ESP_GATT_UUID_BATTERY_SERVICE_SVC

ESP_GATT_UUID_BLOOD_PRESSURE_SVC

ESP_GATT_UUID_ALERT_NTF_SVC

ESP_GATT_UUID_HID_SVC

ESP_GATT_UUID_SCAN_PARAMETERS_SVC

ESP_GATT_UUID_RUNNING_SPEED_CADENCE_SVC

ESP_GATT_UUID_Automation_IO_SVC

ESP_GATT_UUID_CYCLING_SPEED_CADENCE_SVC

ESP_GATT_UUID_CYCLING_POWER_SVC

ESP_GATT_UUID_LOCATION_AND_NAVIGATION_SVC

ESP_GATT_UUID_ENVIRONMENTAL_SENSING_SVC
ESP_GATT_UUID_BODY_COMPOSITION
ESP_GATT_UUID_USER_DATA_SVC
ESP_GATT_UUID_WEIGHT_SCALE_SVC
ESP_GATT_UUID_BOND_MANAGEMENT_SVC
ESP_GATT_UUID_CONT_GLUCOSE_MONITOR_SVC
ESP_GATT_UUID_PRI_SERVICE
ESP_GATT_UUID_SEC_SERVICE
ESP_GATT_UUID_INCLUDE_SERVICE
ESP_GATT_UUID_CHAR_DECLARE
ESP_GATT_UUID_CHAR_EXT_PROP
ESP_GATT_UUID_CHAR_DESCRIPTION
ESP_GATT_UUID_CHAR_CLIENT_CONFIG
ESP_GATT_UUID_CHAR_SRVR_CONFIG
ESP_GATT_UUID_CHAR_PRESENT_FORMAT
ESP_GATT_UUID_CHAR_AGG_FORMAT
ESP_GATT_UUID_CHAR_VALID_RANGE
ESP_GATT_UUID_EXT_RPT_REF_DESCR
ESP_GATT_UUID_RPT_REF_DESCR
ESP_GATT_UUID_NUM_DIGITALS_DESCR
ESP_GATT_UUID_VALUE_TRIGGER_DESCR
ESP_GATT_UUID_ENV_SENSING_CONFIG_DESCR
ESP_GATT_UUID_ENV_SENSING_MEASUREMENT_DESCR
ESP_GATT_UUID_ENV_SENSING_TRIGGER_DESCR
ESP_GATT_UUID_TIME_TRIGGER_DESCR
ESP_GATT_UUID_GAP_DEVICE_NAME
ESP_GATT_UUID_GAP_ICON
ESP_GATT_UUID_GAP_PREF_CONN_PARAM
ESP_GATT_UUID_GAP_CENTRAL_ADDR_RESOL
ESP_GATT_UUID_GATT_SRV_CHGD
ESP_GATT_UUID_ALERT_LEVEL
ESP_GATT_UUID_TX_POWER_LEVEL
ESP_GATT_UUID_CURRENT_TIME
ESP_GATT_UUID_LOCAL_TIME_INFO
ESP_GATT_UUID_REF_TIME_INFO
ESP_GATT_UUID_NW_STATUS
ESP_GATT_UUID_NW_TRIGGER
ESP_GATT_UUID_ALERT_STATUS
ESP_GATT_UUID_RINGER_CP
ESP_GATT_UUID_RINGER_SETTING
ESP_GATT_UUID_GM_MEASUREMENT
ESP_GATT_UUID_GM_CONTEXT
ESP_GATT_UUID_GM_CONTROL_POINT
ESP_GATT_UUID_GM_FEATURE
ESP_GATT_UUID_SYSTEM_ID
ESP_GATT_UUID_MODEL_NUMBER_STR
ESP_GATT_UUID_SERIAL_NUMBER_STR
ESP_GATT_UUID_FW_VERSION_STR
ESP_GATT_UUID_HW_VERSION_STR
ESP_GATT_UUID_SW_VERSION_STR
ESP_GATT_UUID_MANU_NAME
ESP_GATT_UUID_IEEE_DATA
ESP_GATT_UUID_PNP_ID
ESP_GATT_UUID_HID_INFORMATION
ESP_GATT_UUID_HID_REPORT_MAP
ESP_GATT_UUID_HID_CONTROL_POINT
ESP_GATT_UUID_HID_REPORT
ESP_GATT_UUID_HID_PROTO_MODE
ESP_GATT_UUID_HID_BT_KB_INPUT
ESP_GATT_UUID_HID_BT_KB_OUTPUT
ESP_GATT_UUID_HID_BT_MOUSE_INPUT
ESP_GATT_HEART_RATE_MEAS
  Heart Rate Measurement.
ESP_GATT_BODY_SENSOR_LOCATION
  Body Sensor Location.
ESP_GATT_HEART_RATE_CNTL_POINT
  Heart Rate Control Point.
ESP_GATT_UUID_BATTERY_LEVEL
ESP_GATT_UUID_SC_CONTROL_POINT
ESP_GATT_UUID_SENSOR_LOCATION
ESP_GATT_UUID_RSC_MEASUREMENT
ESP_GATT_UUID_RSC_FEATURE
Chapter 2. API Reference

ESP_GATT_UUID_CSC_MEASUREMENT
ESP_GATT_UUID_CSC_FEATURE
ESP_GATT_UUID_SCAN_INT_WINDOW
ESP_GATT_UUID_SCAN_REFRESH
ESP_GATT_ILLEGAL_UUID
  GATT INVALID UUID.
ESP_GATT_ILLEGAL_HANDLE
  GATT INVALID HANDLE.
ESP_GATT_ATTR_HANDLE_MAX
  GATT attribute max handle.
ESP_GATT_MAX_READ_MULTI_HANDLES
ESP_GATT_PERM_READ
  Attribute permissions.
ESP_GATT_PERM_READ_ENCRYPTED
ESP_GATT_PERM_READ_ENC_MITM
ESP_GATT_PERM_WRITE
ESP_GATT_PERM_WRITE_ENCRYPTED
ESP_GATT_PERM_WRITE_ENC_MITM
ESP_GATT_PERM_WRITE_SIGNED
ESP_GATT_PERM_WRITE_SIGNED_MITM
ESP_GATT_PERM_READ_AUTHORIZATION
ESP_GATT_PERM_WRITE_AUTHORIZATION
ESP_GATT_PERM_ENCRYPT_KEY_SIZE (keysize)
ESP_GATT_CHAR_PROP_BIT_BROADCAST
ESP_GATT_CHAR_PROP_BIT_READ
Chapter 2. API Reference

ESP_GATT_CHAR_PROP_BIT_WRITE_NR
ESP_GATT_CHAR_PROP_BIT_WRITE
ESP_GATT_CHAR_PROP_BIT_NOTIFY
ESP_GATT_CHAR_PROP_BIT_INDICATE
ESP_GATT_CHAR_PROP_BIT_AUTH
ESP_GATT_CHAR_PROP_BIT_EXT_PROP

ESP_GATT_MAX_ATTR_LEN
GATT maximum attribute length.

ESP_GATT_RSP_BY_APP
ESP_GATT_AUTO_RSP
ESP_GATT_IF_NONE
If callback report gattc_if/gatts_if as this macro, means this event is not correspond to any app

Type Definitions
typedef uint16_t esp_gatt_perm_t
typedef uint8_t esp_gatt_char_prop_t
typedef uint8_t esp_gatt_if_t
Gatt interface type, different application on GATT client use different gatt_if

Enumerations
enum esp_gatt_prep_write_type
Attribute write data type from the client.
Values:

enumerator ESP_GATT_PREP_WRITE_CANCEL
Prepare write cancel

enumerator ESP_GATT_PREP_WRITE_EXEC
Prepare write execute

enum esp_gatt_status_t
GATT success code and error codes.
Values:
enumerator ESP_GATT_OK
enumerator ESP_GATT_INVALID_HANDLE
enumerator ESP_GATT_READ_NOT_PERMIT
enumerator ESP_GATT_WRITE_NOT_PERMIT
enumerator ESP_GATT_INVALID_PDU
enumerator ESP_GATT_INSUF_AUTHENTICATION
enumerator ESP_GATT_REQ_NOT_SUPPORTED
enumerator ESP_GATT_INVALID_OFFSET
enumerator ESP_GATT_INSUF_AUTHORIZATION
enumerator ESP_GATT_PREPARE_Q_FULL
enumerator ESP_GATT_NOT_FOUND
enumerator ESP_GATT_NOT_LONG
enumerator ESP_GATT_INSUF_KEY_SIZE
enumerator ESP_GATT_INVALID_ATTR_LEN
enumerator ESP_GATT_ERR_UNLIKELY
enumerator ESP_GATT_INSUF_ENCRYPTION
enumerator ESP_GATT_UNSUPPORT_GRP_TYPE
enumerator ESP_GATT_INSUF_RESOURCE
enumerator ESP_GATT_NO_RESOURCES
enumerator ESP_GATT_INTERNAL_ERROR
enumerator ESP_GATT_WRONG_STATE
enumerator ESP_GATT_DB_FULL
enumerator ESP_GATT_BUSY
enumerator ESP_GATT_ERROR
enumerator ESP_GATT_CMD_STARTED
enumerator ESP_GATT_ILLEGAL_PARAMETER
enumerator ESP_GATT_PENDING
enumerator ESP_GATT_AUTH_FAIL
enumerator ESP_GATT_MORE
enumerator ESP_GATT_INVALID_CFG
enumerator ESP_GATT_SERVICE_STARTED
enumerator ESP_GATT_ENCRYPTED_MITM
enumerator ESP_GATT_ENCRYPTED_NO_MITM
enumerator ESP_GATT_NOT_ENCRYPTED
enumerator ESP_GATT_CONGESTED
enumerator ESP_GATT_DUP_REG
enumerator ESP_GATT_ALREADY_OPEN
enumerator ESP_GATT_CANCEL
enumerator ESP_GATT_STACK_RSP
enumerator ESP_GATT_APP_RSP
enumerator ESP_GATT_CCC_CFG_ERR
enumerator ESP_GATT_PRC_IN_PROGRESS
enumerator ESP_GATT_OUT_OF_RANGE

e num esp_gatt_conn_reason_t
   Gatt Connection reason enum.
   Values:
enumerator **ESP_GATT_CONN_UNKNOWN**  
Gatt connection unknown

enumerator **ESP_GATT_CONN_L2C_FAILURE**  
General L2cap failure

enumerator **ESP_GATT_CONN_TIMEOUT**  
Connection timeout

enumerator **ESP_GATT_CONN_TERMINATE_PEER_USER**  
Connection terminate by peer user

enumerator **ESP_GATT_CONN_TERMINATE_LOCAL_HOST**  
Connection terminated by local host

enumerator **ESP_GATT_CONN_FAIL_ESTABLISH**  
Connection fail to establish

enumerator **ESP_GATT_CONN_LMP_TIMEOUT**  
Connection fail for LMP response tout

enumerator **ESP_GATT_CONN_CONN_CANCEL**  
L2CAP connection cancelled

enumerator **ESP_GATT_CONN_NONE**  
No connection to cancel

enum **esp_gatt_auth_req_t**  
Gatt authentication request type.

*Values:*

enumerator **ESP_GATT_AUTH_REQ_NONE**

enumerator **ESP_GATT_AUTH_REQ_NO_MITM**

enumerator **ESP_GATT_AUTH_REQ_MITM**

enumerator **ESP_GATT_AUTH_REQ_SIGNED_NO_MITM**

enumerator **ESP_GATT_AUTH_REQ_SIGNED_MITM**

enum **esp_service_source_t**  
*Values:*

enumerator **ESP_GATT_SERVICE_FROM_REMOTE_DEVICE**

enumerator **ESP_GATT_SERVICE_FROM_NVS_FLASH**
enumerator ESP_GATT_SERVICE_FROM_UNKNOWN

denum esp_gatt_write_type_t
  Gatt write type.
  
  Values:
  
  enumerator ESP_GATT_WRITE_TYPE_NO_RSP
    Gatt write attribute need no response
  
  enumerator ESP_GATT_WRITE_TYPE_RSP
    Gatt write attribute need remote response

enum esp_gatt_db_attr_type_t
  the type of attribute element
  
  Values:
  
  enumerator ESP_GATT_DB_PRIMARY_SERVICE
    Gattc primary service attribute type in the cache
  
  enumerator ESP_GATT_DB_SECONDARY_SERVICE
    Gattc secondary service attribute type in the cache
  
  enumerator ESP_GATT_DB_CHARACTERISTIC
    Gattc characteristic attribute type in the cache
  
  enumerator ESP_GATT_DB_DESCRIPTOR
    Gattc characteristic descriptor attribute type in the cache
  
  enumerator ESP_GATT_DB_INCLUDED_SERVICE
    Gattc include service attribute type in the cache
  
  enumerator ESP_GATT_DB_ALL
    Gattc all the attribute (primary service & secondary service & include service & char & descriptor) type in the cache

**GATT SERVER API**

**Application Example** Check bluetooth/bluedroid/ble folder in ESP-IDF examples, which contains the following demos and their tutorials:

- This is a GATT server demo and its tutorial. This demo creates a GATT service with an attribute table, which releases the user from adding attributes one by one. This is the recommended method of adding attributes.
  - [ble/gatt_server_service_table](https://github.com/espressif/esp-idf/tree/master/examples/bluetooth/bluedroid/ble/gatt_server_service_table)
  - [GATT Server Service Table Example Walkthrough](https://github.com/espressif/esp-idf/tree/master/examples/bluetooth/bluedroid/ble/gatt_server_service_table)

- This is a GATT server demo and its tutorial. This demo creates a GATT service by adding attributes one by one as defined by Bluedroid. The recommended method of adding attributes is presented in example above.
  - [bluetooth/bluedroid/ble/gatt_server](https://github.com/espressif/esp-idf/tree/master/examples/bluetooth/bluedroid/ble/gatt_server)
  - [GATT Server Example Walkthrough](https://github.com/espressif/esp-idf/tree/master/examples/bluetooth/bluedroid/ble/gatt_server)

- This is a BLE SPP-Like demo. This demo, which acts as a GATT server, can receive data from UART and then send the data to the peer device automatically.
  - [ble/ble_spp_server](https://github.com/espressif/esp-idf/tree/master/examples/bluetooth/bluedroid/ble/ble_spp_server)
Chapter 2. API Reference

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_gatts_api.h

Functions

`esp_err_t esp_ble_gatts_register_callback (esp_gatts_cb_t callback)`

This function is called to register application callbacks with BTA GATTS module.

Returns

- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gatts_app_register (uint16_t app_id)`

This function is called to register application identifier.

Returns

- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gatts_app_unregister (esp_gatt_if_t gatts_if)`

unregister with GATT Server.

Parameters

- `gatts_if` - [in] GATT server access interface

Returns

- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gatts_create_service (esp_gatt_if_t gatts_if, esp_gatt_srvc_id_t *service_id, uint16_t num_handle)`

Create a service. When service creation is done, a callback event ESP_GATTS_CREATE_EVT is called to report status and service ID to the profile. The service ID obtained in the callback function needs to be used when adding included service and characteristics/descriptors into the service.

Parameters

- `gatts_if` - [in] GATT server access interface
- `service_id` - [in] service ID.
- `num_handle` - [in] number of handle requested for this service.

Returns

- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gatts_create_attr_tab (const esp_gatts_attr_db_t *gatts_attr_db, esp_gatt_if_t gatts_if, uint16_t max_nb_attr, uint8_t srvc_inst_id)`

Create a service attribute tab.

Parameters

- `gatts_attr_db` - [in] the pointer to the service attr tab
- `gatts_if` - [in] GATT server access interface
- `max_nb_attr` - [in] the number of attribute to be added to the service database.
- `srvc_inst_id` - [in] the instance id of the service

Returns

- ESP_OK : success
- other : failed

`esp_err_t esp_ble_gatts_add_included_service (uint16_t service_handle, uint16_t included_service_handle)`

This function is called to add an included service. This function have to be called between ‘esp_ble_gatts_create_service’ and ‘esp_ble_gatts_add_char’. After included service is included, a callback event ESP_GATTS_ADD_INCL_SRVC_EVT is reported the included service ID.
Parameters
- `service_handle` [in] service handle to which this included service is to be added.
- `included_service_handle` [in] the service ID to be included.

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gatts_add_char(uint16_t service_handle, esp_bt_uuid_t *char_uuid, esp_gatt_perm_t perm, esp_gatt_char_prop_t property, esp_attr_value_t *char_val, esp_attr_control_t *control)
```

This function is called to add a characteristic into a service.

Parameters
- `service_handle` [in] service handle to which this included service is to be added.
- `char_uuid` [in]: Characteristic UUID.
- `perm` [in]: Characteristic value declaration attribute permission.
- `property` [in]: Characteristic Properties
- `char_val` [in]: Characteristic value
- `control` [in]: attribute response control byte

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gatts_add_char_descr(uint16_t service_handle, esp_bt_uuid_t *descr_uuid, esp_gatt_perm_t perm, esp_attr_value_t *char_descr_val, esp_attr_control_t *control)
```

This function is called to add characteristic descriptor. When it’s done, a callback event `ESP_GATTS_ADD_DESCR_EVT` is called to report the status and an ID number for this descriptor.

Parameters
- `service_handle` [in] service handle to which this characteristic descriptor is to be added.
- `descr_uuid` [in]: descriptor UUID.
- `perm` [in]: descriptor access permission.
- `char_descr_val` [in]: Characteristic descriptor value
- `control` [in]: attribute response control byte

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gatts_delete_service(uint16_t service_handle)
```

This function is called to delete a service. When this is done, a callback event `ESP_GATTS_DELETE_EVT` is report with the status.

Parameters `service_handle` [in] service_handle to be deleted.

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gatts_start_service(uint16_t service_handle)
```

This function is called to start a service.

Parameters `service_handle` [in] the service handle to be started.

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gatts_stop_service(uint16_t service_handle)
```

This function is called to stop a service.

Parameters `service_handle` [in] - service to be topped.

Returns
**esp_err_t esp_ble_gatts_send_indicate**

Send indicate or notify to GATT client. Set param need_confirm as false will send notification, otherwise indication. Note: the size of indicate or notify data need less than MTU size, see `esp_ble_gattc_send_mtu_req`.

**Parameters**
- `gatts_if` [in] GATT server access interface
- `conn_id` [in] - connection id to indicate.
- `attr_handle` [in] - attribute handle to indicate.
- `value_len` [in] - indicate value length.
- `value` [in] value to indicate.
- `need_confirm` [in] - Whether a confirmation is required. false sends a GATT notification, true sends a GATT indication.

**Returns**
- ESP_OK : success
- other : failed

**esp_err_t esp_ble_gatts_send_response**

This function is called to send a response to a request.

**Parameters**
- `gatts_if` [in] GATT server access interface
- `trans_id` [in] - transfer id
- `status` [in] - response status

**Returns**
- ESP_OK : success
- other : failed

**esp_err_t esp_ble_gatts_set_attr_value**

This function is called to set the attribute value by the application.

**Parameters**
- `attr_handle` [in] the attribute handle which to be set
- `length` [in] the value length
- `value` [in] the pointer to the attribute value

**Returns**
- ESP_OK : success
- other : failed

**esp_gatt_status_t esp_ble_gatts_get_attr_value**

Retrieve attribute value.

**Parameters**
- `attr_handle` [in] Attribute handle.
- `length` [out] pointer to the attribute value length
- `value` [out] Pointer to attribute value payload, the value cannot be modified by user

**Returns**
- ESP_GATT_OK : success
- other : failed

**esp_err_t esp_ble_gatts_open**

Open a direct open connection or add a background auto connection.

**Parameters**
• **gatts_if** - [in] GATT server access interface
• **remote_bda** - [in] remote device bluetooth device address.
• **is_direct** - [in] direct connection or background auto connection

**Returns**

• ESP_OK : success
• other : failed

```c
esp_err_t esp_ble_gatts_close(esp_gatt_if_t gatts_if, uint16_t conn_id)
```

Close a connection a remote device.

**Parameters**

• **gatts_if** - [in] GATT server access interface
• **conn_id** - [in] connection ID to be closed.

**Returns**

• ESP_OK : success
• other : failed

```c
esp_err_t esp_ble_gatts_send_service_change_indication(esp_gatt_if_t gatts_if,
                                                     esp_bd_addr_t remote_bda)
```

Send service change indication.

**Parameters**

• **gatts_if** - [in] GATT server access interface
• **remote_bda** - [in] remote device bluetooth device address. If remote_bda is NULL then it will send service change indication to all the connected devices and if not then to a specific device.

**Returns**

• ESP_OK : success
• other : failed

```c
esp_err_t esp_ble_gatts_show_local_database(void)
```

Print local database (GATT service table)

**Returns**

• ESP_OK : success
• other : failed

**Unions**

```c
union esp_ble_gatts_cb_param_t
```

# include <esp_gatts_api.h> Gatt server callback parameters union.

**Public Members**

struct esp_ble_gatts_cb_param_t::gatts_reg_evt_param reg

Gatt server callback param of ESP_GATTS_REG_EVT

struct esp_ble_gatts_cb_param_t::gatts_read_evt_param read

Gatt server callback param of ESP_GATTS_READ_EVT

struct esp_ble_gatts_cb_param_t::gatts_write_evt_param write

Gatt server callback param of ESP_GATTS_WRITE_EVT

struct esp_ble_gatts_cb_param_t::gatts_exec_write_evt_param exec_write

Gatt server callback param of ESP_GATTS_EXEC_WRITE_EVT
struct esp_ble_gatts_cb_param_t::gatts_mtu_evt_param mtu
     Gatt server callback param of ESP_GATTS_MTU_EVT

struct esp_ble_gatts_cb_param_t::gatts_conf_evt_param conf
     Gatt server callback param of ESP_GATTS_CONF_EVT (confirm)

struct esp_ble_gatts_cb_param_t::gatts_create_evt_param create
     Gatt server callback param of ESP_GATTS_CREATE_EVT

struct esp_ble_gatts_cb_param_t::gatts_add_incl_srvc_evt_param add_incl_srvc
     Gatt server callback param of ESP_GATTS_ADD_INCL_SRVC_EVT

struct esp_ble_gatts_cb_param_t::gatts_add_char_evt_param add_char
     Gatt server callback param of ESP_GATTS_ADD_CHAR_EVT

struct esp_ble_gatts_cb_param_t::gatts_add_char_descr_evt_param add_char_descr
     Gatt server callback param of ESP_GATTS_ADD_CHAR_DESCR_EVT

struct esp_ble_gatts_cb_param_t::gatts_delete_evt_param del
     Gatt server callback param of ESP_GATTS_DELETE_EVT

struct esp_ble_gatts_cb_param_t::gatts_start_evt_param start
     Gatt server callback param of ESP_GATTS_START_EVT

struct esp_ble_gatts_cb_param_t::gatts_stop_evt_param stop
     Gatt server callback param of ESP_GATTS_STOP_EVT

struct esp_ble_gatts_cb_param_t::gatts_connect_evt_param connect
     Gatt server callback param of ESP_GATTS_CONNECT_EVT

struct esp_ble_gatts_cb_param_t::gatts_disconnect_evt_param disconnect
     Gatt server callback param of ESP_GATTS_DISCONNECT_EVT

struct esp_ble_gatts_cb_param_t::gatts_open_evt_param open
     Gatt server callback param of ESP_GATTS_OPEN_EVT

struct esp_ble_gatts_cb_param_t::gatts_cancel_open_evt_param cancel_open
     Gatt server callback param of ESP_GATTS_CANCEL_OPEN_EVT

struct esp_ble_gatts_cb_param_t::gatts_close_evt_param close
     Gatt server callback param of ESP_GATTS_CLOSE_EVT

struct esp_ble_gatts_cb_param_t::gatts_congest_evt_param congest
     Gatt server callback param of ESP_GATTS_CONGEST_EVT

struct esp_ble_gatts_cb_param_t::gatts_rsp_evt_param rsp
     Gatt server callback param of ESP_GATTS_RESPONSE_EVT
struct esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt_param add_attr_tab
Gatt server callback param of ESP_GATTS_CREAT_ATTR_TAB_EVT

struct esp_ble_gatts_cb_param_t::gatts_set_attr_val_evt_param set_attr_val
Gatt server callback param of ESP_GATTS_SET_ATTR_VAL_EVT

struct esp_ble_gatts_cb_param_t::gatts_send_service_change_evt_param service_change
Gatt server callback param of ESP_GATTS_SEND_SERVICE_CHANGE_EVT

struct gatts_add_attr_tab_evt_param
#include <esp_gatts_api.h> ESP_GATTS_CREAT_ATTR_TAB_EVT.

Public Members

esp_gatt_status_t status
Operation status

esp_bt_uuid_t svc_uuid
Service uuid type

uint8_t svc_inst_id
Service id

uint16_t num_handle
The number of the attribute handle to be added to the gatts database

uint16_t *handles
The number to the handles

struct gatts_add_char_descr_evt_param
#include <esp_gatts_api.h> ESP_GATTS_ADD_CHAR_DESCR_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t attr_handle
Descriptor attribute handle

uint16_t service_handle
Service attribute handle

esp_bt_uuid_t descr_uuid
Characteristic descriptor uuid

struct gatts_add_char_evt_param
#include <esp_gatts_api.h> ESP_GATTS_ADD_CHAR_EVT.
Public Members

\textbf{esp\_gatt\_status\_t \texttt{status}}

Operation status

\textbf{uint16\_t \texttt{attr\_handle}}

Characteristic attribute handle

\textbf{uint16\_t \texttt{service\_handle}}

Service attribute handle

\textbf{esp\_bt\_uuid\_t \texttt{char\_uuid}}

Characteristic uuid

\textbf{struct \texttt{gatts\_add\_incl\_srvc\_evt\_param}}

#include <esp\_gatts\_api.h> ESP\_GATTS\_ADD\_INCL\_SRVC\_EVT.

Public Members

\textbf{esp\_gatt\_status\_t \texttt{status}}

Operation status

\textbf{uint16\_t \texttt{attr\_handle}}

 Included service attribute handle

\textbf{uint16\_t \texttt{service\_handle}}

Service attribute handle

\textbf{struct \texttt{gatts\_cancel\_open\_evt\_param}}

#include <esp\_gatts\_api.h> ESP\_GATTS\_CANCEL\_OPEN\_EVT.

Public Members

\textbf{esp\_gatt\_status\_t \texttt{status}}

Operation status

\textbf{struct \texttt{gatts\_close\_evt\_param}}

#include <esp\_gatts\_api.h> ESP\_GATTS\_CLOSE\_EVT.

Public Members

\textbf{esp\_gatt\_status\_t \texttt{status}}

Operation status

\textbf{uint16\_t \texttt{conn\_id}}

Connection id
struct `gatts_conf_evt_param`

```
#include <esp_gatts_api.h> ESP_GATTS_CONF_EVT.
```

**Public Members**

- `esp_gatt_status_t status`
  - Operation status
- `uint16_t conn_id`
  - Connection id
- `uint16_t handle`
  - Attribute handle
- `uint16_t len`
  - The indication or notification value length, len is valid when send notification or indication failed
- `uint8_t* value`
  - The indication or notification value, value is valid when send notification or indication failed

struct `gatts_congest_evt_param`

```
#include <esp_gatts_api.h> ESP_GATTS_CONGEST_EVT
ESP_GATTS_LISTEN_EVT
```

**Public Members**

- `uint16_t conn_id`
  - Connection id
- `bool congested`
  - Congested or not

struct `gatts_connect_evt_param`

```
#include <esp_gatts_api.h> ESP_GATTS_CONNECT_EVT.
```

**Public Members**

- `uint16_t conn_id`
  - Connection id
- `uint8_t link_role`
  - Link role: master role = 0; slave role = 1
- `esp_bd_addr_t remote_bda`
  - Remote bluetooth device address
**Chapter 2. API Reference**

```c
esp_gatt_conn_params_t conn_params
 current Connection parameters

esp_ble_addr_type_t ble_addr_type
 Remote BLE device address type

uint16_t conn_handle
 HCI connection handle
```

```c
struct gatts_create_evt_param
 #include <esp_gatts_api.h> ESP_GATTS_UNREG_EVT.
 ESP_GATTS_CREATE_EVT
```

**Public Members**

```c
esp_gatt_status_t status
 Operation status

uint16_t service_handle
 Service attribute handle

esp_gatt_srvc_id_t service_id
 Service id, include service uuid and other information
```

```c
struct gatts_delete_evt_param
 #include <esp_gatts_api.h> ESP_GATTS_DELETE_EVT.
```

**Public Members**

```c
esp_gatt_status_t status
 Operation status

uint16_t service_handle
 Service attribute handle
```

```c
struct gatts_disconnect_evt_param
 #include <esp_gatts_api.h> ESP_GATTS_DISCONNECT_EVT.
```

**Public Members**

```c
uint16_t conn_id
 Connection id

esp_bd_addr_t remote_bda
 Remote bluetooth device address
```
esp_gatt_conn_reason_t reason
  Indicate the reason of disconnection

struct gatts_exec_write_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_EXEC_WRITE_EVT.

Public Members

  uint16_t conn_id
  Connection id

  uint32_t trans_id
  Transfer id

  esp_bd_addr_t bda
  The bluetooth device address which been written

  uint8_t exec_write_flag
  Execute write flag

struct gatts_mtu_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_MTU_EVT.

Public Members

  uint16_t conn_id
  Connection id

  uint16_t mtu
  MTU size

struct gatts_open_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_OPEN_EVT.

Public Members

  esp_gatt_status_t status
  Operation status

struct gatts_read_evt_param
  #include <esp_gatts_api.h> ESP_GATTS_READ_EVT.

Public Members

  uint16_t conn_id
  Connection id
uint32_t `trans_id`
Transfer id

`esp_bd_addr_t bda`
The bluetooth device address which been read

uint16_t `handle`
The attribute handle

uint16_t `offset`
Offset of the value, if the value is too long

bool `is_long`
The value is too long or not

bool `need_rsp`
The read operation need to do response

struct `gatts_reg_evt_param`
#include <esp_gatts_api.h> ESP_GATTS_REG_EVT.

**Public Members**

`esp_gatt_status_t status`
Operation status

uint16_t `app_id`
Application id which input in register API

struct `gatts_rsp_evt_param`
#include <esp_gatts_api.h> ESP_GATTS_RESPONSE_EVT.

**Public Members**

`esp_gatt_status_t status`
Operation status

uint16_t `handle`
Attribute handle which send response

struct `gatts_send_service_change_evt_param`
#include <esp_gatts_api.h> ESP_GATTS_SEND_SERVICE_CHANGE_EVT.

**Public Members**
struct gatts_set_attr_val_evt_param
#include <esp_gatts_api.h> ESP_GATTS_SET_ATTR_VAL_EVT.

Public Members

uint16_t svrc_handle
The service handle

uint16_t attr_handle
The attribute handle

esp_gatt_status_t status
Operation status

struct gatts_start_evt_param
#include <esp_gatts_api.h> ESP_GATTS_START_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t service_handle
Service attribute handle

struct gatts_stop_evt_param
#include <esp_gatts_api.h> ESP_GATTS_STOP_EVT.

Public Members

esp_gatt_status_t status
Operation status

uint16_t service_handle
Service attribute handle

struct gatts_write_evt_param
#include <esp_gatts_api.h> ESP_GATTS_WRITE_EVT.

Public Members

uint16_t conn_id
Connection id
uint32_t trans_id
    Transfer id

esp_bd_addr_t bda
    The bluetooth device address which been written

uint16_t handle
    The attribute handle

uint16_t offset
    Offset of the value, if the value is too long

bool need_rsp
    The write operation need to do response

bool is_prep
    This write operation is prepare write

uint16_t len
    The write attribute value length

uint8_t* value
    The write attribute value

Macros

ESP_GATT_PREP_WRITE_CANCEL
    Prepare write flag to indicate cancel prepare write

ESP_GATT_PREP_WRITE_EXEC
    Prepare write flag to indicate execute prepare write

Type Definitions

typedef void (*esp_gatts_cb_t)(esp_gatts_cb_event_t event, esp_gatt_if_t gatts_if, esp_ble_gatts_cb_param_t *param)
    GATT Server callback function type.

    Param event : Event type
    Param gatts_if : GATT server access interface, normally different gatts_if correspond to different profile
    Param param : Point to callback parameter, currently is union type

Enumerations

enum esp_gatts_cb_event_t
    GATT Server callback function events.

    Values:

    enumerator ESP_GATTS_REG_EVT
        When register application id, the event comes
enumerator **ESP_GATT_READ_EVT**  
When gatt client request read operation, the event comes

enumerator **ESP_GATT_WRITE_EVT**  
When gatt client request write operation, the event comes

enumerator **ESP_GATT_EXEC_WRITE_EVT**  
When gatt client request execute write, the event comes

enumerator **ESP_GATT_MTU_EVT**  
When set mtu complete, the event comes

enumerator **ESP_GATT_CONF_EVT**  
When receive confirm, the event comes

enumerator **ESP_GATT_UNREG_EVT**  
When unregister application id, the event comes

enumerator **ESP_GATT_CREATE_EVT**  
When create service complete, the event comes

enumerator **ESP_GATT_ADD_INCL_SRVC_EVT**  
When add included service complete, the event comes

enumerator **ESP_GATT_ADD_CHAR_EVT**  
When add characteristic complete, the event comes

enumerator **ESP_GATT_ADD_CHAR_DESCR_EVT**  
When add descriptor complete, the event comes

enumerator **ESP_GATT_DELETE_EVT**  
When delete service complete, the event comes

enumerator **ESP_GATT_START_EVT**  
When start service complete, the event comes

enumerator **ESP_GATT_STOP_EVT**  
When stop service complete, the event comes

enumerator **ESP_GATT_CONNECT_EVT**  
When gatt client connect, the event comes

enumerator **ESP_GATT_DISCONNECT_EVT**  
When gatt client disconnect, the event comes

enumerator **ESP_GATT_OPEN_EVT**  
When connect to peer, the event comes
enumerator **ESP_GATTS CANCEL_OPEN_EVT**  
When disconnect from peer, the event comes

enumerator **ESP_GATTS_CLOSE_EVT**  
When gatt server close, the event comes

enumerator **ESP_GATTS_LISTEN_EVT**  
When gatt listen to be connected the event comes

enumerator **ESP_GATTS_CONGEST_EVT**  
When congest happen, the event comes

enumerator **ESP_GATTS_RESPONSE_EVT**  
When gatt send response complete, the event comes

enumerator **ESP_GATTS_CREAT_ATTR_TAB_EVT**  
When gatt creat table complete, the event comes

enumerator **ESP_GATTS_SET_ATTR_VAL_EVT**  
When gatt set attr value complete, the event comes

enumerator **ESP_GATTS_SEND_SERVICE_CHANGE_EVT**  
When gatt send service change indication complete, the event comes

### GATT CLIENT API

**Application Example**  
Check bluetooth/bluedroid/ble folder in ESP-IDF examples, which contains the following demos and their tutorials:

- This is a GATT client demo and its tutorial. This demo can scan for devices, connect to the GATT server and discover its services.
  - bluetooth/bluedroid/ble/gatt_client
  - GATT Client Example Walkthrough
- This is a multiple connection demo and its tutorial. This demo can connect to multiple GATT server devices and discover their services.
  - bluetooth/bluedroid/ble/gatte_multi_connect
  - GATT Client Multi-connection Example Walkthrough
- This is a BLE SPP-Like demo. This demo, which acts as a GATT client, can receive data from UART and then send the data to the peer device automatically.
  - bluetooth/bluedroid/ble/ble_spp_client

### API Reference

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_gattc_api.h

**Functions**

```c
esp_err_t esp_ble_gattc_register_callback(esp_gatte_cb_t callback)
```

This function is called to register application callbacks with GATTC module.

**Parameters**  
- **callback**  
  - **[in]**: pointer to the application callback function.
Returns

• ESP_OK: success
• other: failed

*esp_err* esp_ble_gattc_app_register (uint16_t app_id)
This function is called to register application callbacks with GATTC module.

Parameters app_id - [in]: Application Identify (UUID), for different application

Returns

• ESP_OK: success
• other: failed

*esp_err* esp_ble_gattc_app_unregister (esp_gatt_if_t gattc_if)
This function is called to unregister an application from GATTC module.

Parameters gattc_if - [in]: Gatt client access interface.

Returns

• ESP_OK: success
• other: failed

*esp_err* esp_ble_gattc_open (esp_gatt_if_t gattc_if, esp_bd_addr_t remote_bda, esp_ble_addr_type_t remote_addr_type, bool is_direct)
Open a direct connection or add a background auto connection.

Parameters

• gattc_if - [in]: Gatt client access interface.
• remote_bda - [in]: remote device bluetooth device address.
• remote_addr_type - [in]: remote device bluetooth device the address type.
• is_direct - [in]: direct connection or background auto connection(by now, background auto connection is not supported).

Returns

• ESP_OK: success
• other: failed

*esp_err* esp_ble_gattc_aux_open (esp_gatt_if_t gattc_if, esp_bd_addr_t remote_bda, esp_ble_addr_type_t remote_addr_type, bool is_direct)

*esp_err* esp_ble_gattc_close (esp_gatt_if_t gattc_if, uint16_t conn_id)
Close the virtual connection to the GATT server. gattc may have multiple virtual GATT server connections when multiple app_id registered, this API only close one virtual GATT server connection. if there exist other virtual GATT server connections, it does not disconnect the physical connection. if you want to disconnect the physical connection directly, you can use esp_ble_gap_disconnect(esp_bd_addr_t remote_device).

Parameters

• gattc_if - [in]: Gatt client access interface.
• conn_id - [in]: connection ID to be closed.

Returns

• ESP_OK: success
• other: failed

*esp_err* esp_ble_gattc_send_mtu_req (esp_gatt_if_t gattc_if, uint16_t conn_id)
Configure the MTU size in the GATT channel. This can be done only once per connection. Before using, use esp_ble_gatt_set_local_mtu() to configure the local MTU size.

Parameters

• gattc_if - [in]: Gatt client access interface.
• conn_id - [in]: connection ID.

Returns

• ESP_OK: success
• other: failed

*esp_err* esp_ble_gattc_search_service (esp_gatt_if_t gattc_if, uint16_t conn_id, esp_bt_uuid_t *filter_uuid)
This function is called to get service from local cache. This function report service search result by a call-back event, and followed by a service search complete event. Note: 128-bit base UUID will automatically be converted to a 16-bit UUID in the search results. Other types of UUID remain unchanged.

**Parameters**
- `conn_id` - [in] connection ID.
- `filter_uuid` - [in] a UUID of the service application is interested in. If Null, discover for all services.

**Returns**
- `ESP_OK`: success
- other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_service(esp_gatt_if_t gattc_if, uint16_t conn_id, esp_bt_uuid_t svc_uuid, esp_gattc_service_elem_t *result, uint16_t *count, uint16_t offset)
```

Find all the service with the given service uuid in the gattc cache, if the svc_uuid is NULL, find all the service. Note: It just get service from local cache, won’t get from remote devices. If want to get it from remote device, need to used the esp_ble_gattc_cache_refresh, then call esp_ble_gattc_get_service again.

**Parameters**
- `conn_id` - [in] connection ID which identify the server.
- `svc_uuid` - [in] the pointer to the service uuid.
- `result` - [out] The pointer to the service which has been found in the gattc cache.
- `count` - [inout] input the number of service want to find, it will output the number of service has been found in the gattc cache with the given service uuid.
- `offset` - [in] Offset of the service position to get.

**Returns**
- `ESP_OK`: success
- other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_all_char(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_gattc_char_elem_t *result, uint16_t *count, uint16_t offset)
```

Find all the characteristic with the given service in the gattc cache. Note: It just get characteristic from local cache, won’t get from remote devices.

**Parameters**
- `conn_id` - [in] connection ID which identify the server.
- `start_handle` - [in] the attribute start handle.
- `end_handle` - [in] the attribute end handle
- `result` - [out] The pointer to the characteristic in the service.
- `count` - [inout] input the number of characteristic want to find, it will output the number of characteristic has been found in the gattc cache with the given service.
- `offset` - [in] Offset of the characteristic position to get.

**Returns**
- `ESP_OK`: success
- other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_all_descr(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t char_handle, esp_gattc_descr_elem_t *result, uint16_t *count, uint16_t offset)
```

Find all the descriptor with the given characteristic in the gattc cache. Note: It just get descriptor from local cache, won’t get from remote devices.

**Parameters**
- **conn_id** - [in] connection ID which identify the server.
- **char_handle** - [in] the given characteristic handle
- **result** - [out] The pointer to the descriptor in the characteristic.
- **count** - [inout] Input the number of descriptor want to find, it will output the number of descriptor has been found in the gatt cache with the given characteristic.
- **offset** - [in] Offset of the descriptor position to get.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_char_by_uuid (esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_bt_uuid_t char_uuid, esp_gatt_char_elem_t *result, uint16_t *count)
```

Find the characteristic with the given characteristic uuid in the gatt cache Note: It just get characteristic from local cache, won’t get from remote devices.

**Parameters**

- **conn_id** - [in] connection ID which identify the server.
- **start_handle** - [in] the attribute start handle
- **end_handle** - [in] the attribute end handle
- **char_uuid** - [in] the characteristic uuid
- **result** - [out] The pointer to the characteristic in the service.
- **count** - [inout] Input the number of characteristic want to find, it will output the number of characteristic has been found in the gatt cache with the given service.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_descr_by_uuid (esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_bt_uuid_t char_uuid, esp_bt_uuid_t descr_uuid, esp_gattc_descr_elem_t *result, uint16_t *count)
```

Find the descriptor with the given characteristic uuid in the gatt cache Note: It just get descriptor from local cache, won’t get from remote devices.

**Parameters**

- **conn_id** - [in] connection ID which identify the server.
- **start_handle** - [in] the attribute start handle
- **end_handle** - [in] the attribute end handle
- **char_uuid** - [in] the characteristic uuid.
- **descr_uuid** - [in] the descriptor uuid.
- **result** - [out] The pointer to the descriptor in the given characteristic.
- **count** - [inout] Input the number of descriptor want to find, it will output the number of descriptor has been found in the gatt cache with the given characteristic.

**Returns**

- ESP_OK: success
- other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_descr_by_char_handle (esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t char_handle, esp_bt_uuid_t descr_uuid, esp_gattc_descr_elem_t *result, uint16_t *count)
```

Find the descriptor with the given characteristic handle in the gatt cache Note: It just get descriptor from local cache, won’t get from remote devices.

**Parameters**
• `gattc_if` - [in] Gatt client access interface.
• `conn_id` - [in] connection ID which identify the server.
• `char_handle` - [in] the characteristic handle.
• `descr_uuid` - [in] the descriptor uuid.
• `result` - [out] The pointer to the descriptor in the given characteristic.
• `count` - [inout] input the number of descriptor want to find, it will output the number of descriptor has been found in the gattc cache with the given characteristic.

Returns
• ESP_OK: success
• other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_incl_service (esp_gatt_if_t gattc_if, uint16_t conn_id,
                                               uint16_t start_handle, uint16_t end_handle,
                                               esp_bt_uuid_t *incl_uuid,
                                               esp_gattc_incl_svc_elem_t *result, uint16_t *count)
```

Find the include service with the given service handle in the gattc cache Note: It just get include service from local cache, won’t get from remote devices.

Parameters
• `gattc_if` - [in] Gatt client access interface.
• `conn_id` - [in] connection ID which identify the server.
• `start_handle` - [in] the attribute start handle
• `end_handle` - [in] the attribute end handle
• `incl_uuid` - [in] the include service uuid
• `result` - [out] The pointer to the include service in the given service.
• `count` - [inout] input the number of include service want to find, it will output the number of include service has been found in the gattc cache with the given service.

Returns
• ESP_OK: success
• other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_attr_count (esp_gatt_if_t gattc_if, uint16_t conn_id,
                                                  esp_gatt_db_attr_type_t type, uint16_t start_handle,
                                                  uint16_t end_handle, uint16_t char_handle, uint16_t *count)
```

Find the attribute count with the given service or characteristic in the gattc cache.

Parameters
• `gattc_if` - [in] Gatt client access interface.
• `conn_id` - [in] connection ID which identify the server.
• `type` - [in] the attribute type.
• `start_handle` - [in] the attribute start handle, if the type is ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore
• `end_handle` - [in] the attribute end handle, if the type is ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore
• `char_handle` - [in] the characteristic handle, this parameter valid when the type is ESP_GATT_DB_DESCRIPTOR. If the type isn’t ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore.
• `count` - [out] output the number of attribute has been found in the gattc cache with the given attribute type.

Returns
• ESP_OK: success
• other: failed

```c
esp_gatt_status_t esp_ble_gattc_get_db (esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle,
                                        uint16_t end_handle, esp_gattc_db_elem_t *db, uint16_t *count)
```

This function is called to get the GATT database. Note: It just get attribute data base from local cache, won’t get from remote devices.
Parameters
• **gattc_if** - [in] Gatt client access interface.
• **start_handle** - [in] the attribute start handle
• **end_handle** - [in] the attribute end handle
• **conn_id** - [in] connection ID which identify the server.
• **db** - [in] output parameter which will contain the GATT database copy. Caller is responsible for freeing it.
• **count** - [in] number of elements in database.

Returns
• ESP.OK: success
• other: failed

```c
esp_err_t esp_ble_gattc_read_char(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle,
                                 esp_gatt_auth_req_t auth_req)
```

This function is called to read a service’s characteristics of the given characteristic handle.

Parameters
• **gattc_if** - [in] Gatt client access interface.
• **conn_id** - [in] connection ID.
• **handle** - [in] : characteristic handle to read.
• **auth_req** - [in] : authenticate request type

Returns
• ESP.OK: success
• other: failed

```c
esp_err_t esp_ble_gattc_read_by_type(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t start_handle,
                                      uint16_t end_handle, esp_ble_uuid_t *uuid,
                                      esp_gatt_auth_req_t auth_req)
```

This function is called to read a service’s characteristics of the given characteristic UUID.

Parameters
• **gattc_if** - [in] Gatt client access interface.
• **conn_id** - [in] : connection ID.
• **start_handle** - [in] : the attribute start handle.
• **end_handle** - [in] : the attribute end handle
• **uuid** - [in] : The UUID of attribute which will be read.
• **auth_req** - [in] : authenticate request type

Returns
• ESP.OK: success
• other: failed

```c
esp_err_t esp_ble_gattc_read_multiple(esp_gatt_if_t gattc_if, uint16_t conn_id,
                                      esp_gattc_multi_t *read_multi,
                                      esp_gatt_auth_req_t auth_req)
```

This function is called to read multiple characteristic or characteristic descriptors.

Parameters
• **gattc_if** - [in] Gatt client access interface.
• **conn_id** - [in] : connection ID.
• **read_multi** - [in] : pointer to the read multiple parameter.
• **auth_req** - [in] : authenticate request type

Returns
• ESP.OK: success
• other: failed

```c
esp_err_t esp_ble_gattc_read_multiple_variable(esp_gatt_if_t gattc_if, uint16_t conn_id,
                                              esp_gattc_multi_t *read_multi,
                                              esp_gatt_auth_req_t auth_req)
```

This function is called to read multiple variable length characteristic or characteristic descriptors.

Parameters
• **gattc_if** - [in] Gatt client access interface.
Chapter 2. API Reference

- **conn_id** -[in]: connection ID.
- **read_multi** -[in]: pointer to the read multiple parameter.
- **auth_req** -[in]: authenticate request type

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_read_char_descr(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle,
                                         esp_gatt_auth_req_t auth_req)
```

This function is called to read a characteristics descriptor.

**Parameters**
- **gattc_if** -[in]: Gatt client access interface.
- **conn_id** -[in]: connection ID.
- **handle** -[in]: descriptor handle to read.
- **auth_req** -[in]: authenticate request type

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_write_char(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle,
                                   uint16_t value_len, uint8_t *value,
                                   esp_gatt_write_type_t write_type,
                                   esp_gatt_auth_req_t auth_req)
```

This function is called to write characteristic value.

**Parameters**
- **gattc_if** -[in]: Gatt client access interface.
- **conn_id** -[in]: connection ID.
- **handle** -[in]: characteristic handle to write.
- **value_len** -[in]: length of the value to be written.
- **value** -[in]: the value to be written.
- **write_type** -[in]: the type of attribute write operation.
- **auth_req** -[in]: authentication request.

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_write_char_descr(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle,
                                          uint16_t value_len, uint8_t *value,
                                          esp_gatt_write_type_t write_type,
                                          esp_gatt_auth_req_t auth_req)
```

This function is called to write characteristic descriptor value.

**Parameters**
- **gattc_if** -[in]: Gatt client access interface.
- **conn_id** -[in]: connection ID.
- **handle** -[in]: descriptor handle to write.
- **value_len** -[in]: length of the value to be written.
- **value** -[in]: the value to be written.
- **write_type** -[in]: the type of attribute write operation.
- **auth_req** -[in]: authentication request.

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_prepare_write(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t handle,
                                       uint16_t offset, uint16_t value_len, uint8_t *value,
                                       esp_gatt_auth_req_t auth_req)
```

This function is called to prepare write a characteristic value.

**Parameters**
- **gattc_if** -[in]: Gatt client access interface.
• conn_id [in] : connection ID.
• handle [in] : characteristic handle to prepare write.
• offset [in] : offset of the write value.
• value_len [in] : length of the value to be written.
• value [in] : the value to be written.
• auth_req [in] : authentication request.

Returns
• ESP_OK: success
• other: failed

```
esp_err_t esp_ble_gattc_prepare_write_char_descr(esp_gatt_if_t gattc_if, uint16_t conn_id,
                                              uint16_t handle, uint16_t offset, uint16_t value_len, uint8_t* value,
                                              esp_gatt_auth_req_t auth_req)
```

This function is called to prepare write a characteristic descriptor value.

Parameters
• gattc_if [in] Gatt client access interface.
• conn_id [in] : connection ID.
• handle [in] : characteristic descriptor handle to prepare write.
• offset [in] : offset of the write value.
• value_len [in] : length of the value to be written.
• value [in] : the value to be written.
• auth_req [in] : authentication request.

Returns
• ESP_OK: success
• other: failed

```
esp_err_t esp_ble_gattc_execute_write(esp_gatt_if_t gattc_if, uint16_t conn_id, bool is_execute)
```

This function is called to execute write a prepare write sequence.

Parameters
• gattc_if [in] Gatt client access interface.
• conn_id [in] : connection ID.
• is_execute [in] : execute or cancel.

Returns
• ESP_OK: success
• other: failed

```
esp_err_t esp_ble_gattc_register_for_notify(esp_gatt_if_t gattc_if, esp_bd_addr_t server_bda,
                                          uint16_t handle)
```

This function is called to register for notification of a service.

Parameters
• gattc_if [in] Gatt client access interface.
• handle [in] : GATT characteristic handle.

Returns
• ESP_OK: registration succeeds
• other: failed

```
esp_err_t esp_ble_gattc_unregister_for_notify(esp_gatt_if_t gattc_if, esp_bd_addr_t server_bda,
                                           uint16_t handle)
```

This function is called to de-register for notification of a service.

Parameters
• gattc_if [in] Gatt client access interface.
• handle [in] : GATT characteristic handle.

Returns
• ESP_OK: unregister succeeds
• other: failed

```c
esp_err_t esp_ble_gattc_cache_refresh (esp_bd_addr_t remote_bda)
```

Refresh the server cache store in the gattc stack of the remote device. If the device is connected, this API will restart the discovery of service information of the remote device.

**Parameters**
- `remote_bda` - [in] remote device BD address.

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_cache_assoc (esp_gatt_if_t gattc_if, esp_bd_addr_t src_addr, esp_bd_addr_t assoc_addr, bool is_assoc)
```

Add or delete the associated address with the source address. Note: The role of this API is mainly when the client side has stored a server-side database, when it needs to connect another device, but the device’s attribute database is the same as the server database stored on the client-side, calling this API can use the database that the device has stored used as the peer server database to reduce the attribute database search and discovery process and speed up the connection time. The associated address mains that device want to used the database has stored in the local cache. The source address mains that device want to share the database to the associated address device.

**Parameters**
- `src_addr` - [in] the source address which provide the attribute table.
- `assoc_addr` - [in] the associated device address which went to share the attribute table with the source address.
- `is_assoc` - [in] true add the associated device address, false remove the associated device address.

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_cache_get_addr_list (esp_gatt_if_t gattc_if)
```

Get the address list which has store the attribute table in the gattc cache. There will callback ESP_GATTC_GET_ADDR_LIST_EVT event when get address list complete.

**Parameters**

**Returns**
- ESP_OK: success
- other: failed

```c
esp_err_t esp_ble_gattc_cache_clean (esp_bd_addr_t remote_bda)
```

Clean the service cache of this device in the gattc stack.

**Parameters**
- `remote_bda` - [in] remote device BD address.

**Returns**
- ESP_OK: success
- other: failed

**Unions**

```c
union esp_ble_gattc_cb_param_t
```

`#include <esp_gattc_api.h>` Gatt client callback parameters union.

**Public Members**

```c
struct esp_ble_gattc_cb_param_t::gatt_reg_evt_param reg
```

Gatt client callback param of ESP_GATTC_REG_EVT
struct esp_ble_gattc_cb_param_t::gattc_open_evt_param open
        Gatt client callback param of ESP_GATTC_OPEN_EVT

struct esp_ble_gattc_cb_param_t::gattc_close_evt_param close
        Gatt client callback param of ESP_GATTC_CLOSE_EVT

struct esp_ble_gattc_cb_param_t::gattc_cfg_mtu_evt_param cfg_mtu
        Gatt client callback param of ESP_GATTC_CFG_MTU_EVT

struct esp_ble_gattc_cb_param_t::gattc_search_cmpl_evt_param search_cmpl
        Gatt client callback param of ESP_GATTC_SEARCH_CMPL_EVT

struct esp_ble_gattc_cb_param_t::gattc_search_res_evt_param search_res
        Gatt client callback param of ESP_GATTC_SEARCH_RES_EVT

struct esp_ble_gattc_cb_param_t::gattc_read_char_evt_param read
        Gatt client callback param of ESP_GATTC_READ_CHAR_EVT

struct esp_ble_gattc_cb_param_t::gattc_write_evt_param write
        Gatt client callback param of ESP_GATTC_WRITE_DESCR_EVT

struct esp_ble_gattc_cb_param_t::gattc_exec_cmpl_evt_param exec_cmpl
        Gatt client callback param of ESP_GATTC_EXEC_EVT

struct esp_ble_gattc_cb_param_t::gattc_notify_evt_param notify
        Gatt client callback param of ESP_GATTC_NOTIFY_EVT

struct esp_ble_gattc_cb_param_t::gattc_srvc_chg_evt_param srvc_chg
        Gatt client callback param of ESP_GATTC_SRVC_CHG_EVT

struct esp_ble_gattc_cb_param_t::gattc_congest_evt_param congest
        Gatt client callback param of ESP_GATTC_CONGEST_EVT

struct esp_ble_gattc_cb_param_t::gattc_reg_for_notify_evt_param reg_for_notify
        Gatt client callback param of ESP_GATTC_REG_FOR_NOTIFY_EVT

struct esp_ble_gattc_cb_param_t::gattc_unreg_for_notify_evt_param unreg_for_notify
        Gatt client callback param of ESP_GATTC_UNREG_FOR_NOTIFY_EVT

struct esp_ble_gattc_cb_param_t::gattc_connect_evt_param connect
        Gatt client callback param of ESP_GATTC_CONNECT_EVT

struct esp_ble_gattc_cb_param_t::gattc_disconnect_evt_param disconnect
        Gatt client callback param of ESP_GATTC_DISCONNECT_EVT

struct esp_ble_gattc_cb_param_t::gattc_set_assoc_addr_cmp_evt_param set_assoc_cmp
        Gatt client callback param of ESP_GATTC_SET_ASSOC_EVT
struct esp_ble_gattc_cb_param_t::gattc_get_addr_list_evt_param get_addr_list
Gatt client callback param of ESP_GATTC_GET_ADDR_LIST_EVT

struct esp_ble_gattc_cb_param_t::gattc_queue_full_evt_param queue_full
Gatt client callback param of ESP_GATTC_QUEUE_FULL_EVT

struct esp_ble_gattc_cb_param_t::gattc_dis_srvc_cmpl_evt_param dis_srvc_cmpl
Gatt client callback param of ESP_GATTC_DIS_SRVC_CMPL_EVT

struct gattc_cfg_mtu_evt_param
#include <esp_gattc_api.h> ESP_GATTC_CFG_MTU_EVT.

Public Members

  esp_gatt_status_t status
  Operation status

uint16_t conn_id
  Connection id

uint16_t mtu
  MTU size

struct gattc_close_evt_param
#include <esp_gattc_api.h> ESP_GATTC_CLOSE_EVT.

Public Members

  esp_gatt_status_t status
  Operation status

uint16_t conn_id
  Connection id

esp_bd_addr_t remote_bda
  Remote bluetooth device address

  esp_gatt_conn_reason_t reason
  The reason of gatt connection close

struct gattc_congest_evt_param
#include <esp_gattc_api.h> ESP_GATTC_CONGEST_EVT.

Public Members
uint16_t **conn_id**
  Connection id

bool **congested**
  Congested or not

struct **gattc_connect_evt_param**
  #include <esp_gattc_api.h> ESP_GATTC_CONNECT_EVT.

**Public Members**

uint16_t **conn_id**
  Connection id

uint8_t **link_role**
  Link role : master role = 0; slave role = 1

**esp_bd_addr_t** remote_bda
  Remote Bluetooth device address

**esp_gatt_conn_params_t** conn_params
  current connection parameters

**esp_ble_addr_type_t** ble_addr_type
  Remote BLE device address type

uint16_t **conn_handle**
  HCI connection handle

struct **gattc_dis_srvc_cmpl_evt_param**
  #include <esp_gattc_api.h> ESP_GATTC_DIS_SRVC_CMPL_EVT.

**Public Members**

**esp_gatt_status_t** status
  Operation status

uint16_t **conn_id**
  Connection id

struct **gattc_disconnect_evt_param**
  #include <esp_gattc_api.h> ESP_GATTC_DISCONNECT_EVT.

**Public Members**
**Chapter 2. API Reference**

```c
enum esp_gatt_conn_reason_t
{
    disconnection_reason
};
```

- `reason` disconnection reason

```c
uint16_t conn_id
Connection id
```

- `conn_id` Connection id

```c
esp_bd_addr_t remote_bda
Remote bluetooth device address
```

- `remote_bda` Remote bluetooth device address

```c
struct gattc_exec_cmpl_evt_param
#include <esp_gattc_api.h> ESP_GATTC_EXEC_EVT.
```

- **Public Members**

```c
enum esp_gatt_status_t
{
    Operation status
};
```

- `status` Operation status

```c
uint16_t conn_id
Connection id
```

```c
#include <esp_gattc_api.h> ESP_GATTC_GET_ADDR_LIST_EVT.
```

- **Public Members**

```c
struct gattc_get_addr_list_evt_param
```

- `status` Operation status

```c
uint8_t num_addr
The number of address in the gattc cache address list
```

- `num_addr` The number of address in the gattc cache address list

```c
esp_bd_addr_t *addr_list
The pointer to the address list which has been get from the gattc cache
```

- `addr_list` The pointer to the address list which has been get from the gattc cache

```c
struct gattc_notify_evt_param
#include <esp_gattc_api.h> ESP_GATTC_NOTIFY_EVT.
```

- **Public Members**

```c
uint16_t conn_id
Connection id
```

- `conn_id` Connection id

```c
esp_bd_addr_t remote_bda
Remote bluetooth device address
```

- `remote_bda` Remote bluetooth device address
uint16_t handle
   The Characteristic or descriptor handle

uint16_t value_len
   Notify attribute value

uint8_t* value
   Notify attribute value

bool is_notify
   True means notify, false means indicate

struct gattc_open_evt_param
   #include <esp_gattc_api.h> ESP_GATTC_OPEN_EVT.

   Public Members

   esp_gatt_status_t status
      Operation status

   uint16_t conn_id
      Connection id

   esp_bd_addr_t remote_bda
      Remote bluetooth device address

   uint16_t mtu
      MTU size

struct gattc_queue_full_evt_param
   #include <esp_gattc_api.h> ESP_GATTC_QUEUE_FULL_EVT.

   Public Members

   esp_gatt_status_t status
      Operation status

   uint16_t conn_id
      Connection id

   bool is_full
      The gattc command queue is full or not

struct gattc_read_char_evt_param
   #include <esp_gattc_api.h> ESP_GATTC_READ_CHAR_EVT, ESP_GATTC_READ_DESCR_EVT,
   ESP_GATTC_READ_MULTIPLE_EVT, ESP_GATTC_READ_MULTI_VAR_EVT.
Public Members

`esp_gatt_status_t status`
Operation status

`uint16_t conn_id`
Connection id

`uint16_t handle`
Characteristic handle

`uint8_t* value`
Characteristic value

`uint16_t value_len`
Characteristic value length

`struct gattc_reg_evt_param`

```
#include <esp_gattc_api.h>
ESP_GATTC_REG_EVT.
```
Chapter 2. API Reference

```c
uint16_t conn_id
Connection id
```

```c
esp_service_source_t searched_service_source
The source of the service information
```

```c
struct gattc_search_res_evt_param
#include <esp_gattc_api.h> ESP_GATTC_SEARCH_RES_EVT.
```

Public Members

```c
uint16_t conn_id
Connection id
```

```c
uint16_t start_handle
Service start handle
```

```c
uint16_t end_handle
Service end handle
```

```c
esp_gatt_id_t srvc_id
Service id, include service uuid and other information
```

```c
bool is_primary
True if this is the primary service
```

```c
struct gattc_set_assoc_addr_cmp_evt_param
#include <esp_gattc_api.h> ESP_GATTC_SET_ASSOC_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
struct gattc_srvc_chg_evt_param
#include <esp_gattc_api.h> ESP_GATTC_SRVC_CHG_EVT.
```

Public Members

```c
esp_bd_addr_t remote_bda
Remote bluetooth device address
```

```c
struct gattc_unreg_for_notify_evt_param
#include <esp_gattc_api.h> ESP_GATTC_UNREG_FOR_NOTIFY_EVT.
```
Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t handle
The characteristic or descriptor handle
```

```c
struct gattc_write_evt_param
#include <esp_gattc_api.h> ESP_GATTC_WRITE_CHAR_EVT, ESP_GATTC_PREP_WRITE_EVT, ESP_GATTC_WRITE_DESCR_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t conn_id
Connection id
```

```c
uint16_t handle
The Characteristic or descriptor handle
```

```c
uint16_t offset
The prepare write offset, this value is valid only when prepare write
```

Type Definitions

typedef void (*esp_gattc_cb_t)(esp_gattc_cb_event_t event, esp_gatt_if_t gattc_if, esp_ble_gattc_cb_param_t *param)

GATT Client callback function type.

- **Param event**: Event type
- **Param gattc_if**: GATT client access interface, normally different gattc_if correspond to different profile
- **Param param**: Point to callback parameter, currently is union type

Enumerations

enum esp_gattc_cb_event_t

GATT Client callback function events.

**Values:**

- **enumerator ESP_GATTC_REG_EVT**
  When GATT client is registered, the event comes

- **enumerator ESP_GATTC_UNREG_EVT**
  When GATT client is unregistered, the event comes
enumerator **ESP_GATTC_OPEN_EVT**
   When GATT virtual connection is set up, the event comes

enumerator **ESP_GATTC_READ_CHAR_EVT**
   When GATT characteristic is read, the event comes

enumerator **ESP_GATTC_WRITE_CHAR_EVT**
   When GATT characteristic write operation completes, the event comes

enumerator **ESP_GATTC_CLOSE_EVT**
   When GATT virtual connection is closed, the event comes

enumerator **ESP_GATTC_SEARCH_CMPL_EVT**
   When GATT service discovery is completed, the event comes

enumerator **ESP_GATTC_SEARCH_RES_EVT**
   When GATT service discovery result is got, the event comes

enumerator **ESP_GATTC_READ_DESCR_EVT**
   When GATT characteristic descriptor read completes, the event comes

enumerator **ESP_GATTC_WRITE_DESCR_EVT**
   When GATT characteristic descriptor write completes, the event comes

enumerator **ESP_GATTC_NOTIFY_EVT**
   When GATT notification or indication arrives, the event comes

enumerator **ESP_GATTC_PREP_WRITE_EVT**
   When GATT prepare-write operation completes, the event comes

enumerator **ESP_GATTC_EXEC_EVT**
   When write execution completes, the event comes

enumerator **ESP_GATTC_ACL_EVT**
   When ACL connection is up, the event comes

enumerator **ESP_GATTC_CANCEL_OPEN_EVT**
   When GATT client ongoing connection is cancelled, the event comes

enumerator **ESP_GATTC_SRVC_CHG_EVT**
   When “service changed” occurs, the event comes

enumerator **ESP_GATTC_ENC_CMPL_CB_EVT**
   When encryption procedure completes, the event comes

enumerator **ESP_GATTC_CFG_MTU_EVT**
   When configuration of MTU completes, the event comes
enumerator **ESP_GATTC_ADV_DATA_EVT**  
When advertising of data, the event comes

enumerator **ESP_GATTC_MULT_ADV_ENB_EVT**  
When multi-advertising is enabled, the event comes

enumerator **ESP_GATTC_MULT_ADV_UPD_EVT**  
When multi-advertising parameters are updated, the event comes

enumerator **ESP_GATTC_MULT_ADV_DATA_EVT**  
When multi-advertising data arrives, the event comes

enumerator **ESP_GATTC_MULT_ADV_DIS_EVT**  
When multi-advertising is disabled, the event comes

enumerator **ESP_GATTC_CONGEST_EVT**  
When GATT connection congestion comes, the event comes

enumerator **ESP_GATTC_BTH_SCAN_ENB_EVT**  
When batch scan is enabled, the event comes

enumerator **ESP_GATTC_BTH_SCAN_CFG_EVT**  
When batch scan storage is configured, the event comes

enumerator **ESP_GATTC_BTH_SCAN_RD_EVT**  
When Batch scan read event is reported, the event comes

enumerator **ESP_GATTC_BTH_SCAN_THR_EVT**  
When Batch scan threshold is set, the event comes

enumerator **ESP_GATTC_BTH_SCAN_PARAM_EVT**  
When Batch scan parameters are set, the event comes

enumerator **ESP_GATTC_BTH_SCAN_DIS_EVT**  
When Batch scan is disabled, the event comes

enumerator **ESP_GATTC_SCAN_FLT_CFG_EVT**  
When Scan filter configuration completes, the event comes

enumerator **ESP_GATTC_SCAN_FLT_PARAM_EVT**  
When Scan filter parameters are set, the event comes

enumerator **ESP_GATTC_SCAN_FLT_STATUS_EVT**  
When Scan filter status is reported, the event comes

enumerator **ESP_GATTC_ADV_VSC_EVT**  
When advertising vendor spec content event is reported, the event comes
enumerator **ESP_GATTC_REG_FOR_NOTIFY_EVT**
   When register for notification of a service completes, the event comes

enumerator **ESP_GATTC_UNREG_FOR_NOTIFY_EVT**
   When unregister for notification of a service completes, the event comes

enumerator **ESP_GATTC_CONNECT_EVT**
   When the ble physical connection is set up, the event comes

enumerator **ESP_GATTC_DISCONNECT_EVT**
   When the ble physical connection disconnected, the event comes

enumerator **ESP_GATTC_READ_MULTIPLE_EVT**
   When the ble characteristic or descriptor multiple complete, the event comes

enumerator **ESP_GATTC_QUEUE_FULL_EVT**
   When the gattc command queue full, the event comes

enumerator **ESP_GATTC_SET_ASSOC_EVT**
   When the ble gattc set the associated address complete, the event comes

enumerator **ESP_GATTC_GET_ADDR_LIST_EVT**
   When the ble get gattc address list in cache finish, the event comes

enumerator **ESP_GATTC_DIS_SRVC_CMPL_EVT**
   When the ble discover service complete, the event comes

enumerator **ESP_GATTC_READ_MULTI_VAR.EVT**
   When read multiple variable characteristic complete, the event comes

**BLUFI API**

**Overview**  BLUFI is a profile based GATT to config ESP32 WIFI to connect/disconnect AP or setup a softap and etc. Use should concern these things:

1. The event sent from profile. Then you need to do something as the event indicate.
2. Security reference. You can write your own Security functions such as symmetrical encryption/decryption and checksum functions. Even you can define the “Key Exchange/Negotiation” procedure.

**Application Example**  Check bluetooth folder in ESP-IDF examples, which contains the following application:

* This is the BLUFI demo. This demo can set ESP32’s wifi to softap/station/softap&station mode and config wifi connections - bluetooth/blufi

**API Reference**

**Header File**

* components/bt/common/api/include/api/esp_blufi_api.h
Functions

**esp_err_t esp_blufi_register_callbacks (esp_blufi_callbacks_t *callbacks)**

This function is called to receive blufi callback event.

- **Parameters**
  - callbacks - [in] callback functions

- **Returns**
  - ESP_OK - success, other - failed

**esp_err_t esp_blufi_profile_init (void)**

This function is called to initialize blufi_profile.

- **Returns**
  - ESP_OK - success, other - failed

**esp_err_t esp_blufi_profile_deinit (void)**

This function is called to de-initialize blufi_profile.

- **Returns**
  - ESP_OK - success, other - failed

**esp_err_t esp_blufi_send_wifi_conn_report (wifi_mode_t opmode, esp_blufi_sta_conn_state_t sta_conn_state, uint8_t softap_conn_num, esp_blufi_extra_info_t *extra_info)**

This function is called to send wifi connection report.

- **Parameters**
  - opmode - wifi opmode
  - sta_conn_state - station is already in connection or not
  - softap_conn_num - softap connection number
  - extra_info - extra information, such as sta_ssid, softap_ssid and etc.

- **Returns**
  - ESP_OK - success, other - failed

**esp_err_t esp_blufi_send_wifi_list (uint16_t apCount, esp_blufi_ap_record_t *list)**

This function is called to send wifi list.

- **Parameters**
  - apCount - wifi list count
  - list - wifi list

- **Returns**
  - ESP_OK - success, other - failed

**uint16_t esp_blufi_get_version (void)**

Get BLUFI profile version.

- **Returns**
  - Most 8bit significant is Great version, Least 8bit is Sub version

**esp_err_t esp_blufi_send_error_info (esp_blufi_error_state_t state)**

This function is called to send blufi error information.

- **Parameters**
  - state - error state

- **Returns**
  - ESP_OK - success, other - failed

**esp_err_t esp_blufi_send_custom_data (uint8_t *data, uint32_t data_len)**

This function is called to custom data.

- **Parameters**
  - data - custom data value
  - data_len - the length of custom data

- **Returns**
  - ESP_OK - success, other - failed

Unions

union esp_blufi_cb_param_t

#include <esp_blufi_api.h> BLUFI callback parameters union.
Public Members

struct esp_blufi_cb_param_t::blufi_init_finish_evt_param init_finish
Blufi callback param of ESP_BLUFI_EVENT_INIT_FINISH

struct esp_blufi_cb_param_t::blufi_deinit_finish_evt_param deinit_finish
Blufi callback param of ESP_BLUFI_EVENT_DEINIT_FINISH

struct esp_blufi_cb_param_t::blufi_set_wifi_mode_evt_param wifi_mode
Blufi callback param of ESP_BLUFI_EVENT_INIT_FINISH

struct esp_blufi_cb_param_t::blufi_connect_evt_param connect
Blufi callback param of ESP_BLUFI_EVENT_CONNECT

struct esp_blufi_cb_param_t::blufi_disconnect_evt_param disconnect
Blufi callback param of ESP_BLUFI_EVENT_DISCONNECT

struct esp_blufi_cb_param_t::blufi_recv_sta_bssid_evt_param sta_bssid
Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_BSSID

struct esp_blufi_cb_param_t::blufi_recv_sta_ssid_evt_param sta_ssid
Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_SSID

struct esp_blufi_cb_param_t::blufi_recv_softap_ssid_evt_param softap_ssid
Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_SSID

struct esp_blufi_cb_param_t::blufi_recv_softap_passwd_evt_param softap_passwd
Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD

struct esp_blufi_cb_param_t::blufi_recv_softap_max_conn_num_evt_param softap_max_conn_num
Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM

struct esp_blufi_cb_param_t::blufi_recv_softap_auth_mode_evt_param softap_auth_mode
Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_AUTH_MODE

struct esp_blufi_cb_param_t::blufi_recv_softap_channel_evt_param softap_channel
Blufi callback param of ESP_BLUFI_EVENT_RECV_SOFTAP_CHANNEL

struct esp_blufi_cb_param_t::blufi_recv_username_evt_param username
Blufi callback param of ESP_BLUFI_EVENT_RECV_USERNAME

struct esp_blufi_cb_param_t::blufi_recv_client_cert_evt_param client_cert
Blufi callback param of ESP_BLUFI_EVENT_RECV_CLIENT_CERT
struct `esp_blufi_cb_param_t::blufi_recv_server_cert_evt_param` server_cert
Blufi callback param of ESP_BLUFI_EVENT_RECV_SERVER_CERT

struct `esp_blufi_cb_param_t::blufi_recv_client_pkey_evt_param` client_pkey
Blufi callback param of ESP_BLUFI_EVENT_RECV_CLIENT_PRIV_KEY

struct `esp_blufi_cb_param_t::blufi_recv_server_pkey_evt_param` server_pkey
Blufi callback param of ESP_BLUFI_EVENT_RECV_SERVER_PRIV_KEY

struct `esp_blufi_cb_param_t::blufi_get_error_evt_param` report_error
Blufi callback param of ESP_BLUFI_EVENT_REPORT_ERROR

struct `esp_blufi_cb_param_t::blufi_recv_custom_data_evt_param` custom_data
Blufi callback param of ESP_BLUFI_EVENT_RECV_CUSTOM_DATA

struct `blufi_connect_evt_param`
#include `<esp_blufi_api.h>` ESP_BLUFI_EVENT_CONNECT.

**Public Members**

`esp_blufi_bd_addr_t` remote_bda
Blufi Remote bluetooth device address

`uint8_t` server_if
server interface

`uint16_t` conn_id
Connection id

struct `blufi_deinit_finish_evt_param`
#include `<esp_blufi_api.h>` ESP_BLUFI_EVENT_DEINIT_FINISH.

**Public Members**

`esp_blufi_deinit_state_t` state
De-initial status

struct `blufi_disconnect_evt_param`
#include `<esp_blufi_api.h>` ESP_BLUFI_EVENT_DISCONNECT.

**Public Members**

`esp_blufi_bd_addr_t` remote_bda
Blufi Remote bluetooth device address

struct `blufi_get_error_evt_param`
#include `<esp_blufi_api.h>` ESP_BLUFI_EVENT_REPORT_ERROR.
Public Members

```c
esp_blufi_error_state_t state
```
Blufi error state

```
struct blufi_init_finish_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_INIT_FINISH.
```

Public Members

```c
esp_blufi_init_state_t state
```
Initial status

```
struct blufi_recv_ca_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CA_CERT.
```

Public Members

```c
uint8_t* cert
```
CA certificate point

```c
int cert_len
```
CA certificate length

```
struct blufi_recv_client_cert_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CLIENT_CERT
```

Public Members

```c
uint8_t* cert
```
Client certificate point

```c
int cert_len
```
Client certificate length

```
struct blufi_recv_client_pkey_evt_param
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CLIENT_PRIV_KEY
```

Public Members

```c
uint8_t* pkey
```
Client Private Key point, if Client certificate not contain Key

```c
int pkey_len
```
Client Private key length
struct `blufi_recv_custom_data_evt_param`

```c
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CUSTOM_DATA.
```

**Public Members**

- `uint8_t *data`
  - Custom data
- `uint32_t data_len`
  - Custom data Length

struct `blufi_recv_server_cert_evt_param`

```c
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SERVER_CERT
```

**Public Members**

- `uint8_t *cert`
  - Client certificate point
- `int cert_len`
  - Client certificate length

struct `blufi_recv_server_pkey_evt_param`

```c
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SERVER_PRIV_KEY
```

**Public Members**

- `uint8_t *pkey`
  - Client Private Key point, if Client certificate not contain Key
- `int pkey_len`
  - Client Private Key length

struct `blufi_recv_softap_auth_mode_evt_param`

```c
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SOFTAP_AUTH_MODE
```

**Public Members**

- `wifi_auth_mode_t auth_mode`
  - Authentication mode

struct `blufi_recv_softap_channel_evt_param`

```c
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SOFTAP_CHANNEL
```

---
Chapter 2. API Reference

Public Members

uint8_t channel
    Authentication mode

struct blufi_recv_softap_max_conn_num_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM.

Public Members

int max_conn_num
    SSID

struct blufi_recv_softap_passwd_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD.

Public Members

uint8_t *passwd
    Password

int passwd_len
    Password Length

struct blufi_recv_softap_ssid_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SOFTAP_SSID.

Public Members

uint8_t *ssid
    SSID

int ssid_len
    SSID length

struct blufi_recv_sta_bssid_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_STA_BSSID.

Public Members

uint8_t bssid[6]
    BSSID

struct blufi_recv_sta_passwd_evt_param
    #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_STA_PASSWD.
Public Members

tuint8_t *passwd
  Password

int passwd_len
  Password Length

struct blufi_recv_sta_ssid_evt_param
  #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_STA_SSID.

Public Members

uint8_t *ssid
  SSID

int ssid_len
  SSID length

struct blufi_recv_username_evt_param
  #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_USERNAME.

Public Members

uint8_t *name
  Username point

int name_len
  Username length

struct blufi_set_wifi_mode_evt_param
  #include <esp_blufi_api.h> ESP_BLUFI_EVENT_SET_WIFI_MODE.

Public Members

wifi_mode_t op_mode
  Wifi operation mode

Structures

struct esp_blufi_extra_info_t
  BLUFI extra information structure.
Chapter 2. API Reference

Public Members

```c
uint8_t sta_bssid[6]
    BSSID of station interface

bool sta_bssid_set
    is BSSID of station interface set

uint8_t* sta_ssid
    SSID of station interface

int sta_ssid_len
    length of SSID of station interface

uint8_t* sta_passwd
    password of station interface

int sta_passwd_len
    length of password of station interface

uint8_t* softap_ssid
    SSID of softap interface

int softap_ssid_len
    length of SSID of softap interface

uint8_t* softap_passwd
    password of station interface

int softap_passwd_len
    length of password of station interface

uint8_t softap_authmode
    authentication mode of softap interface

bool softap_authmode_set
    is authentication mode of softap interface set

uint8_t softap_max_conn_num
    max connection number of softap interface

bool softap_max_conn_num_set
    is max connection number of softap interface set

uint8_t softap_channel
    channel of softap interface

bool softap_channel_set
    is channel of softap interface set
```
uint8_t sta_max_conn_retry
   max retry of sta establish connection

bool sta_max_conn_retry_set
   is max retry of sta establish connection set

uint8_t sta_conn_end_reason
   reason of sta connection end

bool sta_conn_end_reason_set
   is reason of sta connection end set

int8_t sta_conn_rssi
   rssiofstaconnection

bool sta_conn_rssi_set
   is rssiofstaconnectionset

struct esp_blufi_ap_record_t
   Description of an WiFi AP.

Public Members

uint8_t ssid[33]
   SSID of AP

int8_t rssi
   signal strength of AP

struct esp_blufi_callbacks_t
   BLUFI callback functions type.

Public Members

esp_blufi_event_cb_t event_cb
   BLUFI event callback

esp_blufi_negotiate_data_handler_t negotiate_data_handler
   BLUFI negotiate data function for negotiate share key

esp_blufi_encrypt_func_t encrypt_func
   BLUFI encrypt data function with share key generated by negotiate_data_handler

esp_blufi_decrypt_func_t decrypt_func
   BLUFI decrypt data function with share key generated by negotiate_data_handler

esp_blufi_checksum_func_t checksum_func
   BLUFI check sum function (FCS)
Macros

ESP_BLUFI_BD_ADDR_LEN

Bluetooth address length.

Type Definitions

typedef uint8_t esp_blufi_bd_addr_t[ESP_BLUFI_BD_ADDR_LEN]

Bluetooth device address.

typedef void (*esp_blufi_event_cb_t)(esp_blufi_event_t event, esp_blufi_cb_param_t *param)

BLUFI event callback function type.

Param event : Event type
Param param : Point to callback parameter, currently is union type

typedef void (*esp_blufi_negotiate_data_handler_t)(uint8_t *data, int len, uint8_t **output_data, int *output_len, bool *need_free)

BLUFI negotiate data handler.

Param data : data from phone
Param len : length of data from phone
Param output_data : data want to send to phone
Param output_len : length of data want to send to phone
Param need_free : output reporting if memory needs to be freed or not *

typedef int (*esp_blufi_encrypt_func_t)(uint8_t iv8, uint8_t *crypt_data, int crypt_len)

BLUFI encrypt the data after negotiate a share key.

Param iv8 : initial vector(8bit), normally, blufi core will input packet sequence number
Param crypt_data : plain text and encrypted data, the encrypt function must support autotchothonous encrypt
Param crypt_len : length of plain text
Return Nonnegative number is encrypted length, if error, return negative number;

typedef int (*esp_blufi_decrypt_func_t)(uint8_t iv8, uint8_t *crypt_data, int crypt_len)

BLUFI decrypt the data after negotiate a share key.

Param iv8 : initial vector(8bit), normally, blufi core will input packet sequence number
Param crypt_data : encrypted data and plain text, the encrypt function must support autotchothonous decrypt
Param crypt_len : length of encrypted text
Return Nonnegative number is decrypted length, if error, return negative number;

typedef uint16_t (*esp_blufi_checksum_func_t)(uint8_t iv8, uint8_t *data, int len)

BLUFI checksum.

Param iv8 : initial vector(8bit), normally, blufi core will input packet sequence number
Param data : data need to checksum
Param len : length of data

Enumerations

enum esp_blufi_cb_event_t

Values:
enumerator ESP_BLUFI_EVENT_INIT_FINISH
enumerator ESP_BLUFI_EVENT_DEINIT_FINISH
enumerator ESP_BLUFI_EVENT_SET_WIFI_OPMODE
enumerator ESP_BLUFI_EVENT_BLE_CONNECT
enumerator ESP_BLUFI_EVENT_BLE_DISCONNECT
enumerator ESP_BLUFI_EVENT_REQ_CONNECT_TO_AP
enumerator ESP_BLUFI_EVENT_REQ_DISCONNECT_FROM_AP
enumerator ESP_BLUFI_EVENT_GET_WIFI_STATUS
enumerator ESP_BLUFI_EVENT_DEAUTHENTICATE_STA
enumerator ESP_BLUFI_EVENT_RECV_STA_BSSID
enumerator ESP_BLUFI_EVENT_RECV_STA_SSID
enumerator ESP_BLUFI_EVENT_RECV_STA_PASSWD
enumerator ESP_BLUFI_EVENT_RECV_SOFTAP_SSID
enumerator ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD
enumerator ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM
enumerator ESP_BLUFI_EVENT_RECV_SOFTAP_AUTH_MODE
enumerator ESP_BLUFI_EVENT_RECV_SOFTAP_CHANNEL
enumerator ESP_BLUFI_EVENT_RECV_USERNAME
enumerator ESP_BLUFI_EVENT_RECV_CA_CERT
enumerator ESP_BLUFI_EVENT_RECV_CLIENT_CERT
enumerator ESP_BLUFI_EVENT_RECV_SERVER_CERT
enumerator ESP_BLUFI_EVENT_RECV_CLIENT_PRIV_KEY
enumerator ESP_BLUFI_EVENT_RECV_SERVER_PRIV_KEY
enumerator ESP_BLUFI_EVENT_RECV_SLAVE_DISCONNECT_BLE
enumerator ESP_BLUFI_EVENT_GET_WIFI_LIST
enumerator ESP_BLUFI_EVENT_REPORT_ERROR
enumerator ESP_BLUFI_EVENT_RECV_CUSTOM_DATA

enum esp_blufi_sta_conn_state_t
BLUFI config status.
Values:

enumerator ESP_BLUFI_STA_CONN_SUCCESS
enumerator ESP_BLUFI_STA_CONN_FAIL
enumerator ESP_BLUFI_STA_CONNECTING
enumerator ESP_BLUFI_STA_NO_IP

enum esp_blufi_init_state_t
BLUFI init status.
Values:

enumerator ESP_BLUFI_INIT_OK
enumerator ESP_BLUFI_INIT_FAILED

enum esp_blufi_deinit_state_t
BLUFI deinit status.
Values:

enumerator ESP_BLUFI_DEINIT_OK
enumerator ESP_BLUFI_DEINIT_FAILED

enum esp_blufi_error_state_t
Values:

enumerator ESP_BLUFI_SEQUENCE_ERROR
enumerator ESP_BLUFI_CHECKSUM_ERROR
enumerator ESP_BLUFI_DECRYPT_ERROR
enumerator ESP_BLUFI_ENCRYPT_ERROR
enumerator ESP_BLUFI_INIT_SECURITY_ERROR
enumerator ESP_BLUFI_DH_MALLOC_ERROR
enumerator ESP_BLUFI_DH_PARAM_ERROR
enumerator ESP_BLUFI_READ_PARAM_ERROR
enumerator ESP_BLUFI_MAKE_PUBLIC_ERROR
enumerator ESP_BLUFI_DATA_FORMAT_ERROR
enumerator ESP_BLUFI_CALC_MD5_ERROR
enumerator ESP_BLUFI_WIFI_SCAN_FAIL
enumerator ESP_BLUFI_MSG_STATE_ERROR

2.3.3 CLASSIC BT

CLASSIC BLUETOOTH GAP API

API Reference

Header File

• components/bt/host/bluedroid/api/include/api/esp_gap_bt_api.h

Functions

static inline uint32_t esp_bt_gap_get_cod_srvc (uint32_t cod)
get major service field of COD

Parameters cod - [in] Class of Device

Returns major service bits

static inline uint32_t esp_bt_gap_get_cod_major_dev (uint32_t cod)
get major device field of COD

Parameters cod - [in] Class of Device

Returns major device bits

static inline uint32_t esp_bt_gap_get_cod_minor_dev (uint32_t cod)
get minor service field of COD

Parameters cod - [in] Class of Device

Returns minor service bits

static inline uint32_t esp_bt_gap_get_cod_format_type (uint32_t cod)
get format type of COD

Parameters cod - [in] Class of Device

Returns format type
static inline bool esp_bt_gap_is_valid_cod (uint32_t cod)
    decide the integrity of COD

    Parameters cod [in] Class of Device

    Returns
    • true if cod is valid
    • false otherwise

esp_err_t esp_bt_gap_register_callback (esp_bt_gap_cb_t callback)
    register callback function. This function should be called after esp_bluedroid_enable() completes successfully

    Returns
    • ESP_OK : Succeed
    • ESP_FAIL : others

esp_err_t esp_bt_gap_set_scan_mode (esp_bt_connection_mode_t c_mode, esp_bt_discovery_mode_t d_mode)
    Set discoverability and connectability mode for legacy bluetooth. This function should be called after esp_bluedroid_enable() completes successfully.

    Parameters
    • c_mode [in]: one of the enums of esp_bt_connection_mode_t
    • d_mode [in]: one of the enums of esp_bt_discovery_mode_t

    Returns
    • ESP_OK : Succeed
    • ESP_ERR_INVALID_ARG : if argument invalid
    • ESP_ERR_INVALID_STATE : if bluetooth stack is not yet enabled
    • ESP_FAIL : others

esp_err_t esp_bt_gap_start_discovery (esp_bt_inq_mode_t mode, uint8_t inq_len, uint8_t num_rsps)
    This function starts Inquiry and Name Discovery. This function should be called after esp_bluedroid_enable() completes successfully. When Inquiry is halted and cached results do not contain device name, then Name Discovery will connect to the peer target to get the device name. esp bt_gap cb t will be called with ESP BT GAP DISC_STATE_CHANGED_EVT when Inquiry is started or Name Discovery is completed. esp bt_gap cb t will be called with ESP BT GAP DISC_RES_EVT each time the two types of discovery results are got.

    Parameters
    • mode [in] - Inquiry mode
    • inq_len [in] - Inquiry duration in 1.28 sec units, ranging from 0x01 to 0x30. This parameter only specifies the total duration of the Inquiry process,
    – when this time expires, Inquiry will be halted.
    • num_rsps [in] - Number of responses that can be received before the Inquiry is halted, value 0 indicates an unlimited number of responses.

    Returns
    • ESP_OK : Succeed
    • ESP_ERR_INVALID_STATE : if bluetooth stack is not yet enabled
    • ESP_ERR_INVALID_ARG : if invalid parameters are provided
    • ESP_FAIL : others

esp_err_t esp_bt_gap_cancel_discovery (void)
    Cancel Inquiry and Name Discovery. This function should be called after esp_bluedroid_enable() completes successfully. esp bt_gap cb t will be called with ESP BT GAP_DISC_STATE_CHANGED_EVT if Inquiry or Name Discovery is cancelled by calling this function.

    Returns
    • ESP_OK : Succeed
    • ESP_ERR_INVALID_STATE : if bluetooth stack is not yet enabled
    • ESP_FAIL : others
**esp_err_t esp_bt_gap_get_remote_services(esp_bd_addr_t remote_bda)**

Start SDP to get remote services. This function should be called after esp_bluedroid_enable() completes successfully. esp_bt_gap_cb_t will be called with ESP_BT_GAP_RMT_SRVCS_EVT after service discovery ends.

**Returns**
- ESP_OK : Succeed
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_bt_gap_get_remote_service_record(esp_bd_addr_t remote_bda, esp_bt_uuid_t *uuid)**

Start SDP to look up the service matching uuid on the remote device. This function should be called after esp_bluedroid_enable() completes successfully.

esp_bt_gap_cb_t will be called with ESP_BT_GAP_RMT_SRVC_REC_EVT after service discovery ends.

**Returns**
- ESP_OK : Succeed
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**uint8_t *esp_bt_gap_resolve_eir_data(uint8_t*eir, esp_bt_eir_type_t type,uint8_t*length)**

This function is called to get EIR data for a specific type.

**Parameters**
- eir – [in] - pointer of raw eir data to be resolved
- type – [in] - specific EIR data type
- length – [out] - return the length of EIR data excluding fields of length and data type

**Returns**
- pointer of starting position of eir data excluding eir data type, NULL if not found

**esp_err_t esp_bt_gap_config_eir_data(esp_bt_eir_data_t *eir_data)**

This function is called to config EIR data.

**Parameters**
eir_data – [in] - pointer of EIR data content

**Returns**
- ESP_OK : Succeed
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_INVALID_ARG: if param is invalid
- ESP_FAIL: others

**esp_err_t esp_bt_gap_set_cod(esp_bt_cod_t cod, esp_bt_cod_mode_t mode)**

This function is called to set class of device. The structure esp_bt_gap_cb_t will be called with ESP_BT_GAP_SET_COD_EVT after set COD ends. This function should be called after Bluetooth profiles are initialized, otherwise the user configured class of device can be overwritten. Some profiles have special restrictions on class of device, and changes may make these profiles unable to work.

**Parameters**
- cod – [in] - class of device
- mode – [in] - setting mode

**Returns**
- ESP_OK : Succeed
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_INVALID_ARG: if param is invalid
- ESP_FAIL: others
\textbf{esp_err_t} \textbf{esp\_bt\_gap\_get\_cod}(\textbf{esp\_bt\_cod\_t}*\text{cod})

This function is called to get class of device.

**Parameters** \text{cod} [\textbf{out}] - class of device

**Returns**
- ESP_OK : Succeed
- ESP_FAIL : others

\textbf{esp_err_t} \textbf{esp\_bt\_gap\_read\_rssi\_delta}(\textbf{esp\_bd\_addr\_t}\ \text{remote\_addr})

This function is called to read RSSI delta by address after connected. The RSSI value returned by ESP_BT_GAP_READ_RSSI_DELTA_EVT.

**Parameters** \text{remote\_addr} [\textbf{in}] - remote device address, corresponding to a certain connection handle

**Returns**
- ESP_OK : Succeed
- ESP_FAIL : others

\textbf{esp_err_t} \textbf{esp\_bt\_gap\_remove\_bond\_device}(\textbf{esp\_bd\_addr\_t}\ \text{bd\_addr})

Removes a device from the security database list of peer device.

**Parameters** \text{bd\_addr} [\textbf{in}] : BD address of the peer device

**Returns** - ESP_OK : success
- ESP_FAIL : failed

\textbf{int} \textbf{esp\_bt\_gap\_get\_bond\_device\_num}(\textbf{void})

Get the device number from the security database list of peer device. It will return the device bonded number immediately.

**Returns** - \'>= 0\' : bonded devices number
- ESP_FAIL : failed

\textbf{esp_err_t} \textbf{esp\_bt\_gap\_get\_bond\_device\_list}(\textbf{int}*\text{dev\_num}, \textbf{esp\_bd\_addr\_t}*\text{dev\_list})

Get the device from the security database list of peer device. It will return the device bonded information immediately.

**Parameters**
- \text{dev\_num} -[\textbf{inout}] Indicate the dev_list array(buffer) size as input. If dev_num is large enough, it means the actual number as output. Suggest that dev_num value equal to esp_ble_get_bond_device_num().
- \text{dev\_list} -[\textbf{out}] an array(buffer) of esp_bd_addr_t type. Use for storing the bonded devices address. The dev_list should be allocated by who call this API.

**Returns**
- ESP_OK : Succeed
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

\textbf{esp_err_t} \textbf{esp\_bt\_gap\_set\_pin}(\textbf{esp\_bt\_pin\_type\_t}\ \text{pin\_type}, \textbf{uint8\_t}\ \text{pin\_code\_len}, \textbf{esp\_bt\_pin\_code\_t}\ \text{pin\_code})

Set pin type and default pin code for legacy pairing.

**Parameters**
- \text{pin\_type} -[\textbf{in}] Use variable or fixed pin. If pin_type is ESP_BT_PIN_TYPE_VARIABLE, pin_code and pin_code_len will be ignored, and ESP_BT_GAP_PIN_REQ_EVT will come when control requests for pin code. Else, will use fixed pin code and not callback to users.
- \text{pin\_code\_len} -[\textbf{in}] Length of pin_code
- \text{pin\_code} -[\textbf{in}] Pin code

**Returns** - ESP_OK : success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other : failed
Chapter 2. API Reference

```c
esp_err_t esp_bt_gap_pin_reply(esp_bd_addr_t bd_addr, bool accept, uint8_t pin_code_len, esp_bt_pin_code_t pin_code)
```

Reply the pin_code to the peer device for legacy pairing when ESP_BT_GAP_PIN_REQ_EVT is coming.

**Parameters**
- `bd_addr` - [in] BD address of the peer
- `accept` - [in] Pin_code reply successful or declined.
- `pin_code_len` - [in] Length of pin_code
- `pin_code` - [in] Pin_code

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed

```c
esp_err_t esp_bt_gap_set_security_param(esp_bt_sp_param_t param_type, void* value, uint8_t len)
```

Set a GAP security parameter value. Overrides the default value.

**Parameters**
- `param_type` - [in]: the type of the param which is to be set
- `value` - [in]: the param value
- `len` - [in]: the length of the param value

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed

```c
esp_err_t esp_bt_gap_ssp_passkey_reply(esp_bd_addr_t bd_addr, bool accept, uint32_t passkey)
```

Reply the key value to the peer device in the legacy connection stage.

**Parameters**
- `bd_addr` - [in]: BD address of the peer
- `accept` - [in]: passkey entry successful or declined.
- `passkey` - [in]: passkey value, must be a 6 digit number, can be lead by 0.

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed

```c
esp_err_t esp_bt_gap_ssp_confirm_reply(esp_bd_addr_t bd_addr, bool accept)
```

Reply the confirm value to the peer device in the legacy connection stage.

**Parameters**
- `bd_addr` - [in]: BD address of the peer device
- `accept` - [in]: numbers to compare are the same or different

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed

```c
esp_err_t esp_bt_gap_set_afh_channels(esp_bt_gap_afh_channels channels)
```

Set the AFH channels.

**Parameters**
- `channels` - [in]: The n th such field (in the range 0 to 78) contains the value for channel n: 0 means channel n is bad. 1 means channel n is unknown. The most significant bit is reserved and shall be set to 0. At least 20 channels shall be marked as unknown.

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed

```c
esp_err_t esp_bt_gap_read_remote_name(esp_bd_addr_t remote_bda)
```

Read the remote device name.

**Parameters**
- `remote_bda` - [in] The remote device’s address

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed
**esp_err_t** **esp_bt_gap_set_qos** *(esp_bd_addr_t remote_bda, uint32_t poll)*

Config Quality of Service.

**Parameters**

- **remote_bda** - [in] The remote device’s address
- **poll** - [in] Poll interval, the maximum time between transmissions which from the master to a particular slave on the ACL logical transport. unit is 0.625ms

**Returns**

- **ESP_OK**: success
- **ESP_ERR_INVALID_STATE**: if Bluetooth stack is not yet enabled
- **other**: failed

**Unions**

union **esp_bt_gap_cb_param_t**

#include `<esp_gap_bt_api.h>` GAP state callback parameters.

**Public Members**

- **struct esp_bt_gap_cb_param_t::disc_res_param** **disc_res**
  discovery result parameter struct

- **struct esp_bt_gap_cb_param_t::disc_state_changed_param** **disc_st_chg**
  discovery state changed parameter struct

- **struct esp_bt_gap_cb_param_t::rmt_srvcs_param** **rmt_srvcs**
  services of remote device parameter struct

- **struct esp_bt_gap_cb_param_t::rmt_srvc_rec_param** **rmt_srvc_rec**
  specific service record from remote device parameter struct

- **struct esp_bt_gap_cb_param_t::read_rssi_delta_param** **read_rssi_delta**
  read rssi parameter struct

- **struct esp_bt_gap_cb_param_t::config_eir_data_param** **config_eir_data**
  config EIR data

- **struct esp_bt_gap_cb_param_t::auth_cmpl_param** **auth_cmpl**
  authentication complete parameter struct

- **struct esp_bt_gap_cb_param_t::pin_req_param** **pin_req**
  pin request parameter struct

- **struct esp_bt_gap_cb_param_t::cfm_req_param** **cfm_req**
  confirm request parameter struct

- **struct esp_bt_gap_cb_param_t::key_notif_param** **key_notif**
  passkey notif parameter struct

- **struct esp_bt_gap_cb_param_t::key_req_param** **key_req**
  passkey request parameter struct
struct esp_bt_gap_cb_param_t::set_afh_channels_param set_afh_channels
    set AFH channel parameter struct

struct esp_bt_gap_cb_param_t::read_rmt_name_param read_rmt_name
    read Remote Name parameter struct

struct esp_bt_gap_cb_param_t::mode_chg_param mode_chg
    mode change event parameter struct

struct esp_bt_gap_cb_param_t::bt_remove_bond_dev_cmplEvt_param remove_bond_dev_cmpl
    Event parameter of ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT

struct esp_bt_gap_cb_param_t::qos_cmpl_param qos_cmpl
    QoS complete parameter struct

struct esp_bt_gap_cb_param_t::acl_conn_cmpl_stat_param acl_conn_cmpl_stat
    ACL connection complete status parameter struct

struct esp_bt_gap_cb_param_t::acl_disconn_cmpl_stat_param acl_disconn_cmpl_stat
    ACL disconnection complete status parameter struct

struct acl_conn_cmpl_stat_param
    #include <esp_gap_bt_api.h> ESP_BT_GAP_ACL_CONN_CMPL_STAT_EVT.

Public Members

esp_bt_status_t stat
    ACL connection status

uint16_t handle
    ACL connection handle

esp_bd_addr_t bda
    remote bluetooth device address

struct acl_disconn_cmpl_stat_param
    #include <esp_gap_bt_api.h> ESP_BT_GAP_ACL_DISCONN_CMPL_STAT_EVT.

Public Members

esp_bt_status_t reason
    ACL disconnection reason

uint16_t handle
    ACL connection handle


```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
struct auth_cmpl_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_AUTH_CMPL_EVT.
```

**Public Members**

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
esp_bt_status_t stat
authentication complete status
```

```c
uint8_t device_name[ESP_BT_GAP_MAX_BDNAME_LEN + 1]
device name
```

```c
struct bt_remove_bond_dev_cmpl_evt_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT.
```

**Public Members**

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
esp_bt_status_t status
Indicate the remove bond device operation success status
```

```c
struct cfm_req_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_CFM_REQ_EVT.
```

**Public Members**

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
uint32_t num_val
the numeric value for comparison.
```

```c
struct config_eir_data_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_CONFIG_EIR_DATA_EVT*.
```

**Public Members**
**Chapter 2. API Reference**

**esp_bt_status_t** `stat`
- config EIR status: `ESP_BT_STATUS_SUCCESS`: config success
- `ESP_BT_STATUS_EIR_TOO_LARGE`: the EIR data is more than 240B. The EIR may not contain the whole data. others: failed

```c
uint8_t eir_type_num
```
the number of EIR types in EIR type

```c
esp_bt_eir_type_t eir_type[ESP_BT_EIR_TYPE_MAX_NUM]
```
EIR types in EIR type

**struct** `disc_res_param`
- `#include <esp_gap_bt_api.h>` ESP_BT_GAP_DISC_RES_EVT.

**Public Members**

```c
esp_bd_addr_t bda
```
remote bluetooth device address

```c
int num_prop
```
number of properties got

```c
esp_bt_gap_dev_prop_t *prop
```
properties discovered from the new device

**struct** `disc_state_changed_param`
- `#include <esp_gap_bt_api.h>` ESP_BT_GAP_DISC_STATE_CHANGED_EVT.

**Public Members**

```c
esp_bt_gap_discovery_state_t state
```
discovery state

**struct** `key_notif_param`
- `#include <esp_gap_bt_api.h>` ESP_BT_GAP_KEY_NOTIF_EVT.

**Public Members**

```c
esp_bd_addr_t bda
```
remote bluetooth device address

```c
uint32_t passkey
```
the numeric value for passkey entry.

**struct** `key_req_param`
- `#include <esp_gap_bt_api.h>` ESP_BT_GAP_KEY_REQ_EVT.
Public Members

```c
esp_bd_addr_t bda
    remote bluetooth device address
```

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_MODE_CHG_EVT.
```

Public Members

```c
esp_bd_addr_t bda
    remote bluetooth device address
```

```c
esp_bt_pm_mode_t mode
    PM mode
```

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_PIN_REQ_EVT.
```

Public Members

```c
esp_bd_addr_t bda
    remote bluetooth device address
```

```c
bool min_16_digit
    TRUE if the pin returned must be at least 16 digits
```

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_QOS_CMPL_EVT.
```

Public Members

```c
esp_bt_status_t stat
    QoS status
```

```c
esp_bd_addr_t bda
    remote bluetooth device address
```

```c
uint32_t t_poll
    poll interval, the maximum time between transmissions which from the master to a particular slave on the ACL logical transport. unit is 0.625ms.
```

```c
#include <esp_gap_bt_api.h> ESP_BT_GAP_READ_REMOTE_NAME_EVT.
```
### Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
esp_bt_status_t stat
read Remote Name status
```

```c
uint8_t rmt_name[ESP_BT_GAP_MAX_BDNAME_LEN + 1]
Remote device name
```

```c
struct read_rssi_delta_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_READ_RSSI_DELTA_EVT *.
```

### Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
esp_bt_status_t stat
read rss status
```

```c
int8_t rssi_delta
rssi delta value range -128 ~127. The value zero indicates that the RSSI is inside the Golden Receive Power Range, the Golden Receive Power Range is from ESP_BT_GAP_RSSI_LOW_THRLD to ESP_BT_GAP_RSSI_HIGH_THRLD
```

```c
struct rmt_srvc_rec_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_RMT_SRVC_REC_EVT.
```

### Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```

```c
esp_bt_status_t stat
service search status
```

```c
struct rmt_srvcs_param
#include <esp_gap_bt_api.h> ESP_BT_GAP_RMT_SRVCS_EVT.
```

### Public Members

```c
esp_bd_addr_t bda
remote bluetooth device address
```
\texttt{esp\_bt\_status\_t stat}

service search status

\texttt{int num\_uuids}

number of UUID in \texttt{uuid\_list}

\texttt{esp\_bt\_uuid\_t *uuid\_list}

list of service UUIDs of remote device

\texttt{struct set\_afh\_channels\_param}

\#include <esp\_gap\_bt\_api.h> ESP_BT_GAP_SET_AFH_CHANNELS_EVT.

**Public Members**

\texttt{esp\_bt\_status\_t stat}

set AFH channel status

**Structures**

\texttt{struct esp\_bt\_cod\_t}

Class of device.

**Public Members**

\texttt{uint32\_t reserved\_2}

undefined

\texttt{uint32\_t minor}

minor class

\texttt{uint32\_t major}

major class

\texttt{uint32\_t service}

service class

\texttt{uint32\_t reserved\_8}

undefined

\texttt{struct esp\_bt\_gap\_dev\_prop\_t}

Bluetooth Device Property Descriptor.

**Public Members**

\texttt{esp\_bt\_gap\_dev\_prop\_type\_t type}

Device property type
int **len
Device property value length

void *val
Device property value

struct esp_bt_eir_data_t
EIR data content, according to “Supplement to the Bluetooth Core Specification”.

Public Members

bool fec_required
FEC is required or not, true by default

bool include_txpower
EIR data include TX power, false by default

bool include_uuid
EIR data include UUID, false by default

bool include_name
EIR data include device name, true by default

uint8_t flag
EIR flags, see ESP_BT_EIR_FLAG for details, EIR will not include flag if it is 0, 0 by default

uint16_t manufacturer_len
Manufacturer data length, 0 by default

uint8_t *p_manufacturer_data
Manufacturer data point

uint16_t url_len
URL length, 0 by default

uint8_t *p_url
URL point

Macros

ESP_BT_GAP_RSSI_HIGH_THRLD
RSSI threshold.
High RSSI threshold

ESP_BT_GAP_RSSI_LOW_THRLD
Low RSSI threshold

ESP_BT_GAP_AFH_CHANNELS_LEN
**ESP_BT_GAP_MAX_BDNAME_LEN**

Maximum bytes of Bluetooth device name.

**ESP_BT_GAP_EIR_DATA_LEN**

Maximum size of EIR Significant part.

**ESP_BT_EIR_TYPE_FLAGS**

Extended Inquiry Response data type.
Flag with information such as BR/EDR and LE support

**ESP_BT_EIR_TYPE_INCMPL_16BITS_UUID**

Incomplete list of 16-bit service UUIDs

**ESP_BT_EIR_TYPE_CMPL_16BITS_UUID**

Complete list of 16-bit service UUIDs

**ESP_BT_EIR_TYPE_INCMPL_32BITS_UUID**

Incomplete list of 32-bit service UUIDs

**ESP_BT_EIR_TYPE_CMPL_32BITS_UUID**

Complete list of 32-bit service UUIDs

**ESP_BT_EIR_TYPE_INCMPL_128BITS_UUID**

Incomplete list of 128-bit service UUIDs

**ESP_BT_EIR_TYPE_CMPL_128BITS_UUID**

Complete list of 128-bit service UUIDs

**ESP_BT_EIR_TYPE_SHORT_LOCAL_NAME**

Shortened Local Name

**ESP_BT_EIR_TYPE_CMPL_LOCAL_NAME**

Complete Local Name

**ESP_BT_EIR_TYPE_TX_POWER_LEVEL**

Tx power level, value is 1 octet ranging from -127 to 127, unit is dBm

**ESP_BT_EIR_TYPE_URL**

Uniform resource identifier

**ESP_BT_EIR_TYPE_MANU_SPECIFIC**

Manufacturer specific data

**ESP_BT_EIR_TYPE_MAX_NUM**

MAX number of EIR type

**ESP_BT_EIR_FLAG_LIMIT_DISC**
ESP_BT_EIR_FLAG_GEN_DISC

ESP_BT_EIR_FLAG_BREDR_NOT_SPT

ESP_BT_EIR_FLAG_DMT_CONTROLLER_SPT

ESP_BT_EIR_FLAG_DMT_HOST_SPT

ESP_BT_EIR_MAX_LEN

ESP_BT_PIN_CODE_LEN
    Max pin code length

ESP_BT_IO_CAP_OUT

ESP_BT_IO_CAP_IO

ESP_BT_IO_CAP_IN

ESP_BT_IO_CAP_NONE

ESP_BT_PM_MD_ACTIVE
    Active mode

ESP_BT_PM_MD_HOLD
    Hold mode

ESP_BT_PM_MD_SNIFF
    Sniff mode

ESP_BT_PM_MD_PARK
    Park state

ESP_BT_COD_SRVC_BIT_MASK
    Bits of major service class field.
    Major service bit mask

ESP_BT_COD_SRVC_BIT_OFFSET
    Major service bit offset

ESP_BT_COD_MAJOR_DEV_BIT_MASK
    Bits of major device class field.
    Major device bit mask

ESP_BT_COD_MAJOR_DEV_BIT_OFFSET
    Major device bit offset
Chapter 2. API Reference

ESP_BT_COD_MINOR_DEV_BIT_MASK
   Bits of minor device class field.
   Minor device bit mask

ESP_BT_COD_MINOR_DEV_BIT_OFFSET
   Minor device bit offset

ESP_BT_COD_FORMAT_TYPE_BIT_MASK
   Bits of format type.
   Format type bit mask

ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET
   Format type bit offset

ESP_BT_COD_FORMAT_TYPE_1
   Class of device format type 1.

ESP_BT_GAP_MIN_INQ_LEN
   Minimum and Maximum inquiry length Minimum inquiry duration, unit is 1.28s

ESP_BT_GAP_MAX_INQ_LEN
   Maximum inquiry duration, unit is 1.28s

ESP_BT_GAP_TPOLL_MIN
   Minimum, Default and Maximum poll interval Minimum poll interval, unit is 625 microseconds

ESP_BT_GAP_TPOLL_DFT
   Default poll interval, unit is 625 microseconds

ESP_BT_GAP_TPOLL_MAX
   Maximum poll interval, unit is 625 microseconds

Type Definitions

typedef uint8_t esp_bt_gap_afh_channels[ESP_BT_GAP_AFH_CHANNELS_LEN]

typedef uint8_t esp_bt_eir_type_t

typedef uint8_t esp_bt_pin_code_t[ESP_BT_PIN_CODE_LEN]
   Pin Code (upto 128 bits) MSB is 0

typedef uint8_t esp_bt_io_cap_t
   Combination of the IO Capability

typedef uint8_t esp_bt_pm_mode_t

typedef void (*esp_bt_gap_cb_t)(esp_bt_gap_cb_event_t event, esp_bt_gap_cb_param_t *param)
   bluetooth GAP callback function type
**Param event**: Event type

**Param param**: Pointer to callback parameter

### Enumerations

#### `esp_bt_cod_mode_t`

- **Value**: class of device settings

  - **Enumerator** `ESP_BT_SET_COD_MAJOR_MINOR`: overwrite major, minor class
  - **Enumerator** `ESP_BT_SET_COD_SERVICE_CLASS`: set the bits in the input, the current bit will remain
  - **Enumerator** `ESP_BT_CLR_COD_SERVICE_CLASS`: clear the bits in the input, others will remain
  - **Enumerator** `ESP_BT_SET_COD_ALL`: overwrite major, minor, set the bits in service class
  - **Enumerator** `ESP_BT_INIT_COD`: overwrite major, minor, and service class

#### `esp_bt_connection_mode_t`

- **Value**: Discoverability and Connectability mode.

  - **Enumerator** `ESP_BT_NON_CONNECTABLE`: Non-connectable
  - **Enumerator** `ESP_BT_CONNECTABLE`: Connectable

#### `esp_bt_discovery_mode_t`

- **Value**: 

  - **Enumerator** `ESP_BT_NON_DISCOVERABLE`: Non-discoverable
  - **Enumerator** `ESP_BT_LIMITED_DISCOVERABLE`: Limited Discoverable
  - **Enumerator** `ESP_BT_GENERAL_DISCOVERABLE`: General Discoverable

#### `esp_bt_gap_dev_prop_type_t`

- **Value**: Bluetooth Device Property type.

  - **Value**: 

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*Espressif Systems*  
*Release v5.1.2*  
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enumerator `ESP_BT_GAP_DEV_PROP_BDNAME`
   Bluetooth device name, value type is int8_t[]

enumerator `ESP_BT_GAP_DEV_PROP_COD`
   Class of Device, value type is uint32_t

enumerator `ESP_BT_GAP_DEV_PROP_RSSI`
   Received Signal strength indication, value type is int8_t, ranging from -128 to 127

enumerator `ESP_BT_GAP_DEV_PROP_EIR`
   Extended Inquiry Response, value type is uint8_t[]

enum `esp_bt_cod_srvc_t`
   Major service class field of Class of Device, multiple bits can be set.
   Values:

enumerator `ESP_BT_COD_SRVC_NONE`
   None indicates an invalid value

class `esp_bt_pin_type_t`
   Values:
enumerator **ESP_BT_PIN_TYPE_VARIABLE**
Refer to BTM_PIN_TYPE_VARIABLE

enumerator **ESP_BT_PIN_TYPE_FIXED**
Refer to BTM_PIN_TYPE_FIXED

**enum esp_bt_sp_param_t**

*Values:*

enumerator **ESP_BT_SP_IOCAP_MODE**
Set IO mode

**enum esp_bt_cod_major_dev_t**

*Major device class field of Class of Device.*

*Values:*

enumerator **ESP_BT_COD_MAJOR_DEV_MISC**
Miscellaneous

enumerator **ESP_BT_COD_MAJOR_DEV_COMPUTER**
Computer

enumerator **ESP_BT_COD_MAJOR_DEV_PHONE**
Phone (cellular, cordless, pay phone, modem)

enumerator **ESP_BT_COD_MAJOR_DEV_LAN_NAP**
LAN, Network Access Point

enumerator **ESP_BT_COD_MAJOR_DEV_AV**
Audio/Video (headset, speaker, stereo, video display, VCR)

enumerator **ESP_BT_COD_MAJOR_DEV_PERIPHERAL**
Peripheral (mouse, joystick, keyboard)

enumerator **ESP_BT_COD_MAJOR_DEV_IMAGING**
Imaging (printer, scanner, camera, display)

enumerator **ESP_BT_COD_MAJOR_DEV_WEARABLE**
Wearable

enumerator **ESP_BT_COD_MAJOR_DEV_TOY**
Toy

enumerator **ESP_BT_COD_MAJOR_DEV_HEALTH**
Health

enumerator **ESP_BT_COD_MAJOR_DEV_UNCATEGORIZED**
Uncategorized: device not specified
enum esp_bt_gap_discovery_state_t
    Bluetooth Device Discovery state
    Values:
    enumerator ESP_BT_GAP_DISCOVERY_STOPPED
        Device discovery stopped
    enumerator ESP_BT_GAP_DISCOVERY_STARTED
        Device discovery started

enum esp_bt_gap_cb_event_t
    BT GAP callback events.
    Values:
    enumerator ESP_BT_GAP_DISC_RES_EVT
        Device discovery result event
    enumerator ESP_BT_GAP_DISC_STATE_CHANGED_EVT
        Discovery state changed event
    enumerator ESP_BT_GAP_RMT_SRVCS_EVT
        Get remote services event
    enumerator ESP_BT_GAP_RMT_SRVC_REC_EVT
        Get remote service record event
    enumerator ESP_BT_GAP_AUTH_CMPL_EVT
        Authentication complete event
    enumerator ESP_BT_GAP_PIN_REQ_EVT
        Legacy Pairing Pin code request
    enumerator ESP_BT_GAP_CFM_REQ_EVT
        Security Simple Pairing User Confirmation request.
    enumerator ESP_BT_GAP_KEY_NOTIF_EVT
        Security Simple Pairing Passkey Notification
    enumerator ESP_BT_GAP_KEY_REQ_EVT
        Security Simple Pairing Passkey request
    enumerator ESP_BT_GAP_READ_RSSI_DELTA_EVT
        Read rssi event
    enumerator ESP_BT_GAP_CONFIG_EIR_DATA_EVT
        Config EIR data event
enumerator ESP_BT_GAP_SET_AFH_CHANNELS_EVT
    Set AFH channels event

enumerator ESP_BT_GAP_READ_REMOTE_NAME_EVT
    Read Remote Name event

enumerator ESP_BT_GAP_MODE_CHG_EVT

enumerator ESP_BT_GAP_REMOVE_BOND_DEV_COMPLETE_EVT
    remove bond device complete event

enumerator ESP_BT_GAP_QOS_CMPL_EVT
    QOS complete event

enumerator ESP_BT_GAP_ACL_CONN_CMPL_STAT_EVT
    ACL connection complete status event

enumerator ESP_BT_GAP_ACL_DISCONN_CMPL_STAT_EVT
    ACL disconnection complete status event

enumerator ESP_BT_GAP_EVT_MAX

enum esp_bt_inq_mode_t
    Inquiry Mode
    Values:

enumerator ESP_BT_INQ_MODE_GENERAL_INQUIRY
    General inquiry mode

enumerator ESP_BT_INQ_MODE_LIMITED_INQUIRY
    Limited inquiry mode

Bluetooth A2DP API

Application Example
    Check bluetooth/bluedroid/classic_bt folder in ESP-IDF examples, which contains the following application:
    • This is a A2DP sink client demo. This demo can be discovered and connected by A2DP source device and receive the audio stream from remote device - bluetooth/bluedroid/classic_bt/a2dp_sink

API Reference

Header File
    • components/bt/host/bluedroid/api/include/api/esp_a2dp_api.h
Functions

`esp_err_t esp_a2d_register_callback (esp_a2d_cb_t callback)`

Register application callback function to A2DP module. This function should be called only after esp_bluedroid_enable() completes successfully, used by both A2DP source and sink.

Parameters callback – [in] A2DP event callback function

Returns
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

`esp_err_t esp_a2d_sink_register_data_callback (esp_a2d_sink_data_cb_t callback)`

Register A2DP sink data output function; For now the output is PCM data stream decoded from SBC format. This function should be called only after esp_bluedroid_enable() completes successfully, used only by A2DP sink. The callback is invoked in the context of A2DP sink task whose stack size is configurable through menuconfig.

Parameters callback – [in] A2DP sink data callback function

Returns
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

`esp_err_t esp_a2d_sink_init (void)`

Initialize the bluetooth A2DP sink module. This function should be called after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_INIT_SUCCESS will reported to APP layer. Note: A2DP can work independently. If you want to use AVRC together, you should initiate AVRC first. This function should be called after esp_bluedroid_enable() completes successfully.

Returns
- ESP_OK: if the initialization request is sent successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_a2d_sink_deinit (void)`

De-initialize for A2DP sink module. This function should be called only after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_DEINIT_SUCCESS will reported to APP layer.

Returns
- ESP_OK: if the deinitialization request is sent successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_a2d_sink_connect (esp_bd_addr_t remote_bda)`

Connect to remote bluetooth A2DP source device. This API must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

Parameters remote_bda – [in] remote bluetooth device address

Returns
- ESP_OK: connect request is sent to lower layer successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_a2d_sink_disconnect (esp_bd_addr_t remote_bda)`

Disconnect from the remote A2DP source device. This API must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

Parameters remote_bda – [in] remote bluetooth device address

Returns
- ESP_OK: disconnect request is sent to lower layer successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others
**esp_err_t esp_a2d_sink_set_delay_value (uint16_t delay_value)**

Set delay reporting value. The delay value of sink is caused by buffering (including protocol stack and application layer), decoding and rendering. The default delay value is 120ms, if the set value is less than 120ms, the setting will fail. This API must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

**Parameters** delay_value  – [in] reporting value is in 1/10 millisecond

**Returns**
- ESP_OK: delay value is sent to lower layers successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_a2d_sink_get_delay_value (void)**

Get delay reporting value. This API must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

**Returns**
- ESP_OK: if the request is sent successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_a2d_media_ctrl (esp_a2d_media_ctrl_t ctrl)**

Media control commands. This API can be used for both A2DP sink and source and must be called after esp_a2d_sink_init() and before esp_a2d_sink_deinit().

**Parameters** ctrl  – [in] control commands for A2DP data channel

**Returns**
- ESP_OK: control command is sent to lower layer successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_a2d_source_init (void)**

Initialize the bluetooth A2DP source module. A2DP can work independently. If you want to use AVRC together, you should initiate AVRC first. This function should be called after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_INIT_SUCCESS will reported to the APP layer. Note: A2DP can work independently. If you want to use AVRC together, you should initiate AVRC first.

**Returns**
- ESP_OK: if the initialization request is sent to lower layer successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_a2d_source_deinit (void)**

De-initialize for A2DP source module. This function should be called only after esp_bluedroid_enable() completes successfully, and ESP_A2D_PROF_STATE_EVT with ESP_A2D_DEINIT_SUCCESS will reported to APP layer.

**Returns**
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_a2d_source_register_data_callback (esp_a2d_source_data_cb_t callback)**

Register A2DP source data input function. For now, the input should be PCM data stream. This function should be called only after esp_bluedroid_enable() completes successfully. The callback is invoked in the context of A2DP source task whose stack size is configurable through menuconfig.

**Parameters** callback  – [in] A2DP source data callback function

**Returns**
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer
esp_err_t esp_a2d_source_connect (esp_bd_addr_t remote_bda)

Connect to remote A2DP sink device. This API must be called after esp_a2d_source_init() and before esp_a2d_source_deinit().

Parameters remote_bda –[in] remote bluetooth device address

Returns
- ESP_OK: connect request is sent to lower layer successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

esp_err_t esp_a2d_source_disconnect (esp_bd_addr_t remote_bda)

Disconnect from the remote A2DP sink device. This API must be called after esp_a2d_source_init() and before esp_a2d_source_deinit().

Parameters remote_bda –[in] remote bluetooth device address

Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

Unions

union esp_a2d_cb_param_t

#include <esp_a2dp_api.h> A2DP state callback parameters.

Public Members

struct esp_a2d_cb_param_t:a2d_conn_stat_param conn_stat
A2DP connection status

struct esp_a2d_cb_param_t:a2d_audio_stat_param audio_stat
audio stream playing state

struct esp_a2d_cb_param_t:a2d_audio_cfg_param audio_cfg
media codec configuration information

struct esp_a2d_cb_param_t:media_ctrl_stat_param media_ctrl_stat
status in acknowledgement to media control commands

struct esp_a2d_cb_param_t:a2d_prof_stat_param a2d_prof_stat
status to indicate a2d prof init or deinit

struct esp_a2d_cb_param_t:a2d_psc_cfg_param a2d_psc_cfg_stat
status to indicate protocol service capabilities configured

struct esp_a2d_cb_param_t:a2d_set_stat_param a2d_set_delay_value_stat
A2DP sink set delay report value status

struct esp_a2d_cb_param_t:a2d_get_stat_param a2d_get_delay_value_stat
A2DP sink get delay report value status
struct esp_a2d_cb_param_t::a2d_report_delay_stat_param a2d_report_delay_value_stat
A2DP source received sink report value status

struct a2d_audio_cfg_param
#include <esp_a2dp_api.h> ESP_A2D_AUDIO_CFG_EVT.

Public Members

esp_bd_addr_t remote_bda
remote Bluetooth device address

esp_a2d_mcc_t mcc
A2DP media codec capability information

struct a2d_audio_stat_param
#include <esp_a2dp_api.h> ESP_A2D_AUDIO_STATE_EVT.

Public Members

esp_a2d_audio_state_t state
one of the values from esp_a2d_audio_state_t

esp_bd_addr_t remote_bda
remote Bluetooth device address

struct a2d_conn_stat_param
#include <esp_a2dp_api.h> ESP_A2D_CONNECTION_STATE_EVT.

Public Members

esp_a2d_connection_state_t state
one of values from esp_a2d_connection_state_t

esp_bd_addr_t remote_bda
remote Bluetooth device address

esp_a2d_disc_rsn_t disc_rsn
reason of disconnection for “DISCONNECTED”

struct a2d_get_stat_param
#include <esp_a2dp_api.h> ESP_A2D_SNK_GET_DELAY_VALUE_EVT.

Public Members

uint16_t delay_value
delay report value
struct a2d_prof_stat_param
#include <esp_a2dp_api.h> ESP_A2D_PROF_STATE_EVT.

Public Members

esp_a2d_init_state_t init_state
a2dp profile state param

struct a2d_psc_cfg_param
#include <esp_a2dp_api.h> ESP_A2D_SNK_PSC_CFG_EVT.

Public Members

esp_a2d_psc_t psc_mask
protocol service capabilities configured

struct a2d_report_delay_stat_param
#include <esp_a2dp_api.h> ESP_A2D_REPORT_SNK_DELAY_VALUE_EVT.

Public Members

uint16_t delay_value
delay report value

struct a2d_set_stat_param
#include <esp_a2dp_api.h> ESP_A2D_SNK_SET_DELAY_VALUE_EVT.

Public Members

esp_a2d_set_delay_value_state_t set_state
a2dp profile state param

uint16_t delay_value
delay report value

struct media_ctrl_stat_param
#include <esp_a2dp_api.h> ESP_A2D_MEDIA_CTRL_ACK_EVT.

Public Members

esp_a2d_media_ctrl_t cmd
media control commands to acknowledge

esp_a2d_media_ctrl_ack_t status
acknowledgement to media control commands
Structures

struct esp_a2d_mcc_t
A2DP media codec capabilities union.

Public Members

\texttt{esp\_a2d\_mct\_t} \texttt{type}
A2DP media codec type

\texttt{uint8\_t} \texttt{sbc}[\texttt{ESP\_A2D\_CIE\_LEN\_SBC}]
SBC codec capabilities

\texttt{uint8\_t} \texttt{m12}[\texttt{ESP\_A2D\_CIE\_LEN\_M12}]
MPEG-1,2 audio codec capabilities

\texttt{uint8\_t} \texttt{m24}[\texttt{ESP\_A2D\_CIE\_LEN\_M24}]
MPEG-2,4 AAC audio codec capabilities

\texttt{uint8\_t} \texttt{atrac}[\texttt{ESP\_A2D\_CIE\_LEN\_ATRAC}]
ATRAC family codec capabilities

union \texttt{esp\_a2d\_mcc\_t\_t::\{anonymous\} cie}
A2DP codec information element

Macros

\texttt{ESP\_A2D\_MCT\_SBC}
Media codec types supported by A2DP.

\texttt{SBC}

\texttt{ESP\_A2D\_MCT\_M12}
MPEG-1,2 Audio

\texttt{ESP\_A2D\_MCT\_M24}
MPEG-2,4 AAC

\texttt{ESP\_A2D\_MCT\_ATRAC}
ATRAC family

\texttt{ESP\_A2D\_MCT\_NON\_A2DP}
NON-A2DP

\texttt{ESP\_A2D\_PSC\_DELAY\_RPT}
Protocol service capabilities. This value is a mask.

\texttt{Delay\_Report}

\texttt{ESP\_A2D\_CIE\_LEN\_SBC}
**Type Definitions**

typedef uint8_t esp_a2d_mct_t

typedef uint16_t esp_a2d_psc_t

typedef void (*esp_a2d_cb_t)(esp_a2d_event_t event, esp_a2d_param_t *param)

A2DP profile callback function type.

- **Param event**: Event type
- **Param param**: Pointer to callback parameter

typedef void (*esp_a2d_sink_data_cb_t)(const uint8_t* buf, uint32_t len)

A2DP sink data callback function.

- **Param buf [in]**: pointer to the data received from A2DP source device and is PCM format decoded from SBC decoder; buf references to a static memory block and can be overwritten by upcoming data
- **Param len [in]**: size(in bytes) in buf

typedef int32_t (*esp_a2d_source_data_cb_t)(uint8_t *buf, int32_t len)

A2DP source data read callback function.

- **Param buf [in]**: buffer to be filled with PCM data stream from higher layer
- **Param len [in]**: size(in bytes) of data block to be copied to buf. -1 is an indication to user that data buffer shall be flushed
- **Return** size of bytes read successfully, if the argument len is -1, this value is ignored.

**Enumerations**

enum esp_a2d_connection_state_t

Bluetooth A2DP connection states.

*Values:*

- **enumerator ESP_A2D_CONNECTION_STATE_DISCONNECTED**: connection released
- **enumerator ESP_A2D_CONNECTION_STATE_CONNECTING**: connecting remote device
- **enumerator ESP_A2D_CONNECTION_STATE_CONNECTED**: connection established
- **enumerator ESP_A2D_CONNECTION_STATE_DISCONNECTING**: disconnecting remote device
enum `esp_a2d_disc_rsn_t`  
Bluetooth A2DP disconnection reason.  

Values:  

enumerator `ESP_A2D_DISC_RSN_NORMAL`  
Finished disconnection that is initiated by local or remote device  

enumerator `ESP_A2D_DISC_RSN_ABNORMAL`  
Abnormal disconnection caused by signal loss  

enum `esp_a2d_audio_state_t`  
Bluetooth A2DP datapath states.  

Values:  

enumerator `ESP_A2D_AUDIO_STATE_REMOTE_SUSPEND`  
audio stream datapath suspended by remote device  

enumerator `ESP_A2D_AUDIO_STATE_STOPPED`  
audio stream datapath stopped  

enumerator `ESP_A2D_AUDIO_STATE_STARTED`  
audio stream datapath started  

enum `esp_a2d_media_ctrl_ack_t`  
A2DP media control command acknowledgement code.  

Values:  

enumerator `ESP_A2D_MEDIA_CTRL_ACK_SUCCESS`  
media control command is acknowledged with success  

enumerator `ESP_A2D_MEDIA_CTRL_ACK_FAILURE`  
media control command is acknowledged with failure  

enumerator `ESP_A2D_MEDIA_CTRL_ACK_BUSY`  
media control command is rejected, as previous command is not yet acknowledged  

enum `esp_a2d_media_ctrl_t`  
A2DP media control commands.  

Values:  

enumerator `ESP_A2D_MEDIA_CTRL_NONE`  
Not for application use, use inside stack only.  

enumerator `ESP_A2D_MEDIA_CTRL_CHECK_SRC_RDY`  
check whether AVDTP is connected, only used in A2DP source  

enumerator `ESP_A2D_MEDIA_CTRL_START`  
command to set up media transmission channel
enumerator **ESP_A2D_MEDIA_CTRL_STOP**
command to stop media transmission

enumerator **ESP_A2D_MEDIA_CTRL_SUSPEND**
command to suspend media transmission

definition **esp_a2d_init_state_t**
Bluetooth A2DP Initiation states.
*Values:*

enumerator **ESP_A2D_DEINIT_SUCCESS**
A2DP profile deinit successful event

enumerator **ESP_A2D_INIT_SUCCESS**
A2DP profile deinit successful event

definition **esp_a2d_set_delay_value_state_t**
Bluetooth A2DP set delay report value states.
*Values:*

enumerator **ESP_A2D_SET_SUCCESS**
A2DP profile set delay report value successful

enumerator **ESP_A2D_SET_INVALID_PARAMS**
A2DP profile set delay report value is invalid parameter

definition **esp_a2d_cb_event_t**
A2DP callback events.
*Values:*

enumerator **ESP_A2D_CONNECTION_STATE_EVT**
connection state changed event

enumerator **ESP_A2D_AUDIO_STATE_EVT**
audio stream transmission state changed event

enumerator **ESP_A2D_AUDIO_CFG_EVT**
audio codec is configured, only used for A2DP SINK

enumerator **ESP_A2D_MEDIA_CTRL_ACK_EVT**
acknowledge event in response to media control commands

enumerator **ESP_A2D_PROF_STATE_EVT**
indicate a2dp init&deinit complete

enumerator **ESP_A2D_SNK_PSC_CFG_EVT**
protocol service capabilities configured, only used for A2DP SINK
enumerator **ESP_A2D_SNK_SET_DELAY_VALUE_EVT**
  indicate a2dp sink set delay report value complete, only used for A2DP SINK

enumerator **ESP_A2D_SNK_GET_DELAY_VALUE_EVT**
  indicate a2dp sink get delay report value complete, only used for A2DP SINK

enumerator **ESP_A2D_REPORT_SNK_DELAY_VALUE_EVT**
  report delay value, only used for A2DP SRC

**BT AVRCP APIs**

**Overview**  Bluetooth AVRCP reference APIs.

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_avrc_api.h

**Functions**

```c
esp_err_t esp_avrc_ct_register_callback(esp_avrc_ct_cb_t callback)
```

Register application callbacks to AVRCP module. This function should be called after esp_bluedroid_enable() completes successfully.

**Parameters**

- `callback`  [in] AVRCP controller callback function

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_avrc_ct_init(void)
```

Initialize the bluetooth AVRCP controller module. This function should be called after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be initialized before A2DP.

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_avrc_ct_deinit(void)
```

De-initialize AVRCP controller module. This function should be called after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be deinitialized before A2DP.

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_avrc_ct_send_set_player_value_cmd(uint8_t tl, uint8_t attr_id, uint8_t value_id)
```

Send player application settings command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

**Parameters**

- `tl`  [in]: transaction label, 0 to 15, consecutive commands should use different values
**attr_id** - [in] : player application setting attribute IDs from one of esp_avrc_ps_attr_ids_t

**value_id** - [in] : attribute value defined for the specific player application setting attribute

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_avrc_ct_send_get_rn_capabilities_cmd(uint8_t tl)`

Send GetCapabilities PDU to AVRCP target to retrieve remote device’s supported notification event_ids. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

**Parameters**

- `tl` - [in]: transaction label, 0 to 15, consecutive commands should use different values

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_avrc_ct_send_register_notification_cmd(uint8_t tl, uint8_t event_id, uint32_t event_parameter)`

Send register notification command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

**Parameters**

- `tl` - [in]: transaction label, 0 to 15, consecutive commands should use different values.
- `event_id` - [in]: id of events, e.g. ESP_AVRC_RN_PLAY_STATUS_CHANGE, ESP_AVRC_RN_TRACK_CHANGE, etc.
- `event_parameter` - [in]: playback interval for ESP_AVRC_RN_PLAY_POS_CHANGED; For other events, value of this parameter is ignored.

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_NOT_SUPPORTED: if the event_id is not supported in current implementation
- ESP_FAIL: others

`esp_err_t esp_avrc_ct_send_set_absolute_volume_cmd(uint8_t tl, uint8_t volume)`

Send set absolute volume command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

**Parameters**

- `tl` - [in]: transaction label, 0 to 15, consecutive commands should use different values
- `volume` - [in]: volume, 0 to 0x7f, means 0% to 100%

**Returns**

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_ERR_NOT_SUPPORTED: if the event_id is not supported in current implementation
- ESP_FAIL: others

`esp_err_t esp_avrc_ct_send_metadata_cmd(uint8_t tl, uint8_t attr_mask)`

Send metadata command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

**Parameters**

- `tl` - [in]: transaction label, 0 to 15, consecutive commands should use different values.
• **attr_mask** - [in] : mask of attributes, e.g. ESP_AVRC_MD_ATTR_ID_TITLE | ESP_AVRC_MD_ATTR_ID_ARTIST.

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_avrc_ct_send_passthrough_cmd(uint8_t tl, uint8_t key_code, uint8_t key_state)
```

Send passthrough command to AVRCP target. This function should be called after ESP_AVRC_CT_CONNECTION_STATE_EVT is received and AVRCP connection is established.

**Parameters**
- **tl** - [in] : transaction label, 0 to 15, consecutive commands should use different values.
- **key_code** - [in] : passthrough command code, e.g. ESP_AVRC_PT_CMD_PLAY, ESP_AVRC_PT_CMD_STOP, etc.
- **key_state** - [in] : passthrough command key state, ESP_AVRC_PT_CMD_STATE_PRESSED or ESP_AVRC_PT_CMD_STATE_RELEASED

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_avrc_tg_register_callback(esp_avrc_tg_cb_t callback)
```

Register application callbacks to AVRCP target module. This function should be called after esp_bluedroid_enable() completes successfully.

**Parameters**
- **callback** - [in] AVRCP target callback function

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_avrc_tg_init()
```

Initialize the bluetooth AVRCP target module, This function should be called after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be initialized before A2DP.

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_avrc_tg_deinit()
```

De-initialize AVRCP target module. This function should be called after after esp_bluedroid_enable() completes successfully. Note: AVRC cannot work independently, AVRC should be used along with A2DP and AVRC should be deinitialized before A2DP.

**Returns**
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```
esp_err_t esp_avrc_tg_get_psth_cmd_filter(esp_avrc_psth_filter_t filter, esp_avrc_psth_bit_mask_t *cmd_set)
```

Get the current filter of remote passthrough commands on AVRC target. Filter is given by filter type and bit mask for the passthrough commands. This function should be called after esp_avrc_tg_init(). For filter type ESP_AVRC_PSTH_FILTER_ALLOWED_CMD, the retrieved command set is constant and it covers all of the passthrough commands that can possibly be supported. For filter type ESP_AVRC_PSTH_FILTER_SUPPORT_COMMANDS, the retrieved command set covers the passthrough commands selected to be supported according to current configuration. The configuration can be changed using esp_avrc_tg_set_psth_cmd_filter().

---

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Returns

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not enabled or AVRC TG is not initialized
- ESP_ERR_INVALID_ARG: if filter type is invalid or cmd_set is NULL
- ESP_FAIL: otherwise

```c
esp_err_t esp_avrc_tg_set_psth_cmd_filter(esp_avrc_psth_filter_t filter, const esp_avrc_psth_bit_mask_t *cmd_set)
```

Set the filter of remote passthrough commands on AVRC target. Filter is given by filter type and bit mask for the passthrough commands. This function should be called after esp_avrc_tg_init().

If filter type is ESP_AVRC_PSTH_FILTER_SUPPORT_CMD, the passthrough commands which are set as given in cmd_set will generate ESP_AVRC_CT_PASSTHROUGH_RSP_EVT callback event and are auto-accepted in the protocol stack, other commands are replied with response type “NOT IMPLEMENTED” (8). The set of supported commands should be a subset of allowed command set. The allowed command set can be retrieved using esp_avrc_tg_get_psth_cmd_filter() with filter type “ESP_AVRC_PSTH_FILTER_ALLOWED_CMD”.

Filter type “ESP_AVRC_PSTH_FILTER_ALLOWED_CMD” does not apply to this function.

Returns

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not enabled
- ESP_ERR_INVALID_ARG: if filter type is invalid or cmd_set is NULL
- ESP_ERR_NOT_SUPPORTED: if filter type is ESP_AVRC_PSTH_FILTER_ALLOWED_CMD, or cmd_set includes commands that are not allowed

```c
bool esp_avrc_psth_bit_mask_operation(esp_avrc_bit_mask_op_t op, esp_avrc_psth_bit_mask_t *psth, esp_avrc_pt_cmd_t cmd)
```

Operate on the type `esp_avrc_psth_bit_mask_t` with regard to a specific PASSTHROUGH command.

Parameters

- `op` - [in] operation requested on the bit mask field
- `psth` - [in] pointer to passthrough command bit mask structure
- `cmd` - [in] passthrough command code

Returns

For operation ESP_AVRC_BIT_MASK_OP_SET or ESP_AVRC_BIT_MASK_OP_CLEAR, return true for a successful operation, otherwise return false. For operation ESP_AVRC_BIT_MASK_OP_TEST, return true if the corresponding bit is set, otherwise false.

```c
esp_err_t esp_avrc_tg_get_rn_evt_cap(esp_avrc_rn_evt_cap_t cap, esp_avrc_rn_evt_cap_mask_t *evt_set)
```

Get the requested event notification capabilities on local AVRC target. The capability is returned in a bit mask representation in `evt_set`. This function should be called after esp_avrc_tg_init().

For capability type “ESP_AVRC_RN_CAP_ALLOWED_EVT”, the retrieved event set is constant and it covers all of the notification events that can possibly be supported with current implementation.

For capability type ESP_AVRC_RN_CAP_SUPPORTED_EVT, the event set covers the notification events selected to be supported under current configuration. The configuration can be changed using esp_avrc_tg_set_rn_evt_cap().

Returns

- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not enabled or AVRC TG is not initialized
- ESP_ERR_INVALID_ARG: if cap is invalid or evt_set is NULL
- ESP_FAIL: otherwise
The event notification capabilities on local AVRCP target. The capability is given in a bit mask representation in \texttt{evt\_set} and must be a subset of allowed event IDs with current implementation. This function should be called after \texttt{esp\_avrc\_tg\_init()}.

**Returns**
- \texttt{ESP\_OK}: success
- \texttt{ESP\_ERR\_INVALID\_STATE}: if bluetooth stack is not enabled
- \texttt{ESP\_ERR\_INVALID\_ARG}: if \texttt{evt\_set} is NULL

\begin{verbatim}
bool esp_avrc_rn_evt_bit_mask_operation(esp_avrc_bit_mask_op_t \texttt{op},
    esp_avrc_rn_evt_cap_mask_t *\texttt{events},
    esp_avrc_rn_event_ids_t \texttt{event\_id})
\end{verbatim}

Operate on the type \texttt{esp\_avrc\_rn\_evt\_cap\_mask} with regard to a specific event.

For operation \texttt{ESP\_AVRC\_BIT\_MASK\_OP\_TEST}, return true if the corresponding bit is set, otherwise false.

**Parameters**
- \texttt{op} \texttt{[in]} operation requested on the bit mask field
- \texttt{events} \texttt{[in]} pointer to event notification capability bit mask structure
- \texttt{event\_id} \texttt{[in]} notification event code

**Returns**
For operation \texttt{ESP\_AVRC\_BIT\_MASK\_OP\_SET} or \texttt{ESP\_AVRC\_BIT\_MASK\_OP\_CLEAR}, return true for a successful operation, otherwise return false.

\begin{verbatim}
esp_err_t esp_avrc_tg_send_rn_rsp(esp_avrc_rn_event_ids_t \texttt{event\_id},
    esp_avrc_rn_rsp_t \texttt{rsp},
    esp_avrc_rn_param_t *\texttt{param})
\end{verbatim}

Send RegisterNotification Response to remote AVRCP controller. Local event notification capability can be set using \texttt{esp\_avrc\_tg\_set\_rn\_evt\_cap()}, in a bit mask representation in \texttt{evt\_set}. This function should be called after \texttt{esp\_avrc\_tg\_init()}.

**Parameters**
- \texttt{event\_id} \texttt{[in]} notification event ID that remote AVRCP CT registers
- \texttt{rsp} \texttt{[in]} notification response code
- \texttt{param} \texttt{[in]} parameters included in the specific notification

**Returns**
- \texttt{ESP\_OK}: success
- \texttt{ESP\_ERR\_INVALID\_STATE}: if bluetooth stack is not enabled or AVRC TG is not initialized
- \texttt{ESP\_ERR\_INVALID\_ARG}: if \texttt{evt\_set} is NULL

**Unions**

\begin{verbatim}
union esp_avrc_rn_param_t
    #include <esp_avrc_api.h> AVRCP notification parameters.
\end{verbatim}

**Public Members**

\begin{verbatim}
uint8_t volume
    response data for ESP\_AVRC\_RN\_VOLUME\_CHANGE, ranges 0..127
\end{verbatim}

\begin{verbatim}
esp_avrc_playback_stat_t playback
    response data for ESP\_AVRC\_RN\_PLAY\_STATUS\_CHANGE
\end{verbatim}


```c
uint8_t elm_id[8]
    response data for ESP_AVRC_RN_TRACK_CHANGE

uint32_t play_pos
    response data for ESP_AVRC_RN_PLAY_POS_CHANGED, in millisecond

esp_avrc_batt_stat_t batt
    response data for ESP_AVRC_RN_BATTERY_STATUS_CHANGE

union esp_avrc_ct_cb_param_t
    #include <esp_avrc_api.h> AVRC controller callback parameters.

Public Members

struct esp_avrc_ct_cb_param_t::avrc_ct_conn_stat_param conn_stat
    AVRC connection status

struct esp_avrc_ct_cb_param_t::avrc_ct_psth_rsp_param psth_rsp
    passthrough command response

struct esp_avrc_ct_cb_param_t::avrc_ct_meta_rsp_param meta_rsp
    metadata attributes response

struct esp_avrc_ct_cb_param_t::avrc_ct_change_notify_param change_ntf
    notifications

struct esp_avrc_ct_cb_param_t::avrc_ct_rmt_feats_param rmt_feats
    AVRC features discovered from remote SDP server

struct esp_avrc_ct_cb_param_t::avrc_ct_get_rn_caps_rsp_param get_rn_caps_rsp
    get supported event capabilities response from AVRCP target

struct esp_avrc_ct_cb_param_t::avrc_ct_set_volume_rsp_param set_volume_rsp
    set absolute volume response event

struct avrc_ct_change_notify_param
    #include <esp_avrc_api.h> ESP_AVRC_CT_CHANGE_NOTIFY_EVT.

Public Members

uint8_t event_id
    id of AVRC event notification

esp_avrc_rn_param_t event_parameter
    event notification parameter

struct avrc_ct_conn_stat_param
    #include <esp_avrc_api.h> ESP_AVRC_CT_CONNECTION_STATE_EVT.
```
Chapter 2. API Reference

Public Members

bool \texttt{connected} \label{connected}
whether AVRC connection is set up

\texttt{esp_bd_addr_t \ remote\_bda} \label{remote\_bda}
remote bluetooth device address

\texttt{struct avrc\_ct\_get\_rn\_caps\_rsp\_param} \label{avrc\_ct\_get\_rn\_caps\_rsp\_param}
\#include <esp\_avrc\_api\_h> ESP\_AVRC\_CT\_GET\_RN\_CAPABILITIES\_RSP\__EVT.

Public Members

uint8\_t \texttt{cap\_count} \label{cap\_count}
number of items provided in event or company\_id according to cap\_id used

\texttt{esp\_avrc\_rn\_evt\_cap\_mask\_t \ evt\_set} \label{evt\_set}
supported event\_ids represented in bit-mask

\texttt{struct avrc\_ct\_meta\_rsp\_param} \label{avrc\_ct\_meta\_rsp\_param}
\#include <esp\_avrc\_api\_h> ESP\_AVRC\_CT\_METADATA\_RSP\__EVT.

Public Members

uint8\_t \texttt{attr\_id} \label{attr\_id}
id of metadata attribute

uint8\_t *\texttt{attr\_text} \label{attr\_text}
attribute itself

int \texttt{attr\_length} \label{attr\_length}
attribute character length

\texttt{struct avrc\_ct\_psth\_rsp\_param} \label{avrc\_ct\_psth\_rsp\_param}
\#include <esp\_avrc\_api\_h> ESP\_AVRC\_CT\_PASSTHROUGH\_RSP\__EVT.

Public Members

uint8\_t \texttt{tl} \label{tl}
transaction label, 0 to 15

uint8\_t \texttt{key\_code} \label{key\_code}
passthrough command code

uint8\_t \texttt{key\_state} \label{key\_state}
0 for PRESSED, 1 for RELEASED
**esp_avrc_rsp_t**\_**rsp\_code**

response code

struct **avrc\_ct\_rmt\_feats\_param**

#include <esp\_avrc\_api\_h> ESP\_AVRC\_CT\_REMOTE\_FEATURES\_EVT.

**Public Members**

uint32\_t** feat\_mask**

AVRC feature mask of remote device

uint16\_t** tg\_feat\_flag**

feature flag of remote device as TG

**esp\_bd\_addr\_t**\_**remote\_bda**

remote bluetooth device address

struct **avrc\_ct\_set\_volume\_rsp\_param**

#include <esp\_avrc\_api\_h> ESP\_AVRC\_CT\_SET\_ABSOLUTE\_VOLUME\_RSP\_EVT.

**Public Members**

uint8\_t** volume**

the volume which has actually been set, range is 0 to 0x7f, means 0% to 100%

union **esp\_avrc\_tg\_cb\_param\_t**

#include <esp\_avrc\_api\_h> AVRC target callback parameters.

**Public Members**

struct **esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_conn\_stat\_param**\_**conn\_stat**

AVRC connection status

struct **esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_rmt\_feats\_param**\_**rmt\_feats**

AVRC features discovered through SDP

struct **esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_psth\_cmd\_param**\_**psth\_cmd**

passthrough command

struct **esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_set\_abs\_vol\_param**\_**set\_abs\_vol**

set absolute volume command targeted on audio sink

struct **esp\_avrc\_tg\_cb\_param\_t::avrc\_tg\_reg\_ntf\_param**\_**reg\_ntf**

register notification
struct esp_avrc_tg_cb_param::avrc_tg_set_app_value_param set_app_value
    set player application value

struct avrc_tg_conn_stat_param
    #include <esp_avrc_api.h> ESP_AVRC_TG_CONNECTION_STATE_EVT.

    Public Members

    bool connected
        whether AVRC connection is set up

    esp_bd_addr_t remote_bda
        remote bluetooth device address

struct avrc_tg_psth_cmd_param
    #include <esp_avrc_api.h> ESP_AVRC_TG_PASSTHROUGH_CMD_EVT.

    Public Members

    uint8_t key_code
        passthrough command code

    uint8_t key_state
        0 for PRESSED, 1 for RELEASED

struct avrc_tg_reg_ntf_param
    #include <esp_avrc_api.h> ESP_AVRC_TG_REGISTER_NOTIFICATION_EVT.

    Public Members

    uint8_t event_id
        event id of AVRC RegisterNotification

    uint32_t event_parameter
        event notification parameter

struct avrc_tg_rmt_feats_param
    #include <esp_avrc_api.h> ESP_AVRC_TG_REMOTE_FEATURES_EVT.

    Public Members

    uint32_t feat_mask
        AVRC feature mask of remote device

    uint16_t ct_feat_flag
        feature flag of remote device as CT
**esp_bd_addr_t remote_bda**  
remote bluetooth device address

**struct avrc_tg_set_abs_vol_param**  
#include <esp_avrc_api.h> ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT.

**Public Members**

```c
uint8_t volume
```
volume ranges from 0 to 127

**struct avrc_tg_set_app_value_param**  
#include <esp_avrc_api.h> ESP_AVRC_TG_SET_PLAYER_APP_VALUE_EVT.

**Public Members**

```c
uint8_t num_val
```
attribute num

```c
esp_avrc_set_app_value_param_t *p_vals
```
point to the id and value of player application attribute

**Structures**

**struct esp_avrc_psth_bit_mask_t**  
AVRC passthrough command bit mask.

**Public Members**

```c
uint16_t bits[8]
```
bit mask representation of PASSTHROUGH commands

**struct esp_avrc_rn_evt_cap_mask_t**  
AVRC target notification event capability bit mask.

**Public Members**

```c
uint16_t bits
```
bit mask representation of PASSTHROUGH commands

**struct esp_avrc_set_app_value_param_t**  
AVRCP set app value parameters.
Public Members

```c
uint8_t attr_id
player application attribute id

uint8_t attr_val
player application attribute value
```

Macros

```c
#define ESP_AVRC_TRANS_LABEL_MAX
max transaction label
```

Type Definitions

```c
typedef void (*esp_avrc_ct_cb_t)(esp_avrc_ct_cb_event_t event, esp_avrc_ct_cb_param_t *param)
AVRCP controller callback function type.

Param event : Event type
Param param : Pointer to callback parameter union

typedef void (*esp_avrc_tg_cb_t)(esp_avrc_tg_cb_event_t event, esp_avrc_tg_cb_param_t *param)
AVRCP target callback function type.

Param event : Event type
Param param : Pointer to callback parameter union
```

Enumerations

```c
enum esp_avrc_features_t
AVRC feature bit mask.

Values:

enumerator ESP_AVRC_FEAT_RCTG
remote control target

enumerator ESP_AVRC_FEAT_RCCT
remote control controller

enumerator ESP_AVRC_FEAT_VENDOR
remote control vendor dependent commands

enumerator ESP_AVRC_FEAT_BROWSE
use browsing channel

enumerator ESP_AVRC_FEAT_META_DATA
remote control metadata transfer command/response

enumerator ESP_AVRC_FEAT_ADV_CTRL
remote control advanced control command/response
```
enum `esp_avrc_feature_flag_t`

AVRC supported features flag retrieved in SDP record.

*Values:*

- `ESP_AVRC_FEAT_FLAG_CAT1` *category 1*
- `ESP_AVRC_FEAT_FLAG_CAT2` *category 2*
- `ESP_AVRC_FEAT_FLAG_CAT3` *category 3*
- `ESP_AVRC_FEAT_FLAG_CAT4` *category 4*
- `ESP_AVRC_FEAT_FLAG_BROWSING` *browsing*
- `ESP_AVRC_FEAT_FLAG_COVER_ART_GET_IMAGE_PROP` *Cover Art GetImageProperties*
- `ESP_AVRC_FEAT_FLAG_COVER_ART_GET_IMAGE` *Cover Art GetImage*
- `ESP_AVRC_FEAT_FLAG_COVER_ART_GET_LINKED_THUMBNAIL` *Cover Art GetLinkedThumbnail*

enum `esp_avrc_pt_cmd_t`

AVRC passthrough command code.

*Values:*

- `ESP_AVRC_PT_CMD_SELECT` *select*
- `ESP_AVRC_PT_CMD_UP` *up*
- `ESP_AVRC_PT_CMD_DOWN` *down*
- `ESP_AVRC_PT_CMD_LEFT` *left*
- `ESP_AVRC_PT_CMD_RIGHT` *right*
enumerator ESP_AVRC_PT_CMD_RIGHT_UP
right-up

enumerator ESP_AVRC_PT_CMD_RIGHT_DOWN
right-down

enumerator ESP_AVRC_PT_CMD_LEFT_UP
left-up

enumerator ESP_AVRC_PT_CMD_LEFT_DOWN
left-down

enumerator ESP_AVRC_PT_CMD_ROOT_MENU
root menu

enumerator ESP_AVRC_PT_CMD_SETUP_MENU
setup menu

enumerator ESP_AVRC_PT_CMD_CONT_MENU
contents menu

enumerator ESP_AVRC_PT_CMD_FAV_MENU
favorite menu

enumerator ESP_AVRC_PT_CMD_EXIT
exit

enumerator ESP_AVRC_PT_CMD_0
0

enumerator ESP_AVRC_PT_CMD_1
1

enumerator ESP_AVRC_PT_CMD_2
2

enumerator ESP_AVRC_PT_CMD_3
3

enumerator ESP_AVRC_PT_CMD_4
4

enumerator ESP_AVRC_PT_CMD_5
5

enumerator ESP_AVRC_PT_CMD_6
6
enumerator ESP_AVRC_PT_CMD_7
    7
enumerator ESP_AVRC_PT_CMD_8
    8
enumerator ESP_AVRC_PT_CMD_9
    9
enumerator ESP_AVRC_PT_CMD_DOT
dot
enumerator ESP_AVRC_PT_CMD_ENTER
    enter
enumerator ESP_AVRC_PT_CMD_CLEAR
    clear
enumerator ESP_AVRC_PT_CMD_CHAN_UP
    channel up
enumerator ESP_AVRC_PT_CMD_CHAN_DOWN
    channel down
enumerator ESP_AVRC_PT_CMD_PREV_CHAN
    previous channel
enumerator ESP_AVRC_PT_CMD_SOUND_SEL
    sound select
enumerator ESP_AVRC_PT_CMD_INPUT_SEL
    input select
enumerator ESP_AVRC_PT_CMD_DISP_INFO
    display information
enumerator ESP_AVRC_PT_CMD_HELP
    help
enumerator ESP_AVRC_PT_CMD_PAGE_UP
    page up
enumerator ESP_AVRC_PT_CMD_PAGE_DOWN
    page down
enumerator ESP_AVRC_PT_CMD_POWER
    power
enumerator ESP_AVRC_PT_CMD_VOL_UP
  volume up
enumerator ESP_AVRC_PT_CMD_VOL_DOWN
  volume down
enumerator ESP_AVRC_PT_CMD_MUTE
  mute
enumerator ESP_AVRC_PT_CMD_PLAY
  play
enumerator ESP_AVRC_PT_CMD_STOP
  stop
enumerator ESP_AVRC_PT_CMD_PAUSE
  pause
enumerator ESP_AVRC_PT_CMD_RECORD
  record
enumerator ESP_AVRC_PT_CMD_REWIND
  rewind
enumerator ESP_AVRC_PT_CMD_FAST_FORWARD
  fast forward
enumerator ESP_AVRC_PT_CMD_EJECT
  eject
enumerator ESP_AVRC_PT_CMD_FORWARD
  forward
enumerator ESP_AVRC_PT_CMD_BACKWARD
  backward
enumerator ESP_AVRC_PT_CMD_ANGLE
  angle
enumerator ESP_AVRC_PT_CMD_SUBPICT
  subpicture
enumerator ESP_AVRC_PT_CMD_F1
  F1
enumerator ESP_AVRC_PT_CMD_F2
  F2
Chapter 2. API Reference

enumerator ESP_AVRC_PT_CMD_F3
    F3

enumerator ESP_AVRC_PT_CMD_F4
    F4

enumerator ESP_AVRC_PT_CMD_F5
    F5

enumerator ESP_AVRC_PT_CMD_VENDOR
    vendor unique

enum esp_avrc_psth_filter_t
    AVRC passthrough command filter.
    Values:
        enumerator ESP_AVRC_PSTH_FILTER_ALLOWED_CMD
            all of the PASSTHROUGH commands that can possibly be used, immutable
        enumerator ESP_AVRC_PSTH_FILTER_SUPPORTED_CMD
            PASSTHROUGH commands selectively supported according to the current configuration

enum esp_avrc_bit_mask_op_t
    Values:
        enumerator ESP_AVRC_BIT_MASK_OP_TEST
            operation code to test a specific bit
        enumerator ESP_AVRC_BIT_MASK_OP_SET
            operation code to set a specific bit
        enumerator ESP_AVRC_BIT_MASK_OP_CLEAR
            operation code to clear a specific bit

enum esp_avrc_pt_cmd_state_t
    AVRC passthrough command state.
    Values:
        enumerator ESP_AVRC_PT_CMD_STATE_PRESSED
            key pressed
        enumerator ESP_AVRC_PT_CMD_STATE_RELEASED
            key released
enum esp_avrc_ct_cb_event_t
AVRC Controller callback events.

Values:

enumerator ESP_AVRC_CT_CONNECTION_STATE_EVT
connection state changed event

enumerator ESP_AVRC_CT_PASSTHROUGH_RSP_EVT
passsthrough response event

enumerator ESP_AVRC_CT_METADATA_RSP_EVT
metadata response event

enumerator ESP_AVRC_CT_PLAY_STATUS_RSP_EVT
play status response event

enumerator ESP_AVRC_CT_CHANGE_NOTIFY_EVT
notification event

enumerator ESP_AVRC_CT_REMOTEFEATURES_EVT
feature of remote device indication event

enumerator ESP_AVRC_CT_GET_RN_CAPABILITIES_RSP_EVT
supported notification events capability of peer device

enumerator ESP_AVRC_CT_SET_ABSOLUTE_VOLUME_RSP_EVT
set absolute volume response event

enum esp_avrc_tg_cb_event_t
AVRC Target callback events.

Values:

enumerator ESP_AVRC_TG_CONNECTION_STATE_EVT
connection state changed event

enumerator ESP_AVRC_TG_REMOTEFEATURES_EVT
feature of remote device indication event

enumerator ESP_AVRC_TG_PASSTHROUGH_CMD_EVT
passsthrough command event

enumerator ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT
set absolute volume command from remote device

enumerator ESP_AVRC_TG_REGISTER_NOTIFICATION_EVT
register notification event
**enumerator** `ESP_AVRC_TG_SET PLAYER_APP_VALUE_EVT`  
set application attribute value, attribute refer to esp_avrc_ps_attr_ids_t

**enum** `esp_avrc_md_attr_mask_t`  
AVRC metadata attribute mask.

**Values:**

**enumerator** `ESP AVRC MD_ATTR TITLE`  
title of the playing track

**enumerator** `ESP AVRC MD_ATTR ARTIST`  
track artist

**enumerator** `ESP AVRC MD_ATTR ALBUM`  
album name

**enumerator** `ESP AVRC MD_ATTR TRACK NUM`  
track position on the album

**enumerator** `ESP AVRC MD_ATTR NUM TRACKS`  
number of tracks on the album

**enumerator** `ESP AVRC MD ATTR GENRE`  
track genre

**enumerator** `ESP AVRC MD_ATTR PLAYING TIME`  
total album playing time in miliseconds

**enum** `esp_avrc_rn_event_ids_t`  
AVRC event notification ids.

**Values:**

**enumerator** `ESP AVRC RN_PLAY STATUS CHANGE`  
track status change, eg. from playing to paused

**enumerator** `ESP AVRC RN TRACK CHANGE`  
new track is loaded

**enumerator** `ESP AVRC RN TRACK REACHED END`  
current track reached end

**enumerator** `ESP AVRC RN TRACK REACHED START`  
current track reached start position

**enumerator** `ESP AVRC RN PLAY_POS_CHANGED`  
track playing position changed
enumerator `ESP_AVRC_RN_BATTERY_STATUS_CHANGE`  
battery status changed

enumerator `ESP_AVRC_RN_SYSTEM_STATUS_CHANGE`  
  system status changed

enumerator `ESP_AVRC_RN_APP_SETTING_CHANGE`  
  application settings changed

enumerator `ESP_AVRC_RN_NOW_PLAYING_CHANGE`  
  now playing content changed

enumerator `ESP_AVRC_RN_AVAILABLE_PLAYERS_CHANGE`  
  available players changed

enumerator `ESP_AVRC_RN_ADDRESSED_PLAYER_CHANGE`  
  the addressed player changed

enumerator `ESP_AVRC_RN_UIDS_CHANGE`  
  UIDs changed

enumerator `ESP_AVRC_RN_VOLUME_CHANGE`  
  volume changed locally on TG

enumerator `ESP_AVRC_RN_MAX_EVT`

enum `esp_avrc_rn_evt_cap_t`  
AVRC target notification event notification capability.
Values:

enumerator `ESP_AVRC_RN_CAP_ALLOWED_EVT`  
  all of the notification events that can possibly be supported, immutable

enumerator `ESP_AVRC_RN_CAP_SUPPORTED_EVT`  
  notification events selectively supported according to the current configuration

enumerator `ESP_AVRC_RN_CAP_MAX`

enum `esp_avrc_rn_rsp_t`  
AVRC notification response type.
Values:

enumerator `ESP_AVRC_RN_RSP_INTERIM`  
  initial response to RegisterNotification, should be sent \( T_{mtp}(1000\text{ms}) \) from receiving the command

enumerator `ESP_AVRC_RN_RSP_CHANGED`  
  final response to RegisterNotification command
enum esp_avrc_ps_attr_ids_t
AVRC player setting ids.

Values:

enumerator ESP_AVRC_PS_EQUALIZER
equalizer, on or off
enumerator ESP_AVRC_PS_REPEAT_MODE
repeat mode
enumerator ESP_AVRC_PS_SHUFFLE_MODE
shuffle mode
enumerator ESP_AVRC_PS_SCAN_MODE
scan mode on or off
enumerator ESP_AVRC_PS_MAX_ATTR

enum esp_avrc_ps_eq_value_ids_t
AVRC equalizer modes.

Values:

enumerator ESP_AVRC_PS_EQUALIZER_OFF
equalizer OFF
enumerator ESP_AVRC_PS_EQUALIZER_ON
equalizer ON

enum esp_avrc_ps_rpt_value_ids_t
AVRC repeat modes.

Values:

enumerator ESP_AVRC_PS_REPEAT_OFF
repeat mode off
enumerator ESP_AVRC_PS_REPEAT_SINGLE
single track repeat
enumerator ESP_AVRC_PS_REPEAT_GROUP
group repeat

enum esp_avrc_ps_shf_value_ids_t
AVRC shuffle modes.

Values:

enumerator ESP_AVRC_PS_SHUFFLE_OFF
Chapter 2. API Reference

enumerator ESP_AVRC_PS_SHUFFLE_ALL

enumerator ESP_AVRC_PS_SHUFFLE_GROUP

enum esp_avrc_ps_scn_value_ids_t
   AVRC scan modes.
   Values:

   enumerator ESP_AVRC_PS_SCAN_OFF
      scan off

   enumerator ESP_AVRC_PS_SCAN_ALL
      all tracks scan

   enumerator ESP_AVRC_PS_SCAN_GROUP
      group scan

enum esp_avrc_rsp_t
   AVCTP response codes.
   Values:

   enumerator ESP_AVRC_RSP_NOT_IMPL
      not implemented

   enumerator ESP_AVRC_RSP_ACCEPT
      accept

   enumerator ESP_AVRC_RSP_REJECT
      reject

   enumerator ESP_AVRC_RSP_IN_TRANS
      in transition

   enumerator ESP_AVRC_RSP_IMPL_STBL
      implemented/stable

   enumerator ESP_AVRC_RSP_CHANGED
      changed

   enumerator ESP_AVRC_RSP_INTERIM
      interim

enum esp_avrc_batt_stat_t
   AVRCP battery status.
   Values:

   enumerator ESP_AVRC_BATT_NORMAL
      normal state
Chapter 2. API Reference

enumerator **ESP_AVRC_BATT_WARNING**
unable to operate soon

enumerator **ESP_AVRC_BATT_CRITICAL**
cannot operate any more

enumerator **ESP_AVRC_BATT_EXTERNAL**
plugged to external power supply

enumerator **ESP_AVRC_BATT_FULL_CHARGE**
when completely charged from external power supply

enum **esp_avrc_playback_stat_t**
AVRCP current status of playback.
Values:

enumerator **ESP_AVRC_PLAYBACK_STOPPED**
stopped

enumerator **ESP_AVRC_PLAYBACK_PLAYING**
playing

enumerator **ESP_AVRC_PLAYBACK_PAUSED**
paused

enumerator **ESP_AVRC_PLAYBACK_FWD_SEEK**
forward seek

enumerator **ESP_AVRC_PLAYBACK_REV_SEEK**
reverse seek

enumerator **ESP_AVRC_PLAYBACK_ERROR**
error

**SPP API**

**Application Example** Check bluetooth/bluedroid/classic_bt folder in ESP-IDF examples, which contains the following application:

- This is a SPP demo. This demo can discover the service, connect, send and receive SPP data bluetooth/bluedroid/classic_bt/bt_spp_acceptor, bluetooth/bluedroid/classic_bt/bt_spp_initiator

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_spp_api.h
Functions

`esp_err_t esp_spp_register_callback (esp_spp_cb_t callback)`

This function is called to init callbacks with SPP module.

Parameters `callback` - [in] pointer to the init callback function.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_init (esp_spp_mode_t mode)`

This function is called to init SPP module. When the operation is completed, the callback function will be called with ESP_SPP_INIT_EVT. This function should be called after esp_bluedroid_enable() completes successfully.

Parameters `mode` - [in] Choose the mode of SPP, ESP_SPP_MODE_CB or ESP_SPP_MODE_VFS.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_enhanced_init (const esp_spp_cfg_t *cfg)`

This function is called to init SPP module. When the operation is completed, the callback function will be called with ESP_SPP_INIT_EVT. This function should be called after esp_bluedroid_enable() completes successfully.

Note: The member variable enable_l2cap_etrmin in `esp_spp_cfg_t` can affect all L2CAP channel configurations of the upper layer RFCOMM protocol.

Parameters `cfg` - [in] SPP configuration.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_deinit (void)`

This function is called to uninit SPP module. The operation will close all active SPP connection first, then the callback function will be called with ESP_SPP_CLOSE_EVT, and the number of ESP_SPP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback function will be called with ESP_SPP_UNINIT_EVT. This function should be called after esp_spp_init()/esp_spp_enhanced_init() completes successfully.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_start_discovery (esp_bd_addr_t bd_addr)`

This function is called to performs service discovery for the services provided by the given peer device. When the operation is completed, the callback function will be called with ESP_SPP_DISCOVERY_COMP_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

Parameters `bd_addr` - [in] Remote device bluetooth device address.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_connect (esp_spp_sec_t sec_mask, esp_spp_role_t role, uint8_t remote_scn, esp_bd_addr_t peer_bd_addr)`

This function makes an SPP connection to a remote BD Address. When the connection is initiated or
failed to initiate, the callback is called with ESP_SPP_CL_INIT_EVT. When the connection is established or failed, the callback is called with ESP_SPP_OPEN_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

Parameters
- **sec_mask** [in] Security Setting Mask. Suggest to use ESP_SPP_SEC_NONE, ESP_SPP_SEC_AUTHORIZE or ESP_SPP_SEC_AUTHENTICATE only.
- **role** [in] Master or slave.
- **remote_scn** [in] Remote device bluetooth device SCN.
- **peer_bd_addr** [in] Remote device bluetooth device address.

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_spp_disconnect (uint32_t handle)
```

This function closes an SPP connection. When the operation is completed, the callback function will be called with ESP_SPP_CLOSE_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

Parameters **handle** –[in] The connection handle.

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_spp_start_srv (esp_spp_sec_t sec_mask, esp_spp_role_t role, uint8_t local_scn, const char *name)
```

This function create a SPP server and starts listening for an SPP connection request from a remote Bluetooth device. When the server is started successfully, the callback is called with ESP_SPP_START_EVT. When the connection is established, the callback is called with ESP_SPP_SRV_OPEN_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

Parameters
- **sec_mask** [in] Security Setting Mask. Suggest to use ESP_SPP_SEC_NONE, ESP_SPP_SEC_AUTHORIZE or ESP_SPP_SEC_AUTHENTICATE only.
- **role** [in] Master or slave.
- **local_scn** –[in] The specific channel you want to get. If channel is 0, means get any channel.
- **name** [in] Server’s name.

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_spp_stop_srv (void)
```

This function stops all SPP servers. The operation will close all active SPP connection first, then the callback function will be called with ESP_SPP_CLOSE_EVT, and the number of ESP_SPP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback is called with ESP_SPP_SRV_STOP_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_spp_stop_srv_scn (uint8_t scn)
```

This function stops a specific SPP server. The operation will close all active SPP connection first on the specific SPP server, then the callback function will be called with ESP_SPP_CLOSE_EVT, and the number of ESP_SPP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback is called with ESP_SPP_SRV_STOP_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

Parameters **scn** –[in] Server channel number.

Returns
• ESP_OK: success
• other: failed

`esp_err_t esp_spp_write(uint32_t handle, int len, uint8_t *p_data)`

This function is used to write data, only for ESP_SPP_MODE_CB. When this function need to be called repeatedly, it is strongly recommended to call this function again after the previous event ESP_SPP_WRITE_EVT is received and the parameter ‘cong’ is equal to false. If the previous event ESP_SPP_WRITE_EVT with parameter ‘cong’ is equal to true, the function can only be called again when the event ESP_SPP_CONN_EVT with parameter ‘cong’ equal to false is received. This function must be called after an connection between initiator and acceptor has been established.

**Parameters**
- `handle` [in] The connection handle.
- `len` [in] The length of the data written.

**Returns**
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_vfs_register(void)`

This function is used to register VFS. For now, SPP only supports write, read and close. When the operation is completed, the callback function will be called with ESP_SPP_VFS_REGISTER_EVT. This function must be called after esp_spp_init()/esp_spp_enhanced_init() successful and before esp_spp_deinit().

**Returns**
- ESP_OK: success
- other: failed

`esp_err_t esp_spp_vfs_unregister(void)`

This function is used to unregister VFS. When the operation is completed, the callback function will be called with ESP_SPP_VFS_UNREGISTER_EVT. This function must be called after esp_spp_vfs_register() successful and before esp_spp_deinit().

**Returns**
- ESP_OK: success
- other: failed

**Unions**

union `esp_spp_cb_param_t`

#include <esp_spp_api.h> SPP callback parameters union.

**Public Members**

struct `esp_spp_cb_param_t::spp_init_evt_param init`
SPP callback param of SPP_INIT_EVT

struct `esp_spp_cb_param_t::spp_uninit_evt_param uninit`
SPP callback param of SPP_UNINIT_EVT

struct `esp_spp_cb_param_t::spp_discovery_comp_evt_param disc_comp`
SPP callback param of SPP_DISCOVERY_COMP_EVT

struct `esp_spp_cb_param_t::spp_open_evt_param open`
SPP callback param of ESP_SPP_OPEN_EVT
struct esp_spp_cb_param_t::spp_srv_open_evt_param srv_open
        SPP callback param of ESP_SPP_SRV_OPEN_EVT

struct esp_spp_cb_param_t::spp_close_evt_param close
        SPP callback param of ESP_SPP_CLOSE_EVT

struct esp_spp_cb_param_t::spp_start_evt_param start
        SPP callback param of ESP_SPP_START_EVT

struct esp_spp_cb_param_t::spp_srv_stop_evt_param srv_stop
        SPP callback param of ESP_SPP_SRV_STOP_EVT

struct esp_spp_cb_param_t::spp_cl_init_evt_param cl_init
        SPP callback param of ESP_SPP_CL_INIT_EVT

struct esp_spp_cb_param_t::spp_write_evt_param write
        SPP callback param of ESP_SPP_WRITE_EVT

struct esp_spp_cb_param_t::spp_data_ind_evt_param data_ind
        SPP callback param of ESP_SPP_DATA_IND_EVT

struct esp_spp_cb_param_t::spp_cong_evt_param cong
        SPP callback param of ESP_SPP_CONG_EVT

struct esp_spp_cb_param_t::spp_vfs_register_evt_param vfs_register
        SPP callback param of ESP_SPP_VFS_REGISTER_EVT

struct esp_spp_cb_param_t::spp_vfs_unregister_evt_param vfs_unregister
        SPP callback param of ESP_SPP_VFS_UNREGISTER_EVT

struct spp_cl_init_evt_param
        #include <esp_spp_api.h> ESP_SPP_CL_INIT_EVT.

Public Members

esp_spp_status_t status
        status

uint32_t handle
        The connection handle

uint8_t sec_id
        security ID used by this server

bool use_co
        TRUE to use co_rfc_data

struct spp_close_evt_param
        #include <esp_spp_api.h> ESP_SPP_CLOSE_EVT.


**Public Members**

```c
esp_spp_status_t status

uint32_t port_status

uint32_t handle

bool async
```

FALSE, if local initiates disconnect

```c
#include <esp_spp_api.h>

ESP_SPP_CONG_EVT.
```

**Public Members**

```c
esp_spp_status_t status

uint32_t handle

bool cong
```

TRUE, congested. FALSE, uncongested

```c
#include <esp_spp_api.h>

ESP_SPP_DATA_IND_EVT.
```

**Public Members**

```c
esp_spp_status_t status

uint32_t handle

uint16_t len

uint8_t* data
```

The data received

```c
#include <esp_spp_api.h>

SPP_DISCOVERY_COMP_EVT.
```
Public Members

```
    esp_spp_status_t status
    status
```

```
    uint8_t scn_num
    The num of scn_num
```

```
    uint8_t scn[ESP_SPP_MAX_SCN]
    channel #
```

```
    const char *service_name[ESP_SPP_MAX_SCN]
    service_name
```

```
    struct spp_init_evt_param
    #include <esp_spp_api.h> SPP_INIT_EVT.
```

Public Members

```
    esp_spp_status_t status
    status
```

```
    struct spp_open_evt_param
    #include <esp_spp_api.h> ESP_SPP_OPEN_EVT.
```

Public Members

```
    esp_spp_status_t status
    status
```

```
    uint32_t handle
    The connection handle
```

```
    int fd
    The file descriptor only for ESP_SPP_MODE_VFS
```

```
    esp_bd_addr_t rem_bda
    The peer address
```

```
    struct spp_srv_open_evt_param
    #include <esp_spp_api.h> ESP_SPP_SRV_OPEN_EVT.
```

Public Members

```
    esp_spp_status_t status
    status
```
uint32_t **handle**
The connection handle

uint32_t **new_listen_handle**
The new listen handle

int **fd**
The file descriptor only for ESP_SPP_MODE_VFS

*esp_bd_addr_t* **rem_bda**
The peer address

struct **spp_srv_stop_evt_param**
#include <esp_spp_api.h> ESP_SPP_SRV_STOP_EVT.

**Public Members**

*esp_spp_status_t* **status**
status

uint8_t **scn**
Server channel number

struct **spp_start_evt_param**
#include <esp_spp_api.h> ESP_SPP_START_EVT.

**Public Members**

*esp_spp_status_t* **status**
status

uint32_t **handle**
The connection handle

uint8_t **sec_id**
security ID used by this server

uint8_t **scn**
Server channel number

bool **use_co**
TRUE to use co_rfc_data

struct **spp_uninit_evt_param**
#include <esp_spp_api.h> SPP_UNINIT_EVT.
Public Members

```c
esp_spp_status_t status
```

```
struct spp_vfs_register_evt_param
#include <esp_spp_api.h> ESP_SPP_VFSREGISTER_EVT.
```

Public Members

```c
esp_spp_status_t status
```

```
struct spp_vfs_unregister_evt_param
#include <esp_spp_api.h> ESP_SPP_VFSUNREGISTER_EVT.
```

Public Members

```c
esp_spp_status_t status
```

```
struct spp_write_evt_param
#include <esp_spp_api.h> ESP_SPP_WRITE_EVT.
```

Public Members

```c
esp_spp_status_t status
```

```c
uint32_t handle
The connection handle
```

```c
int len
The length of the data written.
```

```c
bool cong
congestion status
```

Structures

```
struct esp_spp_cfg_t
SPP configuration parameters.
```
Chapter 2. API Reference

Public Members

*esp_spp_mode_t* **mode**

Choose the mode of SPP, ESP_SPP_MODE_CB or ESP_SPP_MODE_VFS.

*bool* **enable_l2cap_ertm**

Enable/disable Logical Link Control and Adaptation Layer Protocol enhanced retransmission mode.

*uint16_t* **tx_buffer_size**

Tx buffer size for a new SPP channel. A smaller setting can save memory, but may incur a decrease in throughput. Only for ESP_SPP_MODE_VFS mode.

Macros

*ESP_SPP_MAX_MTU*

SPP max MTU

*ESP_SPP_MAX_SCN*

SPP max SCN

*ESP_SPP_MIN_TX_BUFFER_SIZE*

SPP min tx buffer

*ESP_SPP_MAX_TX_BUFFER_SIZE*

SPP max tx buffer size

*BT_SPP_DEFAULT_CONFIG ()*

SPP default configuration.

*ESP_SPP_SEC_NONE*

No security. relate to BTA_SEC_NONE in bta/bta_api.h

*ESP_SPP_SEC_AUTHORIZE*

Authorization required (only needed for out going connection ) relate to BTA_SEC_AUTHORIZE in bta/bta_api.h

*ESP_SPP_SEC_AUTHENTICATE*

Authentication required. relate to BTA_SEC_AUTHENTICATE in bta/bta_api.h

*ESP_SPP_SEC_ENCRYPT*

Encryption required. relate to BTA_SEC_ENCRYPT in bta/bta_api.h

*ESP_SPP_SEC_MODE4_LEVEL4*

Mode 4 level 4 service, i.e. incoming/outgoing MITM and P-256 encryption relate to BTA_SEC_MODE4_LEVEL4 in bta/bta_api.h

*ESP_SPP_SEC_MITM*

Man-In-The_Middle protection relate to BTA_SEC_MITM in bta/bta_api.h

*ESP_SPP_SEC_IN_16_DIGITS*

Min 16 digit for pin code relate to BTA_SEC_IN_16_DIGITS in bta/bta_api.h
Type Definitions

typedef uint16_t esp_spp_sec_t

typedef void (*esp_spp_cb_t)(esp_spp_cb_event_t event, esp_spp_cb_param_t *param)

SPP callback function type. When handle ESP_SPP_DATA_IND_EVT, it is strongly recommended to cache incoming data, and process them in other lower priority application task rather than in this callback directly.

**Param event**  Event type
**Param param**  Point to callback parameter, currently is union type

Enumerations

enum esp_spp_status_t

*Values:*

- **enumerator ESP_SPP_SUCCESS**  Successful operation.
- **enumerator ESP_SPP_FAILURE**  Generic failure.
- **enumerator ESP_SPP_BUSY**  Temporarily can not handle this request.
- **enumerator ESP_SPP_NO_DATA**  No data
- **enumerator ESP_SPP_NO_RESOURCE**  No more resource
- **enumerator ESP_SPP_NEED_INIT**  SPP module shall init first
- **enumerator ESP_SPP_NEED_DEINIT**  SPP module shall deinit first
- **enumerator ESP_SPP_NO_CONNECTION**  Connection may have been closed
- **enumerator ESP_SPP_NO_SERVER**  No SPP server

enum esp_spp_role_t

*Values:*

- **enumerator ESP_SPP_ROLE_MASTER**  Role: master
- **enumerator ESP_SPP_ROLE_SLAVE**  Role: slave
Chapter 2. API Reference

**enum esp_spp_mode_t**

*Values:*

- **enumerator ESP_SPP_MODE_CB**  
  When data is coming, a callback will come with data

- **enumerator ESP_SPP_MODE_VFS**  
  Use VFS to write/read data

**enum esp_spp_cb_event_t**

SPP callback function events.

*Values:*

- **enumerator ESP_SPP_INIT_EVT**  
  When SPP is initialized, the event comes

- **enumerator ESP_SPP_UNINIT_EVT**  
  When SPP is deinitialized, the event comes

- **enumerator ESP_SPP_DISCOVERY_COMP_EVT**  
  When SDP discovery complete, the event comes

- **enumerator ESP_SPP_OPEN_EVT**  
  When SPP client connection open, the event comes

- **enumerator ESP_SPP_CLOSE_EVT**  
  When SPP connection closed, the event comes

- **enumerator ESP_SPP_START_EVT**  
  When SPP server started, the event comes

- **enumerator ESP_SPP_CL_INIT_EVT**  
  When SPP client initiated a connection, the event comes

- **enumerator ESP_SPP_DATA_IND_EVT**  
  When SPP connection received data, the event comes, only for ESP_SPP_MODE_CB

- **enumerator ESP_SPP_CONG_EVT**  
  When SPP connection congestion status changed, the event comes, only for ESP_SPP_MODE_CB

- **enumerator ESP_SPP_WRITE_EVT**  
  When SPP write operation completes, the event comes, only for ESP_SPP_MODE_CB

- **enumerator ESP_SPP_SRV_OPEN_EVT**  
  When SPP Server connection open, the event comes

- **enumerator ESP_SPP_SRV_STOP_EVT**  
  When SPP server stopped, the event comes
enumerator **ESP_SPP_VFS_REGISTER_EVT**

When SPP VFS register, the event comes

enumerator **ESP_SPP_VFS_UNREGISTER_EVT**

When SPP VFS unregister, the event comes

**HFP DEFINES**

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_hf_defs.h

**Enumerations**

e num **esp_hf_in_band_ring_state_t**

in-band ring tone state

*Values:*

enumerator **ESP_HF_IN_BAND_RINGTONE_NOT_PROVIDED**

enumerator **ESP_HF_IN_BAND_RINGTONE_PROVIDED**

e num **esp_hf_vr_state_t**

voice recognition state

*Values:*

enumerator **ESP_HF_VR_STATE_DISABLED**

voice recognition disabled

enumerator **ESP_HF_VR_STATE_ENABLED**

voice recognition enabled

e num **esp_hf_volume_control_target_t**

Bluetooth HFP audio volume control target.

*Values:*

enumerator **ESP_HF_VOLUME_CONTROL_TARGET_SPK**

speaker

enumerator **ESP_HF_VOLUME_CONTROL_TARGET_MIC**

microphone

e num **esp_hf_audio_state_t**

Bluetooth HFP audio connection status.

*Values:*

enumerator ESP_HF_AUDIO_STATE_DISCONNECTED
    audio connection released

enumerator ESP_HF_AUDIO_STATE_CONNECTING
    audio connection has been initiated

enumerator ESP_HF_AUDIO_STATE_CONNECTED
    audio connection is established

enumerator ESP_HF_AUDIO_STATE_CONNECTED_MSBC
    mSBC audio connection is established

enum esp_hf_volume_type_t
    Values:

    enumerator ESP_HF_VOLUME_TYPE_SPK

    enumerator ESP_HF_VOLUME_TYPE_MIC

enum esp_hf_network_state_t
    +CIND network service availability status
    Values:

    enumerator ESP_HF_NETWORK_STATE_NOT_AVAILABLE

    enumerator ESP_HF_NETWORK_STATE_AVAILABLE

enum esp_hf_ciev_report_type_t
    +CIEV report type
    Values:

    enumerator ESP_HF_IND_TYPE_CALL
        position of call indicator

    enumerator ESP_HF_IND_TYPE_CALLSETUP
        position of callsetup indicator

    enumerator ESP_HF_IND_TYPE_SERVICE
        position of service indicator

    enumerator ESP_HF_IND_TYPE_SIGNAL
        position of signal strength indicator, range: 0-5

    enumerator ESP_HF_IND_TYPE_ROAM
        position of roaming indicator

    enumerator ESP_HF_IND_TYPE_BATTCHG
        position of battery charge indicator, range: 0-5
enumerator ESP_HF_IND_TYPE_CALLHELD
    position of callheld indicator

enum esp_hf_service_type_t
    +CIEV Service type
    Values:
    enumerator ESP_HF_SERVICE_TYPE_HOME
    enumerator ESP_HF_SERVICE_TYPE_ROAMING

enum esp_hf_call_status_t
    +CIND call status indicator values
    Values:
    enumerator ESP_HF_CALL_STATUS_NO_CALLS
        no call in progress
    enumerator ESP_HF_CALL_STATUS_CALL_IN_PROGRESS
        call is present(active or held)

enum esp_hf_call_setup_status_t
    +CIND call setup status indicator values
    Values:
    enumerator ESP_HF_CALL_SETUP_STATUS_IDLE
        no call setup in progress
    enumerator ESP_HF_CALL_SETUP_STATUS_INCOMING
        incoming call setup in progress
    enumerator ESP_HF_CALL_SETUP_STATUS_OUTGOING_DIALING
        outgoing call setup in dialing state
    enumerator ESP_HF_CALL_SETUP_STATUS_OUTGOING_ALERTING
        outgoing call setup in alerting state

enum esp_hf_roaming_status_t
    +CIND roaming status indicator values
    Values:
    enumerator ESP_HF_ROAMING_STATUS_INACTIVE
        roaming is not active
    enumerator ESP_HF_ROAMING_STATUS_ACTIVE
        a roaming is active
enum esp_hf_call_held_status_t
+CIND call held indicator values

Values:

enumerator ESP_HF_CALL_HELD_STATUS_NONE
   no calls held

enumerator ESP_HF_CALL_HELD_STATUS_HELD_AND_ACTIVE
   both active and held call

enumerator ESP_HF_CALL_HELD_STATUS_HELD
   call on hold, no active call

enum esp_hf_current_call_status_t
+CLCC status of the call

Values:

enumerator ESP_HF_CURRENT_CALL_STATUS_ACTIVE
   active

enumerator ESP_HF_CURRENT_CALL_STATUS_HELD
   held

enumerator ESP_HF_CURRENT_CALL_STATUS_DIALING
   dialing (outgoing calls only)

enumerator ESP_HF_CURRENT_CALL_STATUS_ALERTING
   alerting (outgoing calls only)

enumerator ESP_HF_CURRENT_CALL_STATUS_INCOMING
   incoming (incoming calls only)

enumerator ESP_HF_CURRENT_CALL_STATUS_WAITING
   waiting (incoming calls only)

enumerator ESP_HF_CURRENT_CALL_STATUS_HELD_BY_RESP_HOLD
   call held by response and hold

enum esp_hf_current_call_direction_t
+CLCC direction of the call

Values:

enumerator ESP_HF_CURRENT_CALL_DIRECTION_OUTGOING
   outgoing

enumerator ESP_HF_CURRENT_CALL_DIRECTION_INCOMING
   incoming
enum \texttt{esp\_hf\_current\_call\_mpty\_type\_t} 
+CLCC multi-party call flag

\textbf{Values:}

enumerator \texttt{ESP\_HF\_CURRENT\_CALL\_MPTY\_TYPE\_SINGLE} 
not a member of a multi-party call

enumerator \texttt{ESP\_HF\_CURRENT\_CALL\_MPTY\_TYPE\_MULTI} 
member of a multi-party call

enum \texttt{esp\_hf\_current\_call\_mode\_t} 
+CLCC call mode

\textbf{Values:}

enumerator \texttt{ESP\_HF\_CURRENT\_CALL\_MODE\_VOICE} 

enumerator \texttt{ESP\_HF\_CURRENT\_CALL\_MODE\_DATA} 

enumerator \texttt{ESP\_HF\_CURRENT\_CALL\_MODE\_FAX} 

enum \texttt{esp\_hf\_call\_addr\_type\_t} 
+CLCC address type

\textbf{Values:}

enumerator \texttt{ESP\_HF\_CALL\_ADDR\_TYPE\_UNKNOWN} 
unknown address type

enumerator \texttt{ESP\_HF\_CALL\_ADDR\_TYPE\_INTERNATIONAL} 
international address

enum \texttt{esp\_hf\_subscriber\_service\_type\_t} 
+CNUM service type of the phone number

\textbf{Values:}

enumerator \texttt{ESP\_HF\_SUBSCRIBER\_SERVICE\_TYPE\_UNKNOWN} 
unknown

enumerator \texttt{ESP\_HF\_SUBSCRIBER\_SERVICE\_TYPE\_VOICE} 
voice service

enumerator \texttt{ESP\_HF\_SUBSCRIBER\_SERVICE\_TYPE\_FAX} 
fax service

enum \texttt{esp\_hf\_btrh\_status\_t} 
+BTRH response and hold result code

\textbf{Values:}
Chapter 2. API Reference

enumerator `ESP_HF_BTRH_STATUS_HELD`
  incoming call is put on held in AG

enumerator `ESP_HF_BTRH_STATUS_ACCEPTED`
  held incoming call is accepted in AG

enumerator `ESP_HF_BTRH_STATUS_REJECTED`
  held incoming call is rejected in AG

class `esp hf btrh cmd t`
  AT+BTRH response and hold action code.
  Values:

  enumerator `ESP_HF_BTRH_CMD_HOLD`
    put the incoming call on hold

  enumerator `ESP_HF_BTRH_CMD_ACCEPT`
    accept a held incoming call

  enumerator `ESP_HF_BTRH_CMD_REJECT`
    reject a held incoming call

class `esp hf nrec t`
  Values:

  enumerator `ESP_HF_NREC_STOP`

  enumerator `ESP_HF_NREC_START`

class `esp hf call waiting status t`
  +CCWA resposne status
  Values:

  enumerator `ESP_HF_CALL_WAITING_INACTIVE`

  enumerator `ESP_HF_CALL_WAITING_ACTIVE`

class `esp hf wbs config t`
  Values:

  enumerator `ESP_HF_WBS_NONE`

  enumerator `ESP_HF_WBS_NO`

  enumerator `ESP_HF_WBS_YES`
enum `esp_hf_connection_state_t`

   Bluetooth HFP RFCOMM connection and service level connection status.

   Values:

   enumerator `ESP_HF_CONNECTION_STATE_DISCONNECTED`
   
   RFCOMM data link channel released

   enumerator `ESP_HF_CONNECTION_STATE_CONNECTING`
   
   connecting remote device on the RFCOMM data link

   enumerator `ESP_HF_CONNECTION_STATE_CONNECTED`
   
   RFCOMM connection established

   enumerator `ESP_HF_CONNECTION_STATE_SLC_CONNECTED`
   
   service level connection established

   enumerator `ESP_HF_CONNECTION_STATE_DISCONNECTING`
   
   disconnecting with remote device on the RFCOMM data link

enum `esp_hf_chld_type_t`

   AT+CHLD command values.

   Values:

   enumerator `ESP_HF_CHLD_TYPE_REL`
   
   <0>, Terminate all held or set UDUB( “busy” ) to a waiting call

   enumerator `ESP_HF_CHLD_TYPE_REL_ACC`
   
   <1>, Terminate all active calls and accepts a waiting/held call

   enumerator `ESP_HF_CHLD_TYPE_HOLD_ACC`
   
   <2>, Hold all active calls and accepts a waiting/held call

   enumerator `ESP_HF_CHLD_TYPE_MERGE`
   
   <3>, Add all held calls to a conference

   enumerator `ESP_HF_CHLD_TYPE_MERGE_DETACH`
   
   <4>, connect the two calls and disconnects the subscriber from both calls

   enumerator `ESP_HF_CHLD_TYPE_REL_X`
   
   <1x>, releases specified calls only

   enumerator `ESP_HF_CHLD_TYPE_PRIV_X`
   
   <2x>, request private consultation mode with specified call

enum `esp_hf_at_response_code_t`

Values:
Chapter 2. API Reference

enumerator ESP_HF_AT_RESPONSE_CODE_OK
acknowledges execution of a command line

enumerator ESP_HF_AT_RESPONSE_CODE_ERR
command not accepted

enumerator ESP_HF_AT_RESPONSE_CODE_NO_CARRIER
connection terminated

enumerator ESP_HF_AT_RESPONSE_CODE_BUSY
busy signal detected

enumerator ESP_HF_AT_RESPONSE_CODE_NO_ANSWER
connection completion timeout

enumerator ESP_HF_AT_RESPONSE_CODE_DELAYED
delayed

enumerator ESP_HF_AT_RESPONSE_CODE_BLACKLISTED
blacklisted

enumerator ESP_HF_AT_RESPONSE_CODE_CME
CME error

enum esp_hf_at_response_t
Values:

enumerator ESP_HF_AT_RESPONSE_ERROR

enumerator ESP_HF_AT_RESPONSE_OK

enum esp_hf_cme_err_t
Extended Audio Gateway Error Result Code Response.
Values:

enumerator ESP_HF_CME_AG_FAILURE
ag failure

enumerator ESP_HF_CME_NO_CONNECTION_TO_PHONE
no connection to phone

enumerator ESP_HF_CME_OPERATION_NOT_ALLOWED
operation not allowed

enumerator ESP_HF_CME_OPERATION_NOT_SUPPORTED
operation not supported
enumerator `ESP_HF_CME_PH_SIM_PIN_REQUIRED`
    PH-SIM PIN Required

enumerator `ESP_HF_CME_SIM_NOT_INSERTED`
    SIM not inserted

enumerator `ESP_HF_CME_SIM_PIN_REQUIRED`
    SIM PIN required

enumerator `ESP_HF_CME_SIM_PUK_REQUIRED`
    SIM PUK required

enumerator `ESP_HF_CME_SIM_FAILURE`
    SIM failure

enumerator `ESP_HF_CME_SIM_BUSY`
    SIM busy

enumerator `ESP_HF_CME_INCORRECT_PASSWORD`
    incorrect password

enumerator `ESP_HF_CME_SIM_PIN2_REQUIRED`
    SIM PIN2 required

enumerator `ESP_HF_CME_SIM_PUK2_REQUIRED`
    SIM PUK2 required

enumerator `ESP_HF_CME_MEMORY_FULL`
    memory full

enumerator `ESP_HF_CME_INVALID_INDEX`
    invalid index

enumerator `ESP_HF_CME_MEMORY_FAILURE`
    memory failure

enumerator `ESP_HF_CME_TEXT_STRING_TOO_LONG`
    test string too long

enumerator `ESP_HF_CME_INVALID_CHARACTERS_IN_TEXT_STRING`
    invalid characters in text string

enumerator `ESP_HF_CME_DIAL_STRING_TOO_LONG`
    dial string too long

enumerator `ESP_HF_CME_INVALID_CHARACTERS_IN_DIAL_STRING`
    invalid characters in dial string
enumerator **ESP_HF_CME_NO_NETWORK_SERVICE**  
no network service

enumerator **ESP_HF_CME_NETWORK_TIMEOUT**  
network timeout

enumerator **ESP_HF_CME_NETWORK_NOT_ALLOWED**  
network not allowed & emergency calls only

### HFP CLIENT API

### API Reference

#### Header File

- components/bt/host/bluedroid/api/include/api/esp_hf_client_api.h

#### Functions

**esp_err_t esp_hf_client_register_callback (esp_hf_client_cb_t callback)**  
Register application callback function to HFP client module. This function should be called only after esp_bluedroid_enable() completes successfully.

**Parameters**  
callback - [in] HFP client event callback function

**Returns**  
- ESP_OK: success  
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled  
- ESP_FAIL: if callback is a NULL function pointer

**esp_err_t esp_hf_client_init (void)**  
Initialize the bluetooth HFP client module. This function should be called after esp_bluedroid_enable() completes successfully.

**Returns**  
- ESP_OK: if the initialization request is sent successfully  
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled  
- ESP_FAIL: others

**esp_err_t esp_hf_client_deinit (void)**  
De-initialize for HFP client module. This function should be called only after esp_bluedroid_enable() completes successfully.

**Returns**  
- ESP_OK: success  
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled  
- ESP_FAIL: others

**esp_err_t esp_hf_client_connect (esp_bd_addr_t remote_bda)**  
Establish a Service Level Connection to remote bluetooth HFP audio gateway(AG) device. This function must be called after esp_hf_client_init() and before esp_hf_client_deinit().

**Parameters**  
remote_bda - [in] remote bluetooth device address

**Returns**  
- ESP_OK: connect request is sent to lower layer  
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled  
- ESP_FAIL: others
Chapter 2. API Reference

```c
esp_err_t esp_hf_client_disconnect (esp_bd_addr_t remote_bda)
```

Disconnect from the remote HFP audio gateway. This function must be called after esp_hf_client_init() and before esp_hf_client_deinit().

**Parameters**
- remote_bda [in] remote bluetooth device address

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_connect_audio (esp_bd_addr_t remote_bda)
```

Create audio connection with remote HFP AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Parameters**
- remote_bda [in] remote bluetooth device address

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_disconnect_audio (esp_bd_addr_t remote_bda)
```

Release the established audio connection with remote HFP AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Parameters**
- remote_bda [in] remote bluetooth device address

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_start_voice_recognition (void)
```

Enable voice recognition in the AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_stop_voice_recognition (void)
```

Disable voice recognition in the AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_volume_update (esp_hf_volume_control_target_t type, int volume)
```

Volume synchronization with AG. As a precondition to use this API, Service Level Connection shall exist with AG.

**Parameters**
- type [in] volume control target, speaker or microphone
- volume [in] gain of the speaker of microphone, ranges 0 to 15

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_dial (const char *number)
```

Place a call with a specified number, if number is NULL, last called number is called. As a precondition to use this API, Service Level Connection shall exist with AG.
### Parameters
- **number** – [in] number string of the call. If NULL, the last number is called (aka re-dial)

### Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

#### esp_err_t esp_hf_client_dial_memory(int location)
Place a call with number specified by location (speed dial). As a precondition to use this API, Service Level Connection shall exist with AG.

#### Parameters
- **location** – [in] location of the number in the memory

#### Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

#### esp_err_t esp_hf_client_send_chld_cmd(esp_hf_chld_type_t chld, int idx)
Send call hold and multiparty commands, or enhanced call control commands (Use AT+CHLD). As a precondition to use this API, Service Level Connection shall exist with AG.

#### Parameters
- **chld** – [in] AT+CHLD call hold and multiparty handling AT command.
- **idx** – [in] used in Enhanced Call Control Mechanisms, used if chld is ESP_HF_CHLD_TYPE_REL_X or ESP_HF_CHLD_TYPE_PRIV_X

#### Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

#### esp_err_t esp_hf_client_send_btrh_cmd(esp_hf_btrh_cmd_t btrh)
Send response and hold action command (Send AT+BTRH command) As a precondition to use this API, Service Level Connection shall exist with AG.

#### Parameters
- **btrh** – [in] response and hold action to send

#### Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

#### esp_err_t esp_hf_client_answer_call(void)
Answer an incoming call (send ATA command). As a precondition to use this API, Service Level Connection shall exist with AG.

#### Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

#### esp_err_t esp_hf_client_reject_call(void)
Reject an incoming call or terminate an ongoing call (send AT+CHUP command). As a precondition to use this API, Service Level Connection shall exist with AG.

#### Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

#### esp_err_t esp_hf_client_query_current_calls(void)
Query list of current calls in AG (send AT+CLCC command). As a precondition to use this API, Service Level Connection shall exist with AG.

#### Returns
Chapter 2. API Reference

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

*esp_err_t* esp_hf_client_query_current_operator_name (void)

Query the name of currently selected network operator in AG (use AT+COPS commands). As a precondition to use this API, Service Level Connection shall exist with AG.

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

*esp_err_t* esp_hf_client_retrieve_subscriber_info (void)

Get subscriber information number from AG (send AT+CNUM command). As a precondition to use this API, Service Level Connection shall exist with AG.

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

*esp_err_t* esp_hf_client_send_dtmf (char code)

Transmit DTMF codes during an ongoing call (use AT+VTS commands). As a precondition to use this API, Service Level Connection shall exist with AG.

**Parameters**  
`code` \([\text{in}]\) dtmf code, single ascii character in the set 0-9, #, *, A-D

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

*esp_err_t* esp_hf_client_send_xapl (char* information, uint32_t features)

Send command to enable Vendor specific feature to indicate battery level and docker status. This is Apple-specific commands, but used by most device, including Android and Windows.

**Parameters**
- `information` \([\text{in}]\) XAPL vendorID-productID-version, such as “0505-1995-0610”
  - vendorID: A string representation of the hex value of the vendor ID from the manufacturer, without the 0x prefix.
  - productID: A string representation of the hex value of the product ID from the manufacturer, without the 0x prefix.
  - version: The revision of the software
- `features` \([\text{in}]\) A base-10 representation of a bit field. such as ESP_HF_CLIENT_XAPL_FEAT_BATTERY_REPORT

**Returns**
- ESP_OK: Feature enable request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

*esp_err_t* esp_hf_client_send_iphoneaccev (uint32_t bat_level, bool docked)

Send Battery level and docker status. Enable this feature using XAPL command first. This is Apple-specific commands, but used by most device, including Android and Windows.

**Parameters**
- `bat_level` \([\text{in}]\) Battery Level: value between 0 and 9
- `docked` \([\text{in}]\) Dock State: false = undocked, true = docked

**Returns**
- ESP_OK: battery level is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

*esp_err_t* esp_hf_client_request_last_voice_tag_number (void)

Request a phone number from AG corresponding to last voice tag recorded (send AT+BINP command). As a precondition to use this API, Service Level Connection shall exist with AG.
Chapter 2. API Reference

Returns
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_send_nrec (void)
```

Disable echo cancellation and noise reduction in the AG (use AT+NREC=0 command). As a precondition to use this API, Service Level Connection shall exist with AG.

Returns
- ESP_OK: NREC=0 request is sent to lower layer
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_client_register_data_callback (esp_hf_client_incoming_data_cb_t recv,
                                             esp_hf_client_outgoing_data_cb_t send)
```

Register HFP client data output function; the callback is only used in the case that Voice Over HCI is enabled.

Parameters
- `recv` — [in] HFP client incoming data callback function
- `send` — [in] HFP client outgoing data callback function

Returns
- ESP_OK: success
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

```c
esp_err_t esp_hf_client_pkt_stat_nums_get (uint16_t sync_conn_handle)
```

Get the number of packets received and sent. This function is only used in the case that Voice Over HCI is enabled and the audio state is connected. When the operation is completed, the callback function will be called with ESP_HF_CLIENT_PKT_STAT_NUMS_GET_EVT.

Parameters
- `sync_conn_handle` — [in] the (e)SCO connection handle

Returns
- ESP_OK: if the request is sent successfully
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
void esp_hf_client_outgoing_data_ready (void)
```

Trigger the lower-layer to fetch and send audio data. This function is only used in the case that Voice Over HCI is enabled. After this function is called, lower layer will invoke esp_hf_client_outgoing_data_cb_t to fetch data.

As a precondition to use this API, Service Level Connection shall exist with AG.

```c
void esp_hf_client_pcm_resample_init (uint32_t src_sps, uint32_t bits, uint32_t channels)
```

Initialize the down sampling converter. This is a utility function that can only be used in the case that Voice Over HCI is enabled.

Parameters
- `src_sps` — [in] original samples per second (source audio data, i.e. 48000, 32000, 16000, 44100, 22050, 11025)
- `bits` — [in] number of bits per pcm sample (16)
- `channels` — [in] number of channels (i.e. mono(1), stereo(2)…)

```c
void esp_hf_client_pcm_resample_deinit (void)
```

Deinitialize the down sampling converter.

```c
int32_t esp_hf_client_pcm_resample (void *src, uint32_t in_bytes, void *dst)
```

Down sampling utility to convert high sampling rate into 8K/16bits 1-channel mode PCM samples. This can only be used in the case that Voice Over HCI is enabled.

Parameters
- `src` — [in] pointer to the buffer where the original sampling PCM are stored
Chapter 2. API Reference

- **in_bytes** - [in] length of the input PCM sample buffer in byte
- **dst** - [in] pointer to the buffer which is to be used to store the converted PCM samples

**Returns** number of samples converted

**Unions**

union `esp_hf_client_cb_param_t`

```
#include <esp_hf_client_api.h> // HFP client callback parameters.
```

**Public Members**

```
struct esp_hf_client_cb_param_t::hf_client_conn_stat_param conn_stat
    HF callback param of ESP_HF_CLIENT_CONNECTION_STATE_EVT

struct esp_hf_client_cb_param_t::hf_client_audio_stat_param audio_stat
    HF callback param of ESP_HF_CLIENT_AUDIO_STATE_EVT

struct esp_hf_client_cb_param_t::hf_client_bvra_param bvra
    HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_service_availability_param service_availability
    HF callback param of ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT

struct esp_hf_client_cb_param_t::hf_client_network_roaming_param roaming
    HF callback param of ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT

struct esp_hf_client_cb_param_t::hf_client_signal_strength_ind_param signal_strength
    HF callback param of ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT

struct esp_hf_client_cb_param_t::hf_client_battery_level_ind_param battery_level
    HF callback param of ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT

struct esp_hf_client_cb_param_t::hf_client_current_operator_param cops
    HF callback param of ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT

struct esp_hf_client_cb_param_t::hf_client_call_ind_param call
    HF callback param of ESP_HF_CLIENT_CIND_CALL_EVT

struct esp_hf_client_cb_param_t::hf_client_call_setup_ind_param call_setup
    HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_call_held_ind_param call_held
    HF callback param of ESP_HF_CLIENT_CIND_CALL_HELD_EVT

struct esp_hf_client_cb_param_t::hf_client_btrh_param btrh
    HF callback param of ESP_HF_CLIENT_BRTH_EVT

struct esp_hf_client_cb_param_t::hf_client_clip_param clip
    HF callback param of ESP_HF_CLIENT_CLIP_EVT
```
struct esp_hf_client_cb_param_t::hf_client_ccwa_param ccwa
    HF callback param of ESP_HF_CLIENT_BVRA_EVT

struct esp_hf_client_cb_param_t::hf_client_clcc_param clcc
    HF callback param of ESP_HF_CLIENT_CLCC_EVT

struct esp_hf_client_cb_param_t::hf_client_volume_control_param volume_control
    HF callback param of ESP_HF_CLIENT_VOLUME_CONTROL_EVT

struct esp_hf_client_cb_param_t::hf_client_at_response_param at_response
    HF callback param of ESP_HF_CLIENT_AT_RESPONSE_EVT

struct esp_hf_client_cb_param_t::hf_client_cnum_param cnum
    HF callback param of ESP_HF_CLIENT_CNUM_EVT

struct esp_hf_client_cb_param_t::hf_client_bsirparam bsir
    HF callback param of ESP_HF_CLIENT BSIR_EVT

struct esp_hf_client_cb_param_t::hf_client_binp_param binp
    HF callback param of ESP_HF_CLIENT_BINP_EVT

struct esp_hf_client_cb_param_t::hf_client_pkt_status_nums pkt_nums
    HF callback param of ESP_HF_CLIENT_PKT_STAT_NUMS_GET_EVT

struct hf_client_at_response_param
    #include <esp_hf_client_api.h> ESP_HF_CLIENT_AT_RESPONSE_EVT.

Public Members

esp_hf_at_response_code_t code
    AT response code

esp_hf_cme_err_t cme
    Extended Audio Gateway Error Result Code

struct hf_client_audio_stat_param
    #include <esp_hf_client_api.h> ESP_HF_CLIENT_AUDIO_STATE_EVT.

Public Members

esp_hf_client_audio_state_t state
    audio connection state

esp_bd_addr_t remote_bda
    remote bluetooth device address
Chapter 2. API Reference

```c
uint16_t sync_conn_handle
  (e)SCO connection handle

struct hf_client_battery_level_ind_param
  #include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT.

Public Members

  int value
    battery charge value, ranges from 0 to 5

struct hf_client_binp_param
  #include <esp_hf_client_api.h> ESP_HF_CLIENT_BINP_EVT.

Public Members

  const char *number
    phone number corresponding to the last voice tag in the HF

struct hf_client_bsirparam
  #include <esp_hf_client_api.h> ESP_HF_CLIENT_BSIR_EVT.

Public Members

  esp_hf_client_in_band_ring_state_t state
    setting state of in-band ring tone

struct hf_client_btrh_param
  #include <esp_hf_client_api.h> ESP_HF_CLIENT_BTRH_EVT.

Public Members

  esp_hf_btrh_status_t status
    call hold and response status result code

struct hf_client_bvra_param
  #include <esp_hf_client_api.h> ESP_HF_CLIENT_BVRA_EVT.

Public Members

  esp_hf_vr_state_t value
    voice recognition state

struct hf_client_call_held_ind_param
  #include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_CALL_HELD_EVT.
```
Public Members

*esp hf call held status t* status
bluetooth proprietary call hold status indicator

struct hf client call ind param
#include <esp hf client api h> ESP_HF_CLIENT_CIND_CALL_EVT.

Public Members

*esp hf call status t* status
call status indicator

struct hf client call setup ind param
#include <esp hf client api h> ESP_HF_CLIENT_CIND_CALL_SETUP_EVT.

Public Members

*esp hf call setup status t* status
call setup status indicator

struct hf client ccwa param
#include <esp hf client api h> ESP_HF_CLIENT_CCWA_EVT.

Public Members

const char *number
phone number string of waiting call

struct hf client clcc param
#include <esp hf client api h> ESP_HF_CLIENT_CLCC_EVT.

Public Members

int idx
numbering (starting with 1) of the call

*esp hf current call direction t* dir
direction of the call

*esp hf current call status t* status
status of the call

*esp hf current call mpty type t* mpty
multi-party flag
char *number
    phone number(optional)

struct hf_client_clip_param
    #include <esp_hf_client_api.h> ESP_HF_CLIENT_CLIP_EVT.

Public Members

const char *number
    phone number string of call

struct hf_client_cnum_param
    #include <esp_hf_client_api.h> ESP_HF_CLIENT_CNUM_EVT.

Public Members

const char *number
    phone number string

    esp_hf_subscriber_service_type_t type
        service type that the phone number relates to

struct hf_client_conn_stat_param
    #include <esp_hf_client_api.h> ESP_HF_CLIENT_CONNECTION_STATE_EVT.

Public Members

    esp_hf_client_connection_state_t state
        HF connection state

    uint32_t peer_feat
        AG supported features

    uint32_t chld_feat
        AG supported features on call hold and multiparty services

    esp_bd_addr_t remote_bda
        remote bluetooth device address

struct hf_client_current_operator_param
    #include <esp_hf_client_api.h> ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT.

Public Members

const char *name
    name of the network operator
struct hf_client_network_roaming_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT.

Public Members

    esp_hf_roaming_status_t status
    roaming status

struct hf_client_pkt_status_nums
#include <esp_hf_client_api.h> ESP_HF_CLIENT_PKT_STAT_NUMS_GET_EVT.

Public Members

    uint32_t rx_total
    the total number of packets received

    uint32_t rx_correct
    the total number of packets data correctly received

    uint32_t rx_err
    the total number of packets data with possible invalid

    uint32_t rx_none
    the total number of packets data no received

    uint32_t rx_lost
    the total number of packets data partially lost

    uint32_t tx_total
    the total number of packets send

    uint32_t tx_discarded
    the total number of packets send lost

struct hf_client_service_availability_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT.

Public Members

    esp_hf_network_state_t status
    service availability status

struct hf_client_signal_strength_ind_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT.
Chapter 2. API Reference

Public Members

int value
signal strength value, ranges from 0 to 5

struct hf_client_volume_control_param
#include <esp_hf_client_api.h> ESP_HF_CLIENT_VOLUME_CONTROL_EVT.

Public Members

esp_hf_volume_control_target_t type
volume control target, speaker or microphone

int volume
gain, ranges from 0 to 15

Macros

ESP_BT_HF_CLIENT_NUMBER_LEN
ESP_BT_HF_CLIENT_OPERATOR_NAME_LEN
ESP_BT_HF_AT_SEND_XAPL_LEN
ESP_HF_CLIENT_PEER_FEAT_3WAY
ESP_HF_CLIENT_PEER_FEAT_ECNR
ESP_HF_CLIENT_PEER_FEAT_VREC
ESP_HF_CLIENT_PEER_FEAT_INBAND
ESP_HF_CLIENT_PEER_FEAT_VTAG
ESP_HF_CLIENT_PEER_FEAT_REJECT
ESP_HF_CLIENT_PEER_FEAT_ECS
ESP_HF_CLIENT_PEER_FEAT_ECC
ESP_HF_CLIENT_PEER_FEAT_EXTERR
ESP_HF_CLIENT_PEER_FEAT_CODEC
ESP_HF_CLIENT_PEER_FEAT_HF_IND
Type Definitions

typedef void (*esp_hf_client_incoming_data_cb_t)(const uint8_t *buf, uint32_t len)
    HFP client incoming data callback function, the callback is useful in case of Voice Over HCI.

    Param buf [in] : pointer to incoming data(payload of HCI synchronous data packet), the buffer
        is allocated inside bluetooth protocol stack and will be released after invoke of the callback is
        finished.
    Param len [in] : size(in bytes) in buf

typedef uint32_t (*esp_hf_client_outgoing_data_cb_t)(uint8_t *buf, uint32_t len)
    HFP client outgoing data callback function, the callback is useful in case of Voice Over HCI. Once audio
    connection is set up and the application layer has prepared data to send, the lower layer will call this function
    to read data and then send. This callback is supposed to be implemented as non-blocking, and if data is not
    enough, return value 0 is supposed.

    Param buf [in] : pointer to incoming data(payload of HCI synchronous data packet), the buffer
        is allocated inside bluetooth protocol stack and will be released after invoke of the callback is
        finished.
    Param len [in] : size(in bytes) in buf
    Return length of data successfully read

typedef void (*esp_hf_client_cb_t)(esp_hf_client_cb_event_t event, esp_hf_client_cb_param_t *param)
    HFP client callback function type.
Chapter 2. API Reference

**Param event**: Event type
**Param param**: Pointer to callback parameter

**Enumerations**

```c
enum esp hf_client_connection_state_t
  Bluetooth HFP RFCOMM connection and service level connection status.
  
  Values:
  
  enumerator ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTED
    RFCOMM data link channel released
  
  enumerator ESP_HF_CLIENT_CONNECTION_STATE_CONNECTING
    connecting remote device on the RFCOMM data link
  
  enumerator ESP_HF_CLIENT_CONNECTION_STATE_CONNECTED
    RFCOMM connection established
  
  enumerator ESP_HF_CLIENT_CONNECTION_STATE_SLC_CONNECTED
    service level connection established
  
  enumerator ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTING
    disconnecting with remote device on the RFCOMM dat link

enum esp hf_client_audio_state_t
  Bluetooth HFP audio connection status.
  
  Values:
  
  enumerator ESP_HF_CLIENT_AUDIO_STATE_DISCONNECTED
    audio connection released
  
  enumerator ESP_HF_CLIENT_AUDIO_STATE_CONNECTING
    audio connection has been initiated
  
  enumerator ESP_HF_CLIENT_AUDIO_STATE_CONNECTED
    audio connection is established
  
  enumerator ESP_HF_CLIENT_AUDIO_STATE_CONNECTED_MSBC
    mSBC audio connection is established

enum esp hf_client_in_band_ring_state_t
  in-band ring tone state
  
  Values:
  
  enumerator ESP_HF_CLIENT_IN_BAND_RINGTONE_NOT_PROVIDED
  
  enumerator ESP_HF_CLIENT_IN_BAND_RINGTONE_PROVIDED
```
enum esp_hf_client_cb_event_t
    HF CLIENT callback events.

    Values:

    enumerator ESP_HF_CLIENT_CONNECTION_STATE_EVT
            connection state changed event

    enumerator ESP_HF_CLIENT_AUDIO_STATE_EVT
            audio connection state change event

    enumerator ESP_HF_CLIENT_BVRA_EVT
            voice recognition state change event

    enumerator ESP_HF_CLIENT_CIND_CALL_EVT
            call indication

    enumerator ESP_HF_CLIENT_CIND_CALL_SETUP_EVT
            call setup indication

    enumerator ESP_HF_CLIENT_CIND_CALL_HELD_EVT
            call held indication

    enumerator ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT
            network service availability indication

    enumerator ESP_HF_CLIENT_CIND_SIGNAL_STRENGTH_EVT
            signal strength indication

    enumerator ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT
            roaming status indication

    enumerator ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT
            battery level indication

    enumerator ESP_HF_CLIENT_COPS_CURRENT_OPERATOR_EVT
            current operator information

    enumerator ESP_HF_CLIENT_BTRH_EVT
            call response and hold event

    enumerator ESP_HF_CLIENT_CLIP_EVT
            Calling Line Identification notification

    enumerator ESP_HF_CLIENT_CCWA_EVT
            call waiting notification

    enumerator ESP_HF_CLIENT_CLCC_EVT
            list of current calls notification
enumerator **ESP_HF_CLIENT_VOLUME_CONTROL_EVT**
    audio volume control command from AG, provided by +VGM or +VGS message

eumerator **ESP_HF_CLIENT_AT_RESPONSE_EVT**
    AT command response event

eumerator **ESP_HF_CLIENT_CNUM_EVT**
    subscriber information response from AG

eumerator **ESP_HF_CLIENT_BSIR_EVT**
    setting of in-band ring tone

eumerator **ESP_HF_CLIENT_BINP_EVT**
    requested number of last voice tag from AG

eumerator **ESP_HF_CLIENT_RING_IND_EVT**
    ring indication event

eumerator **ESP_HF_CLIENT_PKT_STAT_NUMS_GET_EVT**
    requested number of packet different status

**HFP AG API**

**API Reference**

**Header File**

- components/bt/host/bluedroid/api/include/api/esp_hf_ag_api.h

**Functions**

`esp_err_t esp_hf_ag_register_callback(esp_hf_cb_t callback)`

Register application callback function to HFP AG module. This function should be called only after esp_bluedroid_enable() completes successfully.

**Parameters**
- `callback` - [in] HFP AG event callback function

**Returns**
- ESP_OK: success
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

`esp_err_t esp_hf_ag_init(void)`

Initialize the Bluetooth HF AG module. This function should be called after esp_bluedroid_enable() completes successfully.

**Returns**
- ESP_OK: if the initialization request is sent successfully
- ESP_INVALID_STATE: if Bluetooth stack is not yet enabled
- ESP_FAIL: others

`esp_err_t esp_hf_ag_deinit(void)`

De-initialize for HF AG module. This function should be called only after esp_bluedroid_enable() completes successfully.

**Returns**
- ESP_OK: success
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_slc_connect (esp_bd_addr_t remote_bda)`

To establish a Service Level Connection to remote bluetooth HFP client device. This function must be called after `esp_hf_ag_init()` and before `esp_hf_ag_deinit()`.

**Parameters** remote_bda - [in] remote bluetooth HFP client device address

**Returns**
• ESP_OK: connect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_slc_disconnect (esp_bd_addr_t remote_bda)`

Disconnect from the remote HFP client. This function must be called after `esp_hf_ag_init()` and before `esp_hf_ag_deinit()`.

**Parameters** remote_bda - [in] remote bluetooth device address

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_audio_connect (esp_bd_addr_t remote_bda)`

Create audio connection with remote HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters** remote_bda - [in] remote bluetooth device address

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_audio_disconnect (esp_bd_addr_t remote_bda)`

Release the established audio connection with remote HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters** remote_bda - [in] remote bluetooth device address

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_vra_control (esp_bd_addr_t remote_bda, esp_hf_vr_state_t value)`

Response of Volume Recognition Command(AT+VRA) from HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
• remote_bda - [in] the device address of voice recognition initiator
• value - [in] 0 - voice recognition disabled, 1- voice recognition enabled

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_volume_control (esp_bd_addr_t remote_bda, esp_hf_volume_control_target_t type, int volume)`

Volume synchronization with HFP client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
• remote_bda - [in] remote bluetooth device address
• type - [in] volume control target, speaker or microphone
• **volume** [in] gain of the speaker of microphone, ranges 0 to 15

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_unknown_at_send(esp_bd_addr_t remote_addr, char *unat)`

Handle Unknown AT command from HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
• **remote_addr** [in] remote bluetooth device address
• **unat** [in] User AT command response to HF Client. It will response “ERROR” by default if unat is NULL.

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_cmee_send(esp_bd_addr_t remote_bda, esp_hf_at_response_code_t response_code, esp_hf_cme_err_t error_code)`

Unsolicited send extend AT error code to HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
• **remote_bda** [in] remote bluetooth device address
• **response_code** [in] AT command response code
• **error_code** [in] CME error code

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_devices_status_indchange(esp_bd_addr_t remote_addr, esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state, esp_hf_network_state_t ntk_state, int signal)`

Unsolicited send device status notification to HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
• **remote_addr** [in] remote bluetooth device address
• **call_state** [in] call state
• **call_setup_state** [in] call setup state
• **ntk_state** [in] network service state
• **signal** [in] signal strength from 0 to 5

**Returns**
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

`esp_err_t esp_hf_ag_ciev_report(esp_bd_addr_t remote_addr, esp_hf_ciev_report_type_t ind_type, int value)`

Send indicator report “+CIEV: <ind><value>” to HFP Client. “CIEV” means “indicator events reporting”, and all indicator types can be sent one type at a time. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
• **remote_addr** [in] remote bluetooth device address
• **ind_type** [in] indicator type
• **value** [in] indicator value
Returns
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

```
esp_err_t esp_hf_ag_cind_response(esp_bd_addr_t remote_addr, esp_hf_call_status_t call_state,
                                 esp_hf_call_setup_status_t call_setup_state, esp_hf_network_state_t
                                 ntk_state, int signal, esp_hf_roaming_status_t roam, int batt_lev,
                                 esp_hf_call_held_status_t call_held_status)
```

Response to device individual indicators to HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Parameters
• remote_addr - [in] remote bluetooth device address
• call_state - [in] call state
• call_setup_state - [in] call setup state
• ntk_state - [in] network service state
• signal - [in] signal strength from 0 to 5
• roam - [in] roam state
• batt_lev - [in] battery level from 0 to 5
• call_held_status - [in] call held status

Returns
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

```
esp_err_t esp_hf_ag_cops_response(esp_bd_addr_t remote_addr, char *name)
```

Reponse for AT+COPS command from HF Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Parameters
• remote_addr - [in] remote bluetooth device address
• name - [in] current operator name

Returns
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others

```
esp_err_t esp_hf_ag_clcc_response(esp_bd_addr_t remote_addr, int index,
                                  esp_hf_current_call_direction_t dir, esp_hf_current_call_status_t
                                  current_call_state, esp_hf_current_call_mode_t mode,
                                  esp_hf_current_call_mpty_type_t mpty, char *number,
                                  esp_hf_call_addr_type_t type)
```

Response to AT+CLCC command from HFP Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

Parameters
• remote_addr - [in] remote bluetooth device address
• index - [in] the index of current call, starting with 1, finishing response with 0 (send OK)
• dir - [in] call direction (incoming/outgoing)
• current_call_state - [in] current call state
• mode - [in] current call mode (voice/data/fax)
• mpty - [in] single or multi type
• number - [in] current call number
• type - [in] international type or unkonw

Returns
• ESP_OK: disconnect request is sent to lower layer
• ESP_INVALID_STATE: if bluetooth stack is not yet enabled
• ESP_FAIL: others
**esp_err_t esp_hf_ag_cnum_response** *(esp_bd_addr_t remote_addr, char *number, int number_type, esp_hf_subscriber_service_type_t service_type)*

Response for AT+CNUM command from HF Client. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**

- **remote_addr** – [in] remote bluetooth device address
- **number** – [in] registration number
- **number_type** – [in] value of number type from 128-143: national or international, may contain prefix and/or escape digits 144-159: international, includes country code prefix, add “+” if needed 160-175: national, but no prefix nor escape digits
- **service_type** – [in] service type (unknown/voice/fax)

**Returns**

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_hf_ag_bsir** *(esp_bd_addr_t remote_addr, esp_hf_in_band_ring_state_t state)*

Inform HF Client that AG Provided in-band ring tone or not. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**

- **remote_addr** – [in] remote bluetooth device address
- **state** – [in] in-band ring tone state

**Returns**

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_hf_ag_answer_call** *(esp_bd_addr_t remote_addr, int num_active, int num_held, esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state, char *number, esp_hf_call_addr_type_t call_addr_type)*

Answer Incoming Call from AG. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**

- **remote_addr** – [in] remote bluetooth device address
- **num_active** – [in] the number of active call
- **num_held** – [in] the number of held call
- **call_state** – [in] call state
- **call_setup_state** – [in] call setup state
- **number** – [in] number of the incoming call
- **call_addr_type** – [in] call address type

**Returns**

- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

**esp_err_t esp_hf_ag_reject_call** *(esp_bd_addr_t remote_addr, int num_active, int num_held, esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state, char *number, esp_hf_call_addr_type_t call_addr_type)*

Reject Incoming Call from AG. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**

- **remote_addr** – [in] remote bluetooth device address
- **num_active** – [in] the number of active call
- **num_held** – [in] the number of held call
Chapter 2. API Reference

- **call_state** [in] call state
- **call_setup_state** [in] call setup state
- **number** [in] number of the incoming call
- **call_addr_type** [in] call address type

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_ag_out_call(esp_bd_addr_t remote_addr, int num_active, int num_held,
                             esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state,
                             char *number, esp_hf_call_addr_type_t call_addr_type)
```

Initiate a call from AG. As a precondition to use this API, Service Level Connection shall exist with HFP client.
If the AG is driven by the HF to call esp_hf_ag_out_call, it needs to response an OK or ERROR to HF. But if the AG is actively calling esp_hf_ag_out_call, it does not need to take a response to HF.

**Parameters**
- **remote_addr** [in] remote bluetooth device address
- **num_active** [in] the number of active call
- **num_held** [in] the number of held call
- **call_state** [in] call state
- **call_setup_state** [in] call setup state
- **number** [in] number of the outgoing call
- **call_addr_type** [in] call address type

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_ag_end_call(esp_bd_addr_t remote_addr, int num_active, int num_held,
                             esp_hf_call_status_t call_state, esp_hf_call_setup_status_t call_setup_state,
                             char *number, esp_hf_call_addr_type_t call_addr_type)
```

End an ongoing call. As a precondition to use this API, Service Level Connection shall exist with HFP client.

**Parameters**
- **remote_addr** [in] remote bluetooth device address
- **num_active** [in] the number of active call
- **num_held** [in] the number of held call
- **call_state** [in] call state
- **call_setup_state** [in] call setup state
- **number** [in] number of the call
- **call_addr_type** [in] call address type

**Returns**
- ESP_OK: disconnect request is sent to lower layer
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

```c
esp_err_t esp_hf_ag_register_data_callback(esp_hf_incoming_data_cb_t recv,
                                          esp_hf_outgoing_data_cb_t send)
```

Register AG data output function. The callback is only used in the case that Voice Over HCI is enabled.

**Parameters**
- **recv** [in] HFP client incoming data callback function
- **send** [in] HFP client outgoing data callback function

**Returns**
- ESP_OK: success
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: if callback is a NULL function pointer

```c
esp_err_t esp_hf_ag_pkt_stat_nums_get(uint16_t sync_conn_handle)
```

Get the number of packets received and sent.
This function is only used in the case that Voice Over HCI is enabled and the audio state is connected.
When the operation is completed, the callback function will be called with ESP_HF_PKT_STAT_NUMS_GET_EVT.

Parameters

- **sync_conn_handle** [in] the (e)SCO connection handle

Returns

- ESP_OK: if the request is sent successfully
- ESP_INVALID_STATE: if bluetooth stack is not yet enabled
- ESP_FAIL: others

void **esp_hf_ag_outgoing_data_ready** (void)

Trigger the lower-layer to fetch and send audio data.

<table>
<thead>
<tr>
<th>Unions</th>
</tr>
</thead>
<tbody>
<tr>
<td>union <strong>esp_hf_cb_param_t</strong></td>
</tr>
</tbody>
</table>

#include <esp_hf_ag_api.h> HFP AG callback parameters.

**Public Members**

struct **esp_hf_cb_param_t::hf_conn_stat_param** conn_stat
AG callback param of ESP_HF_CONNECTION_STATE_EVT

struct **esp_hf_cb_param_t::hf_audio_stat_param** audio_stat
AG callback param of ESP_HF_AUDIO_STATE_EVT

struct **esp_hf_cb_param_t::hf_vra_rep_param** vra_rep
AG callback param of ESP_HF_BVRA_RESPONSE_EVT

struct **esp_hf_cb_param_t::hf_volume_control_param** volume_control
AG callback param of ESP_HF_VOLUME_CONTROL_EVT

struct **esp_hf_cb_param_t::hf_unat_rep_param** unat_rep
AG callback param of ESP_HF_UNAT_RESPONSE_EVT

struct **esp_hf_cb_param_t::hf_out_call_param** out_call
AG callback param of ESP_HF_DIAL_EVT

struct **esp_hf_cb_param_t::hf_ind_upd_param** ind_upd
AG callback param of ESP_HF_IND_UPDATE_EVT
struct esp_hf_cb_param_t::hf_cind_rep_param cind_rep
    AG callback param of ESP_HF_CIND_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_cops_rep_param cops_rep
    AG callback param of ESP_HF_COPS_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_clcc_rep_param clcc_rep
    AG callback param of ESP_HF_CLCC_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_cnum_rep_param cnum_rep
    AG callback param of ESP_HF_CNUM_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_vts_rep_param vts_rep
    AG callback param of ESP_HF_VTS_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_nrec_param nrec
    AG callback param of ESP_HF_NREC_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_ata_rep_param ata_rep
    AG callback param of ESP_HF_ATA_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_chup_rep_param chup_rep
    AG callback param of ESP_HF_CHUP_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_wbs_rep_param wbs_rep
    AG callback param of ESP_HF_WBS_RESPONSE_EVT

struct esp_hf_cb_param_t::hf_bcs_rep_param bcs_rep
    AG callback param of ESP_HF_BCS_RESPONSE_EVT

struct esp_hf_cb_param_t::ag_pkt_status_nums pkt_nums
    AG callback param of ESP_HF_PKT_STAT_NUMS_GET_EVT

struct ag_pkt_status_nums
    #include <esp_hf_ag_api.h> ESP_HF_PKT_STAT_NUMS_GET_EVT.

Public Members

uint32_t rx_total
    the total number of packets received

uint32_t rx_correct
    the total number of packets data correctly received

uint32_t rx_err
    the total number of packets data with possible invalid
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>uint32_t rx_none</code></td>
<td>the total number of packets data no received</td>
</tr>
<tr>
<td><code>uint32_t rx_lost</code></td>
<td>the total number of packets data partially lost</td>
</tr>
<tr>
<td><code>uint32_t tx_total</code></td>
<td>the total number of packets send</td>
</tr>
<tr>
<td><code>uint32_t tx_discarded</code></td>
<td>the total number of packets send lost</td>
</tr>
</tbody>
</table>

**struct hf_ata_rep_param**

```
#include <esp_hf_ag_api.h> ESP_HF_ATA_RESPONSE_EVT.
```

**Public Members**

- `esp_bd_addr_t remote_addr`
remote bluetooth device address

**struct hf_audio_stat_param**

```
#include <esp_hf_ag_api.h> ESP_HF_AUDIO_STATE_EVT.
```

**Public Members**

- `esp_bd_addr_t remote_addr`
Remote bluetooth device address
- `esp_hf_audio_state_t state`
Audio connection state
- `uint16_t sync_conn_handle`
(e)SCO connection handle

**struct hf_bcs_rep_param**

```
#include <esp_hf_ag_api.h> ESP_HF_BCS_RESPONSE_EVT.
```

**Public Members**

- `esp_bd_addr_t remote_addr`
Remote bluetooth device address
- `esp_hf_wbs_config_t mode`
codec mode CVSD or mSBC

**struct hf_chup_rep_param**

```
#include <esp_hf_ag_api.h> ESP_HF_CHUP_RESPONSE_EVT.
```
Chapter 2. API Reference

Public Members

```
esp_bd_addr_t remote_addr
remote bluetooth device address
```

```
#include <esp_hf_ag_api.h> ESP_HF_CIND_RESPONSE_EVT.
```

Public Members

```
esp_bd_addr_t remote_addr
remote bluetooth device address
```

```
#include <esp_hf_ag_api.h> ESP_HF_CLCC_RESPONSE_EVT.
```

Public Members

```
esp_bd_addr_t remote_addr
remote bluetooth device address
```

```
#include <esp_hf_ag_api.h> ESP_HF_CNUM_RESPONSE_EVT.
```

Public Members

```
esp_bd_addr_t remote_addr
remote bluetooth device address
```

```
#include <esp_hf_ag_api.h> ESP_HF_CONNECTION_STATE_EVT.
```

Public Members

```
esp_bd_addr_t remote_bda
Remote bluetooth device address
```

```
esp_hf_connection_state_t state
Connection state
```

```
uint32_t peer_feat
HF supported features
```

```
uint32_t child_feat
AG supported features on call hold and multiparty services
```
struct hf_cops_rep_param
#include <esp_hf_ag_api.h> ESP_HF_COPS_RESPONSE_EVT.

Public Members

esp_bd_addr_t remote_addr
remote bluetooth device address

struct hf_ind_upd_param
#include <esp_hf_ag_api.h> ESP_HF_IND_UPDATE_EVT.

Public Members

esp_bd_addr_t remote_addr
remote bluetooth device address

struct hf_nrec_param
#include <esp_hf_ag_api.h> ESP_HF_NREC_RESPONSE_EVT.

Public Members

esp_bd_addr_t remote_addr
Remote bluetooth device address

esp_hf_nrec_t state
NREC enabled or disabled

struct hf_out_call_param
#include <esp_hf_ag_api.h> ESP_HF_DIAL_EVT.

Public Members

esp_bd_addr_t remote_addr
remote bluetooth device address

dial type

char *num_or_loc
location in phone memory

struct hf_unat_rep_param
#include <esp_hf_ag_api.h> ESP_HF_UNAT_RESPONSE_EVT.
Public Members

```c
esp_bd_addr_t remote_addr
Remote bluetooth device address
```

```c
char *unat
Unknown AT command string
```

```c
struct hf_volume_control_param
#include <esp_hf_ag_api.h> ESP_HF_VOLUME_CONTROL_EVT.
```

Public Members

```c
esp_bd_addr_t remote_addr
Remote bluetooth device address
```

```c
esp_hf_volume_type_t type
Volume control target, speaker or microphone
```

```c
int volume
Gain, ranges from 0 to 15
```

```c
struct hf_vra_rep_param
#include <esp_hf_ag_api.h> ESP_HF_BVRA_RESPONSE_EVT.
```

Public Members

```c
esp_bd_addr_t remote_addr
Remote bluetooth device address
```

```c
esp_hf_vr_state_t value
Voice recognition state
```

```c
struct hf_vts_rep_param
#include <esp_hf_ag_api.h> ESP_HF_VTS_RESPONSE_EVT.
```

Public Members

```c
esp_bd_addr_t remote_addr
Remote bluetooth device address
```

```c
char *code
MTF code from HF Client
```

```c
struct hf_wbs_rep_param
#include <esp_hf_ag_api.h> ESP_HF_WBS_RESPONSE_EVT.
```
Public Members

`esp_bd_addr_t remote_addr`
Remote bluetooth device address

`esp_hf_wbs_config_t codec`
codec mode CVSD or mSBC

Macros

`ESP_HF_PEER_FEAT_3WAY`
`ESP_HF_PEER_FEAT_ECNR`
`ESP_HF_PEER_FEAT_VREC`
`ESP_HF_PEER_FEAT_INBAND`
`ESP_HF_PEER_FEAT_VTAG`
`ESP_HF_PEER_FEAT_REJECT`
`ESP_HF_PEER_FEAT_ECS`
`ESP_HF_PEER_FEAT_ECC`
`ESP_HF_PEER_FEAT_EXERR`
`ESP_HF_PEER_FEAT_CODEC`
`ESP_HF_PEER_FEAT_HP_IND`
`ESP_HF_PEER_FEAT_ESCO_S4`
`ESP_HF_CHLD_FEAT_REL`
`ESP_HF_CHLD_FEAT_REL_ACC`
`ESP_HF_CHLD_FEAT_REL_X`
`ESP_HF_CHLD_FEAT_HOLD_ACC`
`ESP_HF_CHLD_FEAT_PRIV_X`
`ESP_HF_CHLD_FEAT_MERGE`
`ESP_HF_CHLD_FEAT_MERGE_DETACH`
Type Definitions

typedef void (*esp_hf_incoming_data_cb_t)(const uint8_t *buf, uint32_t len)
AG incoming data callback function, the callback is useful in case of Voice Over HCI.

Param buf [in]: pointer to incoming data (payload of HCI synchronous data packet), the buffer
is allocated inside bluetooth protocol stack and will be released after invoke of the callback is
finished.
Param len [in]: size (in bytes) in buf

typedef uint32_t (*esp_hf_outgoing_data_cb_t)(uint8_t *buf, uint32_t len)
AG outgoing data callback function, the callback is useful in case of Voice Over HCI. Once audio connection
is set up and the application layer has prepared data to send, the lower layer will call this function to read data
and then send. This callback is supposed to be implemented as non-blocking, and if data is not enough, return
value 0 is supposed.

Param buf [in]: pointer to incoming data (payload of HCI synchronous data packet), the buffer
is allocated inside bluetooth protocol stack and will be released after invoke of the callback is
finished.
Param len [in]: size (in bytes) in buf
Return length of data successfully read

typedef void (*esp_hf_cb_t)(esp_hf_cb_event_t event, esp_hf_cb_param_t *param)
HF AG callback function type.

Param event: Event type
Param param: Pointer to callback parameter

Enumerations

c enum esp_hf_cb_event_t
HF callback events.

Values:

enumerator ESP_HF_CONNECTION_STATE_EVT
Connection state changed event

enumerator ESP_HF_AUDIO_STATE_EVT
Audio connection state change event

enumerator ESP_HF_BVRA_RESPONSE_EVT
Voice recognition state change event

enumerator ESP_HF_VOLUME_CONTROL_EVT
Audio volume control command from HF Client, provided by +VGM or +VGS message

enumerator ESP_HF_UNAT_RESPONSE_EVT
Unknown AT cmd Response

enumerator ESP_HF_IND_UPDATE_EVT
Indicator Update Event

enumerator ESP_HF_CIND_RESPONSE_EVT
Call And Device Indicator Response
enumerator **ESP_HF_COPS_RESPONSE_EVT**
Current operator information

enumerator **ESP_HF_CLCC_RESPONSE_EVT**
List of current calls notification

enumerator **ESP_HF_CNUM_RESPONSE_EVT**
Subscriber information response from HF Client

enumerator **ESP_HF_VTS_RESPONSE_EVT**
Enable or not DTMF

enumerator **ESP_HF_NREC_RESPONSE_EVT**
Enable or not NREC

enumerator **ESP_HF_ATA_RESPONSE_EVT**
Answer an Incoming Call

enumerator **ESP_HF_CHUP_RESPONSE_EVT**
Reject an Incoming Call

enumerator **ESP_HF_DIAL_EVT**
Origin an outgoing call with specific number or the dial the last number

enumerator **ESP_HF_WBS_RESPONSE_EVT**
Codec Status

enumerator **ESP_HF_BCS_RESPONSE_EVT**
Final Codec Choice

enumerator **ESP_HF_PKT_STAT_NUMS_GET_EVT**
Request number of packet different status

**enum esp_hf_dial_type_t**
Dial type of ESP_HF_DIAL_EVT.

*Values:*

enumerator **ESP_HF_DIAL_NUM**
Dial with a phone number

enumerator **ESP_HF_DIAL_VOIP**
Dial with VoIP

enumerator **ESP_HF_DIAL_MEM**
Dial with a memory position
Bluetooth HID Device API

Overview  A Bluetooth HID device is a device providing the service of human or other data input and output to and from a Bluetooth HID Host. Users can use the Bluetooth HID Device APIs to make devices like keyboards, mice, joysticks and so on.

Application Example  Check bluetooth/bluedroid/classic_bt folder in ESP-IDF examples, which contains the following application:

- This is an example of Bluetooth HID mouse device. The device running this example can be discovered and connected by a Bluetooth HID Host device such as a PC, and the pointer will move left and right after HID connection is established - bluetooth/bluedroid/classic_bt/bt_hid_mouse_device

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_hidd_api.h

Functions

`esp_err_t esp_bt_hid_device_register_callback(esp_hid_cb_t callback)`

This function is called to init callbacks with HID device module.

Parameters  callback  - [in] pointer to the init callback function.

Returns  
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_init(void)`

Initializes HIDD interface. This function should be called after esp_bluedroid_init() and esp_bluedroid_enable() success, and should be called after esp_bt_hid_device_register_callback. When the operation is complete, the callback function will be called with ESP_HIDD_INIT_EVT.

Returns  
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_deinit(void)`

De-initializes HIDD interface. This function should be called after esp_bluedroid_init() and esp_bluedroid_enable() success, and should be called after esp_bt_hid_device_init(). When the operation is complete, the callback function will be called with ESP_HIDD_DEINIT_EVT.

Returns  
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_register_app(esp_hid_app_param_t *app_param, esp_hid_qos_param_t *in_qos, esp_hid_qos_param_t *out_qos)`

Registers HIDD parameters with SDP and sets l2cap Quality of Service. This function should be called after esp_bluedroid_init() and esp_bluedroid_enable() success, and should be called after esp_bt_hid_device_init(). When the operation is complete, the callback function will be called with ESP_HIDD_REGISTER_APP_EVT.

Parameters  
- app_param  - [in] HIDD parameters
- in_qos  - [in] incoming QoS parameters
- out_qos  - [in] outgoing QoS parameters

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_unregister_app (void)`

Removes HIDD parameters from SDP and resets L2cap Quality of Service. This function should be called after `esp_bluedroid_init()` and `esp_bluedroid_enable()` success, and should be called after `esp_bt_hid_device_init()`. When the operation is complete, the callback function will be called with `ESP_HIDD_UNREGISTER_APP_EVT`.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_connect (esp_bd_addr_t bd_addr)`

Connects to the peer HID Host with virtual cable. This function should be called after `esp_bluedroid_init()` and `esp_bluedroid_enable()` success, and should be called after `esp_bt_hid_device_init()`. When the operation is complete, the callback function will be called with `ESP_HIDD_OPEN_EVT`.

Parameters
- `bd_addr` [in] Remote host bluetooth device address.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_disconnect (void)`

Disconnects from the currently connected HID Host. This function should be called after `esp_bluedroid_init()` and `esp_bluedroid_enable()` success, and should be called after `esp_bt_hid_device_init()`. When the operation is complete, the callback function will be called with `ESP_HIDD_CLOSE_EVT`.

Note: The disconnect operation will not remove the virtually cabled device. If the connect request from the different HID Host, it will reject the request.

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_send_report (esp_hidd_report_type_t type, uint8_t id, uint16_t len, uint8_t *data)`

Sends HID report to the currently connected HID Host. This function should be called after `esp_bluedroid_init()` and `esp_bluedroid_enable()` success, and should be called after `esp_bt_hid_device_init()`. When the operation is complete, the callback function will be called with `ESP_HIDD_SEND_REPORT_EVT`.

Parameters
- `type` [in] type of report
- `id` [in] report id as defined by descriptor
- `len` [in] length of report
- `data` [in] report data

Returns
- ESP_OK: success
- other: failed

`esp_err_t esp_bt_hid_device_report_error (esp_hidd_handshake_error_t error)`

Sends HID Handshake with error info for invalid set_report to the currently connected HID Host. This function should be called after `esp_bluedroid_init()` and `esp_bluedroid_enable()` success, and should be called after `esp_bt_hid_device_init()`. When the operation is complete, the callback function will be called with `ESP_HIDD_REPORT_ERR_EVT`.

Parameters
- `error` [in] type of error

Returns
- ESP_OK: success


- other: failed

```c
esp_err_t esp_bt_hid_device_virtual_cable_unplug(void)
```

Remove the virtually cabled device. This function should be called after esp_bluedroid_init() and esp_bluedroid_enable() success, and should be called after esp_bt_hid_device_init(). When the operation is complete, the callback function will be called with ESP_HIDD_VC_UNPLUG_EVT.

**Note:** If the connection exists, then HID Device will send a VIRTUAL_CABLE_UNPLUG control command to the peer HID Host, and the connection will be destroyed. If the connection does not exist, then HID Device will only unplug on its single side. Once the unplug operation is success, the related pairing and bonding information will be removed, then the HID Device can accept connection request from the different HID Host.

**Returns**
- ESP_OK: success
- other: failed

**Unions**

union esp_hidd_cb_param_t

```c
#include <esp_hidd_api.h>
```

HID device callback parameters union.

**Public Members**

- struct esp_hidd_cb_param_t::hidd_init_evt_param init
  HIDD callback param of ESP_HIDD_INIT_EVT
- struct esp_hidd_cb_param_t::hidd_deinit_evt_param deinit
  HIDD callback param of ESP_HIDD_DEINIT_EVT
- struct esp_hidd_cb_param_t::hidd_register_app_evt_param register_app
  HIDD callback param of ESP_HIDD_REGISTER_APP_EVT
- struct esp_hidd_cb_param_t::hidd_unregister_app_evt_param unregister_app
  HIDD callback param of ESP_HIDD_UNREGISTER_APP_EVT
- struct esp_hidd_cb_param_t::hidd_open_evt_param open
  HIDD callback param of ESP_HIDD_OPEN_EVT
- struct esp_hidd_cb_param_t::hidd_close_evt_param close
  HIDD callback param of ESP_HIDD_CLOSE_EVT
- struct esp_hidd_cb_param_t::hidd_send_report_evt_param send_report
  HIDD callback param of ESP_HIDD_SEND_REPORT_EVT
- struct esp_hidd_cb_param_t::hidd_report_err_evt_param report_err
  HIDD callback param of ESP_HIDD_REPORT_ERR_EVT
- struct esp_hidd_cb_param_t::hidd_get_report_evt_param get_report
  HIDD callback param of ESP_HIDD_GET_REPORT_EVT
struct esp_hidd_cb_param_t::hidd_set_report_evt_param set_report
HIDD callback param of ESP_HIDD_SET_REPORT_EVT

struct esp_hidd_cb_param_t::hidd_set_protocol_evt_param set_protocol
HIDD callback param of ESP_HIDD_SET_PROTOCOL_EVT

struct esp_hidd_cb_param_t::hidd_intr_data_evt_param intr_data
HIDD callback param of ESP_HIDD_INTR_DATA_EVT

struct esp_hidd_cb_param_t::hidd_vc_unplug_evt_param vc_unplug
HIDD callback param of ESP_HIDD_VC_UNPLUG_EVT

struct hidd_close_evt_param
#include <esp_hidd_api.h> ESP_HIDD_CLOSE_EVT.

Public Members

esp_hidd_status_t status
operation status

esp_hidd_connection_state_t conn_status
connection status

struct hidd_deinit_evt_param
#include <esp_hidd_api.h> ESP_HIDD_DEINIT_EVT.

Public Members

esp_hidd_status_t status
operation status

struct hidd_get_report_evt_param
#include <esp_hidd_api.h> ESP_HIDD_GET_REPORT_EVT.

Public Members

esp_hidd_report_type_t report_type
report type

uint8_t report_id
report id

uint16_t buffer_size
buffer size

struct hidd_init_evt_param
#include <esp_hidd_api.h> ESP_HIDD_INIT_EVT.
Chapter 2. API Reference

Public Members

```c
#include <esp_hidd_api.h>

// ESP_HIDD_INTR_DATA_EVT

// Public Members

uint8_t report_id
interrupt channel report id

uint16_t len
interrupt channel report data length

uint8_t* data
interrupt channel report data pointer
```

Public Members

```c
#include <esp_hidd_api.h>

// ESP_HIDD_OPEN_EVT

// Public Members

esp_hidd_status_t status
operation status

esp_hidd_connection_state_t conn_status
connection status

esp_bd_addr_t bd_addr
host address
```

Public Members

```c
#include <esp_hidd_api.h>

// ESP_HIDD_REGISTER_APP_EVT

// Public Members

esp_hidd_status_t status
operation status

bool in_use
indicate whether use virtual cable plug host address

esp_bd_addr_t bd_addr
host address
```
struct hidd_report_err_evt_param
#include <esp_hidd_api.h> ESP_HIDD_REPORT_ERR_EVT.

Public Members

esp_hidd_status_t status
operation status

uint8_t reason
lower layer failed reason(ref hiddefs.h)

struct hidd_send_report_evt_param
#include <esp_hidd_api.h> ESP_HIDD_SEND_REPORT_EVT.

Public Members

esp_hidd_status_t status
operation status

uint8_t reason
lower layer failed reason(ref hiddefs.h)

esp_hidd_report_type_t report_type
report type

uint8_t report_id
report id

struct hidd_set_protocol_evt_param
#include <esp_hidd_api.h> ESP_HIDD_SET_PROTOCOL_EVT.

Public Members

esp_hidd_protocol_mode_t protocol_mode
protocol mode

struct hidd_set_report_evt_param
#include <esp_hidd_api.h> ESP_HIDD_SET_REPORT_EVT.

Public Members

esp_hidd_report_type_t report_type
report type

uint8_t report_id
report id
uint16_t len
    set_report data length

uint8_t *data
    set_report data pointer

struct hidd_unregister_app_evt_param
    #include <esp_hidd_api.h> ESP_HIDD_UNREGISTER_APP_EVT.

Public Members

esp_hidd_status_t status
    operation status

struct hidd_vc_unplug_param
    #include <esp_hidd_api.h> ESP_HIDD_VC_UNPLUG_EVT.

Public Members

esp_hidd_status_t status
    operation status

    esp_hidd_connection_state_t conn_status
        connection status

Structures

struct esp_hidd_app_param_t
    HID device characteristics for SDP server.

Public Members

const char *name
    service name

const char *description
    service description

const char *provider
    provider name

uint8_t subclass
    HID device subclass

uint8_t *desc_list
    HID descriptor list
int desc_list_len
    size in bytes of HID descriptor list

struct esp_hid_qos_param_t
    HIDD Quality of Service parameters negotiated over L2CAP.

Public Members

uint8_t service_type
    the level of service, 0 indicates no traffic

uint32_t token_rate
    token rate in bytes per second, 0 indicates “don’t care”

uint32_t token_bucket_size
    limit on the burstness of the application data

uint32_t peak_bandwidth
    bytes per second, value 0 indicates “don’t care”

uint32_t access_latency
    maximum acceptable delay in microseconds

uint32_t delay_variation
    the difference in microseconds between the max and min delay

Macros

ESP_HID_CLASS_UNKNOWN
    subclass of hid device
    unknown HID device subclass

ESP_HID_CLASS_JOS
    joystick

ESP_HID_CLASS_GPD
    game pad

ESP_HID_CLASS_RMC
    remote control

ESP_HID_CLASS_SED
    sensing device

ESP_HID_CLASS_DGT
    digitizer tablet

ESP_HID_CLASS_CDR
    card reader
**ESP_HID_CLASS_KBD**
keyboard

**ESP_HID_CLASS_MIC**
pointing device

**ESP_HID_CLASS_COM**
combo keyboard/pointing

**Type Definitions**

typedef void (*esp_hd_cb_t)(esp_hidd_cb_event_t event, esp_hidd_cb_param_t *param)
HID device callback function type.

**Param event**  Event type
**Param param**  Point to callback parameter, currently is union type

**Enumerations**

define esp_hidd_handshake_error_t
HIDD handshake result code.

*Values:*

- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_SUCCESS**
  successful
- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_NOT_READY**
  not ready, device is too busy to accept data
- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_ERR_INVALID_REP_ID**
  invalid report ID
- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_ERR_UNSUPPORTED_REQ**
  device does not support the request
- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_ERR_INVALID_PARAM**
  parameter value is out of range or inappropriate
- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_ERR_UNKNOWN**
  device could not identify the error condition
- enumerator **ESP_HID_PAR_HANDSHAKE_RSP_ERR_FATAL**
  restart is essential to resume functionality

define esp_hidd_report_type_t
HIDD report types.

*Values:*

- enumerator **ESP_HIDD_REPORT_TYPE_OTHER**
  unknown report type
enumerator **ESP_HIDD_REPORT_TYPE_INPUT**
input report

enumerator **ESP_HIDD_REPORT_TYPE_OUTPUT**
output report

enumerator **ESP_HIDD_REPORT_TYPE_FEATURE**
feature report

enumerator **ESP_HIDD_REPORT_TYPE_INTRDATA**
special value for reports to be sent on interrupt channel, INPUT is assumed

enum **esp_hidd_connection_state_t**
HIDD connection state.

Values:

enumerator **ESP_HIDD_CONN_STATE_CONNECTED**
HID connection established

enumerator **ESP_HIDD_CONN_STATE_CONNECTING**
connection to remote Bluetooth device

enumerator **ESP_HIDD_CONN_STATE_DISCONNECTED**
connection released

enumerator **ESP_HIDD_CONN_STATE_DISCONNECTING**
disconnecting to remote Bluetooth device

enumerator **ESP_HIDD_CONN_STATE_UNKNOWN**
unknown connection state

enum **esp_hidd_protocol_mode_t**
HID device protocol modes.

Values:

enumerator **ESP_HIDD_REPORT_MODE**
Report Protocol Mode

enumerator **ESP_HIDD_BOOT_MODE**
Boot Protocol Mode

enumerator **ESP_HIDD_UNSUPPORTED_MODE**
unsupported

enum **esp_hidd_boot_report_id_t**
HID Boot Protocol report IDs.

Values:
enumerator `ESP_HIDD_BOOT_REPORT_ID_KEYBOARD`
   report ID of Boot Protocol keyboard report

enumerator `ESP_HIDD_BOOT_REPORT_ID_MOUSE`
   report ID of Boot Protocol mouse report

enum [anonymous]
   HID Boot Protocol report size including report ID.
   Values:

enumerator `ESP_HIDD_BOOT_REPORT_SIZE_KEYBOARD`
   report size of Boot Protocol keyboard report

enumerator `ESP_HIDD_BOOT_REPORT_SIZE_MOUSE`
   report size of Boot Protocol mouse report

enum `esp_hidd_cb_event_t`
   HID device callback function events.
   Values:

enumerator `ESP_HIDD_INIT_EVT`
   When HID device is initialized, the event comes

enumerator `ESP_HIDD_DEINIT_EVT`
   When HID device is deinitialized, the event comes

enumerator `ESP_HIDD_REGISTER_APP_EVT`
   When HID device application registered, the event comes

enumerator `ESP_HIDD_UNREGISTER_APP_EVT`
   When HID device application unregistered, the event comes

enumerator `ESP_HIDD_OPEN_EVT`
   When HID device connection to host opened, the event comes

enumerator `ESP_HIDD_CLOSE_EVT`
   When HID device connection to host closed, the event comes

enumerator `ESP_HIDD_SEND_REPORT_EVT`
   When HID device send report to lower layer, the event comes

enumerator `ESP_HIDD_REPORT_ERR_EVT`
   When HID device report handshank error to lower layer, the event comes

enumerator `ESP_HIDD_GET_REPORT_EVT`
   When HID device receives GET_REPORT request from host, the event comes
enumerator **ESP_HIDD_SET_REPORT_EVT**
When HID device receives SET_REPORT request from host, the event comes

enumerator **ESP_HIDD_SET_PROTOCOL_EVT**
When HID device receives SET_PROTOCOL request from host, the event comes

enumerator **ESP_HIDD_INTR_DATA_EVT**
When HID device receives DATA from host on intr, the event comes

enumerator **ESP_HIDD_VC_UNPLUG_EVT**
When HID device initiates Virtual Cable Unplug, the event comes

enumerator **ESP_HIDD_API_ERR_EVT**
When HID device has API error, the event comes

enum **esp_hidd_status_t**

Values:

enumerator **ESP_HIDD_SUCCESS**

enumerator **ESP_HIDD_ERROR**
general ESP HD error

enumerator **ESP_HIDD_NO_RES**
out of system resources

enumerator **ESP_HIDD_BUSY**
Temporarily can not handle this request.

enumerator **ESP_HIDD_NO_DATA**
No data.

enumerator **ESP_HIDD_NEED_INIT**
HIDD module shall init first

enumerator **ESP_HIDD_NEED_DEINIT**
HIDD module shall deinit first

enumerator **ESP_HIDD_NEED_REG**
HIDD module shall register first

enumerator **ESP_HIDD_NEED_DEREG**
HIDD module shall deregister first

enumerator **ESP_HIDD_NO_CONNECTION**
connection may have been closed
Bluetooth HID Host API

Overview  A Bluetooth HID host is a device or software that is capable of connecting and communicating with Bluetooth HID devices, such as keyboards, mice. Users can use the Bluetooth HID Host APIs to send output data or control commands to the HID devices, enabling them to control the behavior or settings of the devices.

Application Example  Check bluetooth folder in ESP-IDF examples, which contains the following application:

- Example bluetooth/esp_hid_host is implemented using the generic esp_hid APIs. esp_hid APIs are build upon the Bluetooth HID APIs and can be a reference.

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_hid_api.h

Functions

- esp_err_t esp_bt_hid_host_register_callback (esp_hh_cb_t callback)
  This function is called to init callbacks with HID host module.
  Parameters callback - [in] pointer to the init callback function.
  Returns
  - ESP_OK: success
  - other: failed

- esp_err_t esp_bt_hid_host_init (void)
  This function initializes HID host. This function should be called after esp_bluedroid_enable() and esp_bluedroid_init() success, and should be called after esp_bt_hid_host_register_callback(). When the operation is complete the callback function will be called with ESP_HIDH_INIT_EVT.
  Returns
  - ESP_OK: success
  - other: failed

- esp_err_t esp_bt_hid_host_deinit (void)
  Closes the interface. This function should be called after esp_bluedroid_enable() and esp_bluedroid_init() success, and should be called after esp_bt_hid_host_init(). When the operation is complete the callback function will be called with ESP_HIDH_DEINIT_EVT.
  Returns
  - ESP_OK: success
  - other: failed

- esp_err_t esp_bt_hid_host_connect (esp_bd_addr_t bd_addr)
  Connect to HID device. When the operation is complete the callback function will be called with ESP_HIDH_OPEN_EVT.
  Parameters bd_addr - [in] Remote device bluetooth device address.
  Returns
  - ESP_OK: success
  - other: failed

- esp_err_t esp_bt_hid_host_disconnect (esp_bd_addr_t bd_addr)
  Disconnect from HID device. When the operation is complete the callback function will be called with ESP_HIDH_CLOSE_EVT.
  Parameters bd_addr - [in] Remote device bluetooth device address.
  Returns
  - ESP_OK: success
  - other: failed
esp_err_t esp_bt_hid_host_virtual_cable_unplug(esp_bd_addr_t bd_addr)

Virtual UnPlug (VUP) the specified HID device. When the operation is complete the callback function will be called with ESP_HID_HC_UNPLUG_EVT.

Parameters  

Returns  
- ESP_OK: success
- other: failed

esp_err_t esp_bt_hid_host_set_info (esp_bd_addr_t bd_addr, esp_hidh_hid_info_t *hid_info)

Set the HID device descriptor for the specified HID device. When the operation is complete the callback function will be called with ESP_HID_H_SET_INFO_EVT.

Parameters

Returns
- ESP_OK: success
- other: failed

esp_err_t esp_bt_hid_host_get_protocol (esp_bd_addr_t bd_addr)

Get the HID proto mode. When the operation is complete the callback function will be called with ESP_HID_H_GET_PROTO_EVT.

Parameters

Returns
- ESP_OK: success
- other: failed

esp_err_t esp_bt_hid_host_set_protocol (esp_bd_addr_t bd_addr, esp_hidh_protocol_mode_t protocol_mode)

Set the HID proto mode. When the operation is complete the callback function will be called with ESP_HID_H_SET_PROTO_EVT.

Parameters

Returns
- ESP_OK: success
- other: failed

esp_err_t esp_bt_hid_host_get_idle (esp_bd_addr_t bd_addr)

Get the HID Idle Time. When the operation is complete the callback function will be called with ESP_HID_H_GET_IDLE_EVT.

Parameters

Returns
- ESP_OK: success
- other: failed

esp_err_t esp_bt_hid_host_set_idle (esp_bd_addr_t bd_addr, uint16_t idle_time)

Set the HID Idle Time. When the operation is complete the callback function will be called with ESP_HID_H_SET_IDLE_EVT.

Parameters
- idle_time – [in] Idle time rate

Returns
- ESP_OK: success
- other: failed

esp_err_t esp_bt_hid_host_get_report (esp_bd_addr_t bd_addr, esp_hidh_report_type_t report_type, uint8_t report_id, int buffer_size)

Send a GET_REPORT to HID device. When the operation is complete the callback function will be called with ESP_HID_H_GET_RPT_EVT.
Chapter 2. API Reference

Parameters
- **bd_addr** - [in] Remote device Bluetooth device address.
- **report_type** - [in] Report type
- **report_id** - [in] Report id
- **buffer_size** - [in] Buffer size

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_bt_hid_host_set_report(esp_bd_addr_t bd_addr, esp_hidh_report_type_t report_type, uint8_t *report, size_t len)
```

Send a SET_REPORT to HID device. When the operation is complete the callback function will be called with ESP_HIDH_SET_RPT_EVT.

Parameters
- **bd_addr** - [in] Remote device Bluetooth device address.
- **report_type** - [in] Report type
- **report** - [in] Report data pointer
- **len** - [in] Report data length

Returns
- ESP_OK: success
- other: failed

```c
esp_err_t esp_bt_hid_host_send_data(esp_bd_addr_t bd_addr, uint8_t *data, size_t len)
```

Send data to HID device. When the operation is complete the callback function will be called with ESP_HIDH_DATA_EVT.

Parameters
- **bd_addr** - [in] Remote device Bluetooth device address.
- **data** - [in] Data pointer
- **len** - [in] Data length

Returns
- ESP_OK: success
- other: failed

Unions

```c
union esp_hidh_cb_param_t
```

#include <esp_hidh_api.h> HID host callback parameters union.

Public Members

```c
struct esp_hidh_cb_param_t::hidh_init_evt_param init
```

HIDH callback param of ESP_HIDH_INIT_EVT

```c
struct esp_hidh_cb_param_t::hidh_uninit_evt_param deinit
```

HIDH callback param of ESP_HIDH_DEINIT_EVT

```c
struct esp_hidh_cb_param_t::hidh_open_evt_param open
```

HIDH callback param of ESP_HIDH_OPEN_EVT

```c
struct esp_hidh_cb_param_t::hidh_close_evt_param close
```

HIDH callback param of ESP_HIDH_CLOSE_EVT

```c
struct esp_hidh_cb_param_t::hidh_unplug_evt_param unplug
```

HIDH callback param of ESP_HIDH_VC_UNPLUG_EVT
struct esp_hidh_cb_param_t::hidh_get_proto_evt_param get_proto
    HIDH callback param of ESP_HIDH_GETPROTO_EVT

struct esp_hidh_cb_param_t::hidh_set_proto_evt_param set_proto
    HIDH callback param of ESP_HIDH_SETPROTO_EVT

struct esp_hidh_cb_param_t::hidh_get_rpt_evt_param get_rpt
    HIDH callback param of ESP_HIDH_GETRPT_EVT

struct esp_hidh_cb_param_t::hidh_set_rpt_evt_param set_rpt
    HIDH callback param of ESP_HIDH_SETRPT_EVT

struct esp_hidh_cb_param_t::hidh_send_data_evt_param send_data
    HIDH callback param of ESP_HIDH_DATA_EVT

struct esp_hidh_cb_param_t::hidh_getIdle_evt_param get_idle
    HIDH callback param of ESP_HIDH_GET_IDLE_EVT

struct esp_hidh_cb_param_t::hidh_setIdle_evt_param set_idle
    HIDH callback param of ESP_HIDH_SET_IDLE_EVT

struct esp_hidh_cb_param_t::hidh_dataInd_evt_param data_ind
    HIDH callback param of ESP_HIDH_DATA_IND_EVT

struct esp_hidh_cb_param_t::hidh_addDev_evt_param add_dev
    HIDH callback param of ESP_HIDH_ADD_DEV_EVT

struct esp_hidh_cb_param_t::hidh_rmvDev_evt_param rmv_dev
    HIDH callback param of ESP_HIDH_RMV_DEV_EVT

struct esp_hidh_cb_param_t::hidh_get_dscp_evt_param dscp
    HIDH callback param of ESP_HIDH_GET_DSCP_EVT

struct esp_hidh_cb_param_t::hidh_set_info_evt_param set_info
    HIDH callback param of ESP_HIDH_SET_INFO_EVT

struct hidh_add_dev_evt_param
    #include <esp_hidh_api.h> ESP_HIDH_ADD_DEV_EVT.

**Public Members**

*esp_hidh_status_t* status
    operation status

*uint8_t* handle
    device handle
esp_bd_addr_t bd_addr
  device address

struct hidh_close_evt_param
#include <esp_hidh_api.h> ESP_HIDH_CLOSE_EVT.

**Public Members**

esp_hidh_status_t status
  operation status

uint8_t reason
  lower layer failed reason(ref hiddefs.h)

esp_hidh_connection_state_t conn_status
  connection status

uint8_t handle
  device handle

struct hidh_data_ind_evt_param
#include <esp_hidh_api.h> ESP_HIDH_DATA_IND_EVT.

**Public Members**

esp_hidh_status_t status
  operation status

uint8_t handle
  device handle

esp_hidh_protocol_mode_t proto_mode
  protocol mode

uint16_t len
  data length

uint8_t* data
  data pointer

struct hidh_get_dscp_evt_param
#include <esp_hidh_api.h> ESP_HIDH_GET_DSCP_EVT.

**Public Members**


```c
enum esp_hidh_status_t { status, operation status, uint8_t handle, device handle, bool added, Indicate if added, uint16_t vendor_id, Vendor ID, uint16_t product_id, Product ID, uint16_t version, Version, uint16_t ssr_max_latency, SSR max latency in slots, uint16_t ssr_min_tout, SSR min timeout in slots, uint8_t ctry_code, Country Code, uint16_t dl_len, Device descriptor length, uint8_t* dsc_list, Device descriptor pointer, struct hidh_get_idle_evt_param, #include <esp_hidh_api.h> ESP_HIDH_GET_IDLE_EVT, 
```

**Public Members**

```c
enum esp_hidh_status_t { status, operation status, uint8_t handle, device handle, uint8_t idle_rate, idle rate, struct hidh_get_proto_evt_param, #include <esp_hidh_api.h> ESP_HIDH_GET_PROTO_EVT, 
```
Chapter 2. API Reference

Public Members

```c
esp_hidh_status_t status
```
operation status

```c
uint8_t handle
```
device handle

```c
esp_hidh_protocol_mode_t proto_mode
```
protocol mode

```c
struct hidh_get_rpt_evt_param
```
```
#include <esp_hidh_api.h> ESP_HIDH_GET_RPT_EVT.
```

Public Members

```c
esp_hidh_status_t status
```
operation status

```c
uint8_t handle
```
device handle

```c
uint16_t len
```
data length

```c
uint8_t *data
```
data pointer

```c
struct hidh_init_evt_param
```
```
#include <esp_hidh_api.h> ESP_HIDH_INIT_EVT.
```

Public Members

```c
esp_hidh_status_t status
```
status

```c
struct hidh_open_evt_param
```
```
#include <esp_hidh_api.h> ESP_HIDH_OPEN_EVT.
```

Public Members

```c
esp_hidh_status_t status
```
operation status

```c
esp_hidh_connection_state_t conn_status
```
connection status
bool is_orig
    indicate if host initiate the connection

uint8_t handle
    device handle

    esp_bd_addr_t bd_addr
    device address

struct hidh_remove_dev_evt_param
    #include <esp_hidh_api.h> ESP_HIDH_RMV_DEV_EVT.

Public Members

    esp_hidh_status_t status
        operation status

uint8_t handle
    device handle

    esp_bd_addr_t bd_addr
    device address

struct hidh_send_data_evt_param
    #include <esp_hidh_api.h> ESP_HIDH_DATA_EVT.

Public Members

    esp_hidh_status_t status
        operation status

uint8_t handle
    device handle

uint8_t reason
    lower layer failed reason(ref hiddefs.h)

struct hidh_set_idle_evt_param
    #include <esp_hidh_api.h> ESP_HIDH_SET_IDLE_EVT.

Public Members

    esp_hidh_status_t status
        operation status
```c
uint8_t handle
  device handle

struct hidh_set_info_evt_param
  #include <esp_hidh_api.h> ESP_HIDH_SET_INFO_EVT.

Public Members

  esp_hidh_status_t status
  operation status

uint8_t handle
  device handle

  esp_bd_addr_t bd_addr
  device address

struct hidh_set_proto_evt_param
  #include <esp_hidh_api.h> ESP_HIDH_SET_PROTO_EVT.

Public Members

  esp_hidh_status_t status
  operation status

uint8_t handle
  device handle

struct hidh_set_rpt_evt_param
  #include <esp_hidh_api.h> ESP_HIDH_SET_RPT_EVT.

Public Members

  esp_hidh_status_t status
  operation status

uint8_t handle
  device handle

struct hidh_uninit_evt_param
  #include <esp_hidh_api.h> ESP_HIDH_DEINIT_EVT.

Public Members

  esp_hidh_status_t status
  status
```
```c
struct hidh_unplug_evt_param
#include <esp_hidh_api.h> ESP_HIDH_VC_UNPLUG_EVT.

Public Members

esp_hidh_status_t status
operation status

esp_hidh_connection_state_t conn_status
connection status

uint8_t handle
device handle

Structures

struct esp_hidh_hid_info_t
HID device information from HID Device Service Record and Device ID Service Record.

Public Members

int attr_mask
device attribute bit mask, refer to esp_hidh_dev_attr_t

uint8_t sub_class
HID device subclass

uint8_t app_id
application ID, refer to esp_hidh_dev_app_id_t

int vendor_id
Device ID information: vendor ID

int product_id
Device ID information: product ID

int version
Device ID information: version

uint8_t ctry_code
SDP attributes of HID devices: HID country code (https://www.usb.org/sites/default/files/hid1_11.pdf)

int dl_len
SDP attributes of HID devices: HID device descriptor length

uint8_t dsc_list[BTHH_MAX_DSC_LEN]
SDP attributes of HID devices: HID device descriptor definition
```
Chapter 2. API Reference

Macros

BTHH_MAX_DSC_LEN
maximum size of HID Device report descriptor

Type Definitions

typedef void (*esp_hh_cb_t)(esp_hidh_cb_event_t event, esp_hidh_cb_param_t *param)
HID host callback function type.

Param event Event type
Param param Point to callback parameter, currently is union type

Enumerations

enum esp_hidh_connection_state_t
HID host connection state.

Values:

enumerator ESP_HIDH_CONN_STATE_CONNECTED
connected state

enumerator ESP_HIDH_CONN_STATE_CONNECTING
connecting state

enumerator ESP_HIDH_CONN_STATE_DISCONNECTED
disconnected state

enumerator ESP_HIDH_CONN_STATE_DISCONNECTING
disconnecting state

enumerator ESP_HIDH_CONN_STATE_UNKNOWN
unknown state (initial state)

enum esp_hidh_status_t
HID handshake error code and vendor-defined result code.

Values:

enumerator ESP_HIDH_OK
successful

enumerator ESP_HIDH_HS_HID_NOT_READY
handshake error: device not ready

enumerator ESP_HIDH_HS_INVALID_RPT_ID
handshake error: invalid report ID

enumerator ESP_HIDH_HS_TRANS_NOT_SPT
handshake error: HID device does not support the request
enumerator **ESP_HIDH_HS_INVALID_PARAM**  
handshake error: parameter value does not meet the expected criteria of called function or API

enumerator **ESP_HIDH_HS_ERROR**  
handshake error: HID device could not identify the error condition

enumerator **ESP_HIDH_ERR**  
general ESP HID Host error

enumerator **ESP_HIDH_ERR_SDP**  
SDP error

enumerator **ESP_HIDH_ERR_PROTO**  
SET_PROTOCOL error, only used in ESP_HIDH_OPEN_EVT callback

enumerator **ESP_HIDH_ERR_DB_FULL**  
device database full, used in ESP_HIDH_OPEN_EVT/ESP_HIDH_ADD_DEV_EVT

enumerator **ESP_HIDH_ERR_TOD_UNSPT**  
type of device not supported

enumerator **ESP_HIDH_ERR_NO_RES**  
out of system resources

enumerator **ESP_HIDH_ERR_AUTH_FAILED**  
authentication fail

enumerator **ESP_HIDH_ERR_HDL**  
connection handle error

enumerator **ESP_HIDH_ERR_SEC**  
encryption error

enumerator **ESP_HIDH_BUSY**  
vendor-defined: temporarily can not handle this request

enumerator **ESP_HIDH_NO_DATA**  
vendor-defined: no data.

enumerator **ESP_HIDH_NEED_INIT**  
vendor-defined: HIDH module shall initialize first

enumerator **ESP_HIDH_NEED_DEINIT**  
vendor-defined: HIDH module shall de-deinitialize first

enumerator **ESP_HIDH_NO_CONNECTION**  
vendor-defined: connection may have been closed
enum esp_hidh_protocol_mode_t
   HID host protocol modes.
   Values:
   
   enumerator ESP_HIDH_BOOT_MODE
      boot protocol mode
   
   enumerator ESP_HIDH_REPORT_MODE
      report protocol mode
   
   enumerator ESP_HIDH_UNSUPPORTED_MODE
      unsupported protocol mode

enum esp_hidh_report_type_t
   HID host report types.
   Values:
   
   enumerator ESP_HIDH_REPORT_TYPE_OTHER
      unsupported report type
   
   enumerator ESP_HIDH_REPORT_TYPE_INPUT
      input report type
   
   enumerator ESP_HIDH_REPORT_TYPE_OUTPUT
      output report type
   
   enumerator ESP_HIDH_REPORT_TYPE_FEATURE
      feature report type

enum esp_hidh_cb_event_t
   HID host callback function events.
   Values:
   
   enumerator ESP_HIDH_INIT_EVT
      when HID host is initialized, the event comes
   
   enumerator ESP_HIDH_DEINIT_EVT
      when HID host is deinitialized, the event comes
   
   enumerator ESP_HIDH_OPEN_EVT
      when HID host connection opened, the event comes
   
   enumerator ESP_HIDH_CLOSE_EVT
      when HID host connection closed, the event comes
   
   enumerator ESP_HIDH_GET_RPT_EVT
      when Get_Report command is called, the event comes
enumerator ESP_HIDH_SET_RPT_EVT
    when Set_Report command is called, the event comes

denumerator ESP_HIDH_GET_PROTO_EVT
    when Get_Protocol command is called, the event comes

denumerator ESP_HIDH_SET_PROTO_EVT
    when Set_Protocol command is called, the event comes

denumerator ESP_HIDH_GET_IDLE_EVT
    when Get_Idle command is called, the event comes

denumerator ESP_HIDH_SET_IDLE_EVT
    when Set_Idle command is called, the event comes

denumerator ESP_HIDH_GET_DSCP_EVT
    when HIDH is initialized, the event comes

denumerator ESP_HIDH_ADD_DEV_EVT
    when a device is added, the event comes

denumerator ESP_HIDH_RMV_DEV_EVT
    when a device is removed, the event comes

denumerator ESP_HIDH_VC_UNPLUG_EVT
    when virtually unplugged, the event comes

denumerator ESP_HIDH_DATA_EVT
    when send data on interrupt channel, the event comes

denumerator ESP_HIDH_DATA_IND_EVT
    when receive data on interrupt channel, the event comes

denumerator ESP_HIDH_SET_INFO_EVT
    when set the HID device descriptor, the event comes

enum esp_hidh_dev_attr_t
    HID device information from HID Device Service Record and Device ID Service Record.
    Values:
    enumerator ESP_HIDH_DEV_ATTR_VIRTUAL_CABLE
        whether Virtual Cables is supported
    enumerator ESP_HIDH_DEV_ATTR_NORMALLY_CONNECTABLE
        whether device is in Page Scan mode when there is no active connection
    enumerator ESP_HIDH_DEV_ATTR_RECONNECT_INITIATE
        whether the HID device initiates the reconnection process
enum esp_hidh_dev_app_id_t

application ID (non-zero) for each type of device

Values:

enumerator ESP_HIDH_APP_ID_MOUSE
    pointing device

enumerator ESP_HIDH_APP_ID_KEYBOARD
    keyboard

enumerator ESP_HIDH_APP_ID_REMOTE_CONTROL
    remote control

enumerator ESP_HIDH_APP_ID_JOYSTICK
    joystick

enumerator ESP_HIDH_APP_ID_GAMEPAD
    gamepad

Classic Bluetooth L2CAP API

Application Example
Check bluetooth/bluedroid/classic_bt folder in ESP-IDF examples, which contains the following application:

- This is a BT_L2CAP demo. This demo can connect, send and receive L2CAP data bluetooth/bluedroid/classic_bt/bt_l2cap_client, bluetooth/bluedroid/classic_bt/bt_l2cap_server

API Reference

Header File

- components/bluetooth/bluedroid/api/include/api/esp_l2cap_bt_api.h

Functions

esp_err_t esp_bt_l2cap_register_callback (esp_bt_l2cap_cb_t callback)
This function is called to init callbacks with L2CAP module.

Parameters

- callback – [in] pointer to the init callback function.

Returns

- ESP_OK: success
- other: failed

esp_err_t esp_bt_l2cap_init (void)
This function is called to init L2CAP module. When the operation is completed, the callback function will be called with ESP_BT_L2CAP_INIT_EVT. This function should be called after esp_bluedroid_enable() completes successfully.

Returns

- ESP_OK: success
- other: failed
**esp_err_t esp_bt_l2cap_deinit (void)**

This function is called to uninit l2cap module. The operation will close all active L2CAP connection first, then the callback function will be called with ESP_BT_L2CAP_CLOSE_EVT, and the number of ESP_BT_L2CAP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback function will be called with ESP_BT_L2CAP_UNINIT_EVT. This function should be called after esp_bt_l2cap_init() completes successfully.

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t esp_bt_l2cap_connect (esp_bt_l2cap_cntl_flags_t cntl_flag, uint16_t remote_psm, esp_bd_addr_t peer_bd_addr)**

This function makes an L2CAP connection to a remote BD Address. When the connection is initiated or failed to initiate, the callback is called with ESP_BT_L2CAP_CL_INIT_EVT. When the connection is established or failed, the callback is called with ESP_BT_L2CAP_OPEN_EVT. This function must be called after esp_bt_l2cap_init() successful and before esp_bt_l2cap_deinit().

**Parameters**
- remote_psm – [in] Remote device bluetooth Profile PSM.

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t esp_bt_l2cap_start_srv (esp_bt_l2cap_cntl_flags_t cntl_flag, uint16_t local_psm)**

This function create a L2CAP server and starts listening for an L2CAP connection request from a remote Bluetooth device. When the server is started successfully, the callback is called with ESP_BT_L2CAP_START_EVT. When the connection is established, the callback is called with ESP_BT_L2CAP_OPEN_EVT. This function must be called after esp_bt_l2cap_init() successful and before esp_bt_l2cap_deinit().

**Parameters**
- local_psm – [in] Dynamic PSM.

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t esp_bt_l2cap_stop_all_srv (void)**

This function stops all L2CAP servers. The operation will close all active L2CAP connection first, then the callback function will be called with ESP_BT_L2CAP_CLOSE_EVT, and the number of ESP_BT_L2CAP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback is called with ESP_BT_L2CAP_SRV_STOP_EVT. This function must be called after esp_bt_l2cap_init() successful and before esp_bt_l2cap_deinit().

**Returns**
- ESP_OK: success
- other: failed

**esp_err_t esp_bt_l2cap_stop_srv (uint16_t local_psm)**

This function stops a specific L2CAP server. The operation will close all active L2CAP connection first on the specific L2CAP server, then the callback function will be called with ESP_BT_L2CAP_CLOSE_EVT, and the number of ESP_BT_L2CAP_CLOSE_EVT is equal to the number of connection. When the operation is completed, the callback is called with ESP_BT_L2CAP_SRV_STOP_EVT. This function must be called after esp_bt_l2cap_init() successful and before esp_bt_l2cap_deinit().

**Parameters**
- local_psm – [in] Dynamic PSM.

**Returns**
- ESP_OK: success
• other: failed

\texttt{esp_err_t esp_bt_l2cap_vfs_register (void)}

This function is used to register VFS. Only supports write, read and close. This function must be called after \texttt{esp_bt_l2cap_init()} successful and before \texttt{esp_bt_l2cap_deinit()}.

\textbf{Returns}

• ESP_OK: success
• other: failed

\texttt{esp_err_t esp_bt_l2cap_vfs_unregister (void)}

This function is used to unregister VFS. This function must be called after \texttt{esp_bt_l2cap_init()} successful and before \texttt{esp_bt_l2cap_deinit()}.

\textbf{Returns}

• ESP_OK: success
• other: failed

\textbf{Unions}

\texttt{union esp\_bt\_l2cap\_cb\_param\_t}

\texttt{#include <esp\_l2cap\_bt\_api\_h>} L2CAP callback parameters union.

\textbf{Public Members}

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_init\_evt\_param init}

L2CAP callback param of ESP_BT_L2CAP_INIT_EVT

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_uninit\_evt\_param uninit}

L2CAP callback param of ESP_BT_L2CAP_UNINIT_EVT

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_open\_evt\_param open}

L2CAP callback param of ESP_BT_L2CAP_OPEN_EVT

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_close\_evt\_param close}

L2CAP callback param of ESP_BT_L2CAP_CLOSE_EVT

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_start\_evt\_param start}

L2CAP callback param of ESP_BT_L2CAP_START_EVT

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_cl\_init\_evt\_param cl\_init}

L2CAP callback param of ESP_BT_L2CAP_CL_INIT_EVT

\texttt{struct esp\_bt\_l2cap\_cb\_param\_t::l2cap\_srv\_stop\_evt\_param srv\_stop}

L2CAP callback param of ESP_BT_L2CAP_SRV_STOP_EVT

\texttt{struct l2cap\_cl\_init\_evt\_param}

\texttt{#include <esp\_l2cap\_bt\_api\_h>} ESP_BT_L2CAP_CL_INIT_EVT.

\textbf{Public Members}
The connection handle

security ID used by this server

#include <esp_l2cap_bt_api.h> ESP_BT_L2CAP_CLOSE_EVT.

Public Members

bool async
FALSE, if local initiates disconnect

#include <esp_l2cap_bt_api.h> ESP_BT_L2CAP_INIT_EVT.

Public Members

int fd
File descriptor
**Chapter 2. API Reference**

```c
esp_bd_addr_t rem_bda
   The peer address

int32_t tx_mtu
   The transmit MTU
```

**struct l2cap_srv_stop_evt_param**

#include <esp_l2cap_bt_api.h> ESP_BT_L2CAP_SRV_STOP_EVT.

**Public Members**

```c
esp(bt) l2cap_status_t status
```

```c
uint8_t psm
   local psm
```

**struct l2cap_start_evt_param**

#include <esp_l2cap_bt_api.h> ESP_BT_L2CAP_START_EVT.

**Public Members**

```c
esp(bt) l2cap_status_t status
```

```c
uint32_t handle
   The connection handle
```

```c
uint8_t sec_id
   security ID used by this server
```

**struct l2cap_uninit_evt_param**

#include <esp_l2cap_bt_api.h> ESP_BT_L2CAP_UNINIT_EVT.

**Public Members**

```c
esp(bt) l2cap_status_t status
```

---

**Macros**

ESP_BT_L2CAP_SEC_NONE

Security Setting Mask. Use these three mask mode:

- a. ESP_BT_L2CAP_SEC_NONE
- b. ESP_BT_L2CAP_SEC_AUTHENTICATE
- c. (ESP_BT_L2CAP_SEC_ENCRYPT|ESP_BT_L2CAP_SEC_AUTHENTICATE) No security
Chapter 2. API Reference

ESP_BT_L2CAP_SEC_AUTHORIZE
Authorization required

ESP_BT_L2CAP_SEC_AUTHENTICATE
Authentication required

ESP_BT_L2CAP_SEC_ENCRYPT
Encryption required

Type Definitions
typedef uint32_t esp_bt_l2cap_cntl_flags_t
typedef void(*esp_bt_l2cap_cb_t)(esp_bt_l2cap_cb_event_t event, esp_bt_l2cap_cb_param_t *param)
L2CAP callback function type.

Param event Event type
Param param Point to callback parameter, currently is union type

Enumerations
c enum esp_bt_l2cap_status_t
L2CAP operation success and failure codes.
Values:

enumerator ESP_BT_L2CAP_SUCCESS
Successful operation.

enumerator ESP_BT_L2CAP_FAILURE
Generic failure.

enumerator ESP_BT_L2CAP_BUSY
Temporarily cannot handle this request.

enumerator ESP_BT_L2CAP_NO_RESOURCE
No more resource.

enumerator ESP_BT_L2CAP_NEED_INIT
L2CAP module shall init first

enumerator ESP_BT_L2CAP_NEED_DEINIT
L2CAP module shall deinit first

enumerator ESP_BT_L2CAP_NO_CONNECTION
Connection may have been closed

enumerator ESP_BT_L2CAP_NO_SERVER
No server
Chapter 2. API Reference

enum esp_bt_l2cap_cb_event_t
L2CAP callback function events.

Values:

enumerator ESP_BT_L2CAP_INIT_EVT
When L2CAP is initialized, the event comes

enumerator ESP_BT_L2CAP_UNINIT_EVT
When L2CAP is deinitialized, the event comes

enumerator ESP_BT_L2CAP_OPEN_EVT
When L2CAP Client connection open, the event comes

enumerator ESP_BT_L2CAP_CLOSE_EVT
When L2CAP connection closed, the event comes

enumerator ESP_BT_L2CAP_START_EVT
When L2CAP server started, the event comes

enumerator ESP_BT_L2CAP_CL_INIT_EVT
When L2CAP client initiated a connection, the event comes

enumerator ESP_BT_L2CAP_SRV_STOP_EVT
When L2CAP server stopped, the event comes

BT SDP APIs

Overview Bluetooth SDP reference APIs.

API Reference

Header File

- components/bt/host/bluedroid/api/include/api/esp_sdp_api.h

Functions

esp_err_t esp_sdp_register_callback (esp_sdp_cb_t callback)
This function is called to init callbacks with SDP module.

Parameters callback – [in] pointer to the init callback function.

Returns

- ESP_OK: success
- other: failed

esp_err_t esp_sdp_init (void)
This function is called to init SDP module. When the operation is completed, the callback function will be called with ESP_SDP_INIT_EVT. This function should be called after esp_bluedroid_enable() completes successfully.

Returns

- ESP_OK: success
- other: failed
**esp_err_t esp_sdp_deinit (void)**

This function is called to de-initialize SDP module. The operation will remove all SDP records, then the callback function will be called with ESP_SDP_REMOVE_RECORD_COMP_EVT, and the number of ESP_SDP_REMOVE_RECORD_COMP_EVT is equal to the number of SDP records. When the operation is completed, the callback function will be called with ESP_SDP_DEINIT_EVT. This function should be called after esp_sdp_init() completes successfully.

**Returns**

- ESP_OK: success
- other: failed

**esp_err_t esp_sdp_search_record (esp_bd_addr_t bd_addr, esp_bt_uuid_t uuid)**

This function is called to perform service discovery for the services provided by the given peer device. When the operation is completed, the callback function will be called with ESP_SDP_SEARCH_COMP_EVT. This function must be called after esp_sdp_init() successful and before esp_sdp_deinit().

**Parameters**


**Returns**

- ESP_OK: success
- other: failed

**esp_err_t esp_sdp_create_record (esp_bluetooth_sdp_record_t *record)**

This function is called to create SDP records. When the operation is completed, the callback function will be called with ESP_SDP_CREATE_RECORD_COMP_EVT. This function must be called after esp_sdp_init() successful and before esp_sdp_deinit().

**Parameters**


**Returns**

- ESP_OK: success
- other: failed

**esp_err_t esp_sdp_remove_record (int record_handle)**

This function is called to remove a SDP record. When the operation is completed, the callback function will be called with ESP_SDP_REMOVE_RECORD_COMP_EVT. This function must be called after esp_sdp_init() successful and before esp_sdp_deinit().

**Parameters**


**Returns**

- ESP_OK: success
- other: failed

**Unions**

union esp_bluetooth_sdp_record_t

#include <esp_sdp_api.h> SDP record parameters union.

**Public Members**

**esp_bluetooth_sdp_hdr_overlay_t hdr**

General info

**esp_bluetooth_sdp_mas_record_t mas**

Message Access Profile - Server
**Chapter 2. API Reference**

```c
#include <esp_sdp_api.h>

union esp_sdp_cb_param_t
    #include <esp_sdp_api.h> SDP callback parameters union.

**Public Members**

```c
struct esp_sdp_cb_param_t::sdp_init_evt_param init
    SDP callback param of ESP_SDP_INIT_EVT

struct esp_sdp_cb_param_t::sdp_deinit_evt_param deinit
    SDP callback param of ESP_SDP_DEINIT_EVT

struct esp_sdp_cb_param_t::sdp_search_evt_param search
    SDP callback param of ESP_SDP_SEARCH_COMP_EVT

struct esp_sdp_cb_param_t::sdp_create_record_evt_param create_record
    SDP callback param of ESP_SDP_CREATE_RECORD_COMP_EVT

struct esp_sdp_cb_param_t::sdp_remove_record_evt_param remove_record
    SDP callback param of ESP_SDP_REMOVE_RECORD_COMP_EVT

struct sdp_create_record_evt_param
    #include <esp_sdp_api.h> ESP_SDP_CREATE_RECORD_COMP_EVT.
```

**Public Members**

```c
esp_sdp_status_t status
    status

int record_handle
    SDP record handle

struct sdp_deinit_evt_param
    #include <esp_sdp_api.h> ESP_SDP_DEINIT_EVT.
```
Public Members

```c
esp_sdp_status_t status
```

struct `sdp_init_evt_param`

```c
#include <esp_sdp_api.h> ESP_SDP_INIT_EVT.
```

Public Members

```c
esp_sdp_status_t status
```

struct `sdp_remove_record_evt_param`

```c
#include <esp_sdp_api.h> ESP_SDP_REMOVE_RECORD_COMP_EVT.
```

Public Members

```c
esp_sdp_status_t status
```

```c
esp_bd_addr_t remote_addr
```

```c
esp_bt_uuid_t sdp_uuid
```

```c
int record_count
```

```c
esp_bluetooth_sdp_record_t *records
```

### Structures

struct `bluetooth_sdp_hdr_overlay`

Some signals need additional pointers, hence we introduce a generic way to handle these pointers.
Public Members

\textbf{esp\_blue\_tooth\_sdp\_types\_t type}
SDP type

\textbf{esp\_bt\_uuid\_t uuid}
UUID type, include uuid and uuid length

uint32\_t \textbf{service\_name\_length}
Service name length

char *\textbf{service\_name}
Service name

int32\_t \textbf{rfcomm\_channel\_number}
rfcomm channel number, if not used set to -1

int32\_t \textbf{l2cap\_psm}
L2cap psm, if not used set to -1

int32\_t \textbf{profile\_version}
Profile version

int \textbf{user1\_ptr\_len}
See \texttt{esp\_blue\_tooth\_sdp\_ops\_record\_t}

uint8\_t *\textbf{user1\_ptr}
See \texttt{esp\_blue\_tooth\_sdp\_ops\_record\_t}

int \textbf{user2\_ptr\_len}
See \texttt{esp\_blue\_tooth\_sdp\_ops\_record\_t}

uint8\_t *\textbf{user2\_ptr}
See \texttt{esp\_blue\_tooth\_sdp\_ops\_record\_t}

\textbf{struct \texttt{bluetooth\_sdp\_mas\_record}}
Message Access Profile - Server parameters.

Public Members

\textbf{esp\_blue\_tooth\_sdp\_hdr\_overlay\_t hdr}
General info

uint32\_t \textbf{mas\_instance\_id}
MAS Instance ID

uint32\_t \textbf{supported\_features}
Map supported features
uint32_t supported_message_types
  Supported message types

struct bluetooth_sdp_mns_record
  Message Access Profile - Client (Notification Server) parameters.

Public Members

exp_bluetooth_sdp_hdr_overlay_t hdr
  General info

uint32_t supported_features
  Supported features

struct bluetooth_sdp_pse_record
  Phone Book Profile - Server parameters.

Public Members

exp_bluetooth_sdp_hdr_overlay_t hdr
  General info

uint32_t supported_features
  Pbap Supported Features

uint32_t supported_repositories
  Supported Repositories

struct bluetooth_sdp_pce_record
  Phone Book Profile - Client parameters.

Public Members

exp_bluetooth_sdp_hdr_overlay_t hdr
  General info

struct bluetooth_sdp_ops_record
  Object Push Profile parameters.

Public Members

exp_bluetooth_sdp_hdr_overlay_t hdr
  General info

int supported_formats_list_len
  Supported formats list length
Chapter 2. API Reference

```c
uint8_t supported_formats_list[SDP_OPP_SUPPORTED_FORMATS_MAX_LENGTH]
    Supported formats list

struct bluetooth_sdp_sap_record
    SIM Access Profile parameters.

Public Members

    esp_bluetooth_sdp_hdr_overlay_t hdr
        General info

Macros

ESP_SDP_SERVER_NAME_MAX
    Service name max length

SDP_OPP_SUPPORTED_FORMATS_MAX_LENGTH
    OPP supported format list maximum length

Type Definitions

typedef struct bluetooth_sdp_hdr_overlay esp_bluetooth_sdp_hdr_overlay_t
    Some signals need additional pointers, hence we introduce a generic way to handle these pointers.
typedef struct bluetooth_sdp_mas_record esp_bluetooth_sdp_mas_record_t
    Message Access Profile - Server parameters.
typedef struct bluetooth_sdp_mns_record esp_bluetooth_sdp_mns_record_t
    Message Access Profile - Client (Notification Server) parameters.
typedef struct bluetooth_sdp_pse_record esp_bluetooth_sdp_pse_record_t
    Phone Book Profile - Server parameters.
typedef struct bluetooth_sdp_pce_record esp_bluetooth_sdp_pce_record_t
    Phone Book Profile - Client parameters.
typedef struct bluetooth_sdp_ops_record esp_bluetooth_sdp_ops_record_t
    Object Push Profile parameters.
typedef struct bluetooth_sdp_sap_record esp_bluetooth_sdp_sap_record_t
    SIM Access Profile parameters.
typedef void (*esp_sdp_cb_t)(esp_sdp_cb_event_t event, esp_sdp_cb_param_t *param)
    SDP callback function type.
    Param event Event type
    Param param Point to callback parameter, currently is union type
```
Enumerations

enum esp_sdp_status_t

Values:

- enumerator ESP_SDP_SUCCESS
  Successful operation.

- enumerator ESP_SDP_FAILURE
  Generic failure.

- enumerator ESP_SDP_NO_RESOURCE
  No more resource

- enumerator ESP_SDP_NEED_INIT
  SDP module shall init first

- enumerator ESP_SDP_NEED_DEINIT
  SDP module shall deinit first

- enumerator ESP_SDP_NO_CREATE_RECORD
  No record created

enum esp_sdp_cb_event_t

SDP callback function events.

Values:

- enumerator ESP_SDP_INIT_EVT
  When SDP is initialized, the event comes

- enumerator ESP_SDP_DEINIT_EVT
  When SDP is deinitialized, the event comes

- enumerator ESP_SDP_SEARCH_COMP_EVT
  When SDP search complete, the event comes

- enumerator ESP_SDP_CREATE_RECORD_COMP_EVT
  When create SDP records complete, the event comes

- enumerator ESP_SDP_REMOVE_RECORD_COMP_EVT
  When remove a SDP record complete, the event comes

enum esp_bluetooth_sdp_types_t

SDP record type.

Values:

- enumerator ESP_SDP_TYPE_RAW
  Used to carry raw SDP search data for unknown UUIDs
enumerator **ESP_SDP_TYPE_MAP_MAS**
Message Access Profile - Server

denumerator **ESP_SDP_TYPE_MAP_MNS**
Message Access Profile - Client (Notification Server)

denumerator **ESP_SDP_TYPE_PBAP_PSE**
Phone Book Profile - Server

denumerator **ESP_SDP_TYPE_PBAP_PCE**
Phone Book Profile - Client

denumerator **ESP_SDP_TYPE_OPP_SERVER**
Object Push Profile

denumerator **ESP_SDP_TYPE_SAP_SERVER**
SIM Access Profile

### 2.3.4 Controller & VHCI

#### Application Example

Check bluetooth/hci folder in ESP-IDF examples, which contains the following application:

- This is a BLE advertising demo with virtual HCI interface. Send Reset/ADV_PARAM/ADV_DATA/ADV_ENABLE HCI command for BLE advertising - bluetooth/hci/controller_vhci_ble_adv.

#### API Reference

**Header File**

- components/bt/include/esp32/include/esp_bt.h

**Functions**

```c
esp_err_t esp_ble_tx_power_set (esp_ble_power_type_t power_type, esp_power_level_t power_level)
```

Set BLE TX power Connection Tx power should only be set after connection created.

**Parameters**

- **power_type**: The type of which tx power, could set Advertising/Connection/Default and etc
- **power_level**: Power level(index) corresponding to absolute value(dbm)

**Returns**

ESP_OK - success, other - failed

```c
esp_power_level_t esp_ble_tx_power_get (esp_ble_power_type_t power_type)
```

Get BLE TX power Connection Tx power should only be get after connection created.

**Parameters**

- **power_type**: The type of which tx power, could set Advertising/Connection/Default and etc

**Returns**

>= 0 - Power level, < 0 - Invalid
**esp_err_t esp_bredr_tx_power_set** (esp_power_level_t min_power_level, esp_power_level_t max_power_level)

Set BR/EDR TX power. BR/EDR power control will use the power in the range of minimum value and maximum value. The power level will affect the global BR/EDR TX power, such as inquiry, page, connection, and so on. Please call the function after esp_bt_controller_enable and before any function which cause RF to TX. So you can call the function before doing discovery, profile init, and so on. For example, if you want BR/EDR use the new TX power to do inquiry, you should call this function before inquiry. Another word, if call this function when BR/EDR is in inquiry (ING), please do inquiry again after call this function. Default minimum power level is ESP_PWR_LVL_N0, and maximum power level is ESP_PWR_LVL_P3.

**Parameters**
- **min_power_level**: The minimum power level
- **max_power_level**: The maximum power level

**Returns**
- ESP_OK: success, other: failed

**esp_err_t esp_bredr_tx_power_get** (esp_power_level_t *min_power_level, esp_power_level_t *max_power_level)

Get BR/EDR TX power. If the argument is not NULL, then store the corresponding value.

**Parameters**
- **min_power_level**: The minimum power level
- **max_power_level**: The maximum power level

**Returns**
- ESP_OK: success, other: failed

**esp_err_t esp_bredr_sco_datapath_set** (esp_sco_data_path_t data_path)

Set default SCO data path. Should be called after controller is enabled, and before (e)SCO link is established.

**Parameters**
- **data_path**: SCO data path

**Returns**
- ESP_OK: success, other: failed

**esp_err_t esp_bt_controller_init** (esp_bt_controller_config_t *cfg)

Initialize BT controller to allocate task and other resource. This function should be called only once, before any other BT functions are called.

**Parameters**
- **cfg**: Initial configuration of BT controller. Different from previous version, there is a mode and some connection configuration in “cfg” to configure controller work mode and allocate the resource which is needed.

**Returns**
- ESP_OK: success, other: failed

**esp_err_t esp_bt_controller_deinit** (void)

De-initialize BT controller to free resource and delete task. You should stop advertising and scanning, as well as disconnect all existing connections before de-initializing BT controller.

This function should be called only once, after any other BT functions are called.

**Returns**
- ESP_OK: success, other: failed

**esp_err_t esp bt_controller_enable** (esp_bt_mode_t mode)

Enable BT controller. Due to a known issue, you cannot call esp_bt_controller_enable() a second time to change the controller mode dynamically. To change controller mode, call esp_bt_controller_disable() and then call esp bt_controller_enable() with the new mode.

**Parameters**
- **mode**: The mode (BLE/BT/BTDM) to enable. For compatible of API, retain this argument. This mode must be equal as the mode in “cfg” of esp bt_controller_init().

**Returns**
- ESP_OK: success, other: failed

**esp_err_t esp bt_controller_disable** (void)

Disable BT controller.

**Returns**
- ESP_OK: success, other: failed

**esp bt_controller_status_t esp bt_controller_get_status** (void)

Get BT controller is initialised/de-initialised/enabled/disabled.
Returns status value

```c
bool esp_vhci_host_check_send_available(void)
```

esp_vhci_host_check_send_available used for check actively if the host can send packet to controller or not.

**Returns** true for ready to send, false means cannot send packet

```c
void esp_vhci_host_send_packet(uint8_t *data, uint16_t len)
```

esp_vhci_host_send_packet host send packet to controller

Should not call this function from within a critical section or when the scheduler is suspended.

**Parameters**
- **data** – the packet point
- **len** – the packet length

```c
esp_err_t esp_vhci_host_register_callback(const esp_vhci_host_callback_t *callback)
```

esp_vhci_host_register_callback register the vhci reference callback struct defined by vhci_host_callback structure.

**Parameters**
- **callback** – esp_vhci_host_callback type variable

**Returns**
- ESP_OK - success, ESP_FAIL - failed

```c
esp_err_t esp_bt_controller_mem_release(esp_bt_mode_t mode)
```

This function releases the BSS, data and other sections of the controller to heap. The total size is about 70k bytes.

esp_bt_controller_mem_release(mode) should be called only before esp_bt_controller_init() or after esp_bt_controller_deinit().

Note that once BT controller memory is released, the process cannot be reversed. It means you cannot use the bluetooth mode which you have released by this function.

If your firmware will later upgrade the Bluetooth controller mode (BLE -> BT Classic or disabled -> enabled) then do not call this function.

If the app calls esp_bt_controller_enable(ESP_BT_MODE_BLE) to use BLE only then it is safe to call esp_bt_controller_mem_release(ESP_BT_MODE_CLASSIC_BT) at initialization time to free unused BT Classic memory.

If the mode is ESP_BT_MODE_BTD, then it may be useful to call API esp_bt_mem_release(ESP_BT_MODE_BTD) instead, which internally calls esp_bt_controller_mem_release(ESP_BT_MODE_BTD) and additionally releases the BSS and data consumed by the BT/BLE host stack to heap. For more details about usage please refer to the documentation of esp_bt_mem_release() function.

**Parameters**
- **mode** – the mode want to release memory

**Returns**
- ESP_OK - success, other - failed

```c
esp_err_t esp_bt_mem_release(esp_bt_mode_t mode)
```

This function first releases controller memory by internally calling esp_bt_controller_mem_release(). Additionally, if the mode is set to ESP_BT_MODE_BTD, it also releases the BSS and data consumed by the BT/BLE host stack to heap.

Note that once BT memory is released, the process cannot be reversed. It means you cannot use the bluetooth mode which you have released by this function.

If your firmware will later upgrade the Bluetooth controller mode (BLE -> BT Classic or disabled -> enabled) then do not call this function.
If you never intend to use Bluetooth in a current boot-up cycle, you can call `esp_bt_mem_release(ESP_BT_MODE_BTDM)` before `esp_bt_controller_init` or after `esp_bt_controller_deinit`.

For example, if a user only uses Bluetooth for setting the WiFi configuration, and does not use Bluetooth in the rest of the product operation. In such cases, after receiving the WiFi configuration, you can disable/deinit Bluetooth and release its memory. Below is the sequence of APIs to be called for such scenarios:

```c
esp_bluedroid_disable();
esp_bluedroid_deinit();
esp_bt_controller_disable();
esp_bt_controller_deinit();
esp_bt_mem_release(ESP_BT_MODE_BTDM);
```

**Note:** In case of NimBLE host, to release BSS and data memory to heap, the mode needs to be set to ESP_BT_MODE_BTDM as controller is dual mode.

---

**Parameters**

- **mode**: the mode whose memory is to be released

**Returns**

- ESP_OK - success
- other - failed

```c
esp_err_t esp_bt_sleep_enable (void)
```

enable Bluetooth to enter modem sleep

Note that this function shall not be invoked before `esp_bt_controller_enable()`

There are currently two options for Bluetooth modem sleep, one is ORIG mode, and another is EVED Mode. EVED Mode is intended for BLE only.

For ORIG mode: Bluetooth modem sleep is enabled in controller start up by default if CONFIG_CTRL_BTDM_MODEM_SLEEP is set and “ORIG mode” is selected. In ORIG modem sleep mode, Bluetooth controller will switch off some components and pause to work every now and then, if there is no event to process; and wakeup according to the scheduled interval and resume the work. It can also wakeup earlier upon external request using function “esp_bt_controller_wakeup_request”.

**Returns**

- ESP_OK : success
- other : failed

```c
esp_err_t esp_bt_sleep_disable (void)
```

disable Bluetooth modem sleep

Note that this function shall not be invoked before `esp_bt_controller_enable()`

If `esp_bt_sleep_disable()` is called, Bluetooth controller will not be allowed to enter modem sleep;

If ORIG modem sleep mode is in use, if this function is called, Bluetooth controller may not immediately wake up if it is dormant then. In this case, `esp_bt_controller_wakeup_request()` can be used to shorten the time for wakeup.

**Returns**

- ESP_OK : success
- other : failed

```c
esp_err_t esp_ble_scan_duplicate_list_flush (void)
```

Manually clear scan duplicate list.

Note that scan duplicate list will be automatically cleared when the maximum amount of device in the filter is reached the amount of device in the filter can be configured in menuconfig.

**Note:** This function name is incorrectly spelled, it will be fixed in release 5.x version.
Returns

- ESP_OK: success
- other: failed

void esp_wifi BT_power_domain_on (void)
  bt Wi-Fi power domain power on

void esp_wifi BT_power_domain_off (void)
  bt Wi-Fi power domain power off

Structures

struct esp BT_controller_config_t
  Controller config options, depend on config mask. Config mask indicate which functions enabled, this means some options or parameters of some functions enabled by config mask.

Public Members

uint16_t controller_task_stack_size
  Bluetooth controller task stack size

uint8_t controller_task_prio
  Bluetooth controller task priority

uint8_t hci_uart_no
  If use UART1/2 as HCI IO interface, indicate UART number

uint32_t hci_uart_baudrate
  If use UART1/2 as HCI IO interface, indicate UART baudrate

uint8_t scan_duplicate_mode
  scan duplicate mode

uint8_t scan_duplicate_type
  scan duplicate type

uint16_t normal_adv_size
  Normal adv size for scan duplicate

uint16_t mesh_adv_size
  Mesh adv size for scan duplicate

uint16_t send_adv_reserved_size
  Controller minimum memory value

uint32_t controller_debug_flag
  Controller debug log flag

uint8_t mode
  Controller mode: BR/EDR, BLE or Dual Mode
uint8_t `ble_max_conn`
   BLE maximum connection numbers

uint8_t `bt_max_acl_conn`
   BR/EDR maximum ACL connection numbers

uint8_t `bt_sco_datapath`
   SCO data path, i.e. HCI or PCM module

bool `auto_latency`
   BLE auto latency, used to enhance classic BT performance

bool `bt_legacy_auth_vs_evt`
   BR/EDR Legacy auth complete event required to protect from BIAS attack

uint8_t `bt_max_sync_conn`
   BR/EDR maximum ACL connection numbers. Effective in menuconfig

uint8_t `ble_sca`
   BLE low power crystal accuracy index

uint8_t `pcm_role`
   PCM role (master & slave)

uint8_t `pcm_polar`
   PCM polar trig (falling clk edge & rising clk edge)

bool `hli`
   Using high level interrupt or not

uint16_t `dup_list_refresh_period`
   Duplicate scan list refresh period

uint32_t `magic`
   Magic number

struct `esp_vhci_host_callback`:

   `esp_vhci_host_callback` used for vhci call host function to notify what host need to do

**Public Members**

void (*`notify_host_send_available`)(void)
   callback used to notify that the host can send packet to controller

int (*`notify_host_recv`)(uint8_t *data, uint16_t len)
   callback used to notify that the controller has a packet to send to the host
Macros

ESP_BT_CONTROLLER_CONFIG_MAGIC_VAL
BT_CONTROLLER_INIT_CONFIG_DEFAULT()

Type Definitions

typedef struct esp_vhci_host_callback esp_vhci_host_callback_t
    esp_vhci_host_callback used for vhci call host function to notify what host need to do

Enumerations

enum esp_bt_mode_t
    Bluetooth mode for controller enable/disable.
    Values:
    enumerator ESP_BT_MODE_IDLE
        Bluetooth is not running
    enumerator ESP_BT_MODE_BLE
        Run BLE mode
    enumerator ESP_BT_MODE_CLASSIC_BT
        Run Classic BT mode
    enumerator ESP_BT_MODE_BTDM
        Run dual mode

enum [anonymous]
    BLE sleep clock accuracy(SCA), values for ble_sca field in esp_bt_controller_config_t, currently only ESP_BLE_SCA_500PPM and ESP_BLE_SCA_250PPM are supported.
    Values:
    enumerator ESP_BLE_SCA_500PPM
        BLE SCA at 500ppm
    enumerator ESP_BLE_SCA_250PPM
        BLE SCA at 250ppm
    enumerator ESP_BLE_SCA_150PPM
        BLE SCA at 150ppm
    enumerator ESP_BLE_SCA_100PPM
        BLE SCA at 100ppm
    enumerator ESP_BLE_SCA_75PPM
        BLE SCA at 75ppm
    enumerator ESP_BLE_SCA_50PPM
        BLE SCA at 50ppm
enumerator **ESP_BLE_SCA_30PPM**
BLE SCA at 30ppm

enumerator **ESP_BLE_SCA_20PPM**
BLE SCA at 20ppm

enum **esp_bt_controller_status_t**
Bluetooth controller enable/disable/initialised/de-initialised status.

Values:

enumerator **ESP_BT_CONTROLLER_STATUS_IDLE**

enumerator **ESP_BT_CONTROLLER_STATUS_INITED**

enumerator **ESP_BT_CONTROLLER_STATUS_ENABLED**

enumerator **ESP_BT_CONTROLLER_STATUS_NUM**

enum **esp_ble_power_type_t**
BLE tx power type ESP_BLE_PWR_TYPE_CONN_HDL0-8: for each connection, and only be set after connection completed. when disconnect, the correspond TX power is not effected. ESP_BLE_PWR_TYPE_ADV: for advertising/scan response. ESP_BLE_PWR_TYPE_SCAN: for scan.

ESP_BLE_PWR_TYPE_DEFAULT: if each connection’s TX power is not set, it will use this default value. if neither in scan mode nor in adv mode, it will use this default value. If none of power type is set, system will use ESP_PWR_LVL_P3 as default for ADV/SCAN/CONN0-9.

Values:

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL0**
For connection handle 0

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL1**
For connection handle 1

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL2**
For connection handle 2

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL3**
For connection handle 3

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL4**
For connection handle 4

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL5**
For connection handle 5

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL6**
For connection handle 6
enumerator **ESP_BLE_PWR_TYPE_CONN_HDL7**
   For connection handle 7

enumerator **ESP_BLE_PWR_TYPE_CONN_HDL8**
   For connection handle 8

enumerator **ESP_BLE_PWR_TYPE_ADV**
   For advertising

enumerator **ESP_BLE_PWR_TYPE_SCAN**
   For scan

enumerator **ESP_BLE_PWR_TYPE_DEFAULT**
   For default, if not set other, it will use default value

enumerator **ESP_BLE_PWR_TYPE_NUM**
   TYPE numbers

**enum esp_power_level_t**

   Bluetooth TX power level(index), it’s just a index corresponding to power(dbm).

   Values:

enumerator **ESP_PWR_LVL_N12**
   Corresponding to -12dbm

enumerator **ESP_PWR_LVL_N9**
   Corresponding to -9dbm

enumerator **ESP_PWR_LVL_N6**
   Corresponding to -6dbm

enumerator **ESP_PWR_LVL_N3**
   Corresponding to -3dbm

enumerator **ESP_PWR_LVL_N0**
   Corresponding to 0dbm

enumerator **ESP_PWR_LVL_P3**
   Corresponding to +3dbm

enumerator **ESP_PWR_LVL_P6**
   Corresponding to +6dbm

enumerator **ESP_PWR_LVL_P9**
   Corresponding to +9dbm

enumerator **ESP_PWR_LVL_N14**
   Backward compatibility! Setting to -14dbm will actually result to -12dbm
Chapter 2. API Reference

enumerator **ESP_PWR_LVL_N11**
   Backward compatibility! Setting to -11dbm will actually result to -9dbm

enumerator **ESP_PWR_LVL_N8**
   Backward compatibility! Setting to -8dbm will actually result to -6dbm

enumerator **ESP_PWR_LVL_N5**
   Backward compatibility! Setting to -5dbm will actually result to -3dbm

enumerator **ESP_PWR_LVL_N2**
   Backward compatibility! Setting to -2dbm will actually result to 0dbm

enumerator **ESP_PWR_LVL_P1**
   Backward compatibility! Setting to +1dbm will actually result to +3dbm

enumerator **ESP_PWR_LVL_P4**
   Backward compatibility! Setting to +4dbm will actually result to +6dbm

enumerator **ESP_PWR_LVL_P7**
   Backward compatibility! Setting to +7dbm will actually result to +9dbm

enum **esp_sco_data_path_t**
   Bluetooth audio data transport path.
   
   Values:

   enumerator **ESP_SCO_DATA_PATH_HCI**
      data over HCI transport

   enumerator **ESP_SCO_DATA_PATH_PCM**
      data over PCM interface

2.3.5 ESP-BLE-MESH

With various features of ESP-BLE-MESH, users can create a managed flooding mesh network for several scenarios, such as lighting, sensor and etc.

For an ESP32 to join and work on an ESP-BLE-MESH network, it must be provisioned firstly. By provisioning, the ESP32, as an unprovisioned device, will join the ESP-BLE-MESH network and become an ESP-BLE-MESH node, communicating with other nodes within or beyond the radio range.

Apart from ESP-BLE-MESH nodes, inside ESP-BLE-MESH network, there is also ESP32 that works as ESP-BLE-MESH Provisioner, which could provision unprovisioned devices into ESP-BLE-MESH nodes and configure the nodes with various features.

For information how to start using ESP32 and ESP-BLE-MESH, please see the Section *Getting Started with ESP-BLE-MESH*. If you are interested in information on ESP-BLE-MESH architecture, including some details of software implementation, please see Section *ESP-BLE-MESH Architecture*.

**Application Examples and Demos**

Please refer to Sections *ESP-BLE-MESH Examples* and *ESP-BLE-MESH Demo Videos*. 
API Reference

ESP-BLE-MESH APIs are divided into the following parts:

- ESP-BLE-MESH Definitions
- ESP-BLE-MESH Core API Reference
- ESP-BLE-MESH Models API Reference

ESP-BLE-MESH Definitions

This section contains only one header file, which lists the following items of ESP-BLE-MESH.

- ID of all the models and related message opcodes
- Structs of model, element and Composition Data
- Structs of used by ESP-BLE-MESH Node/Provisioner for provisioning
- Structs used to transmit/receive messages
- Event types and related event parameters

Header File

- components/bt/esp_ble_mesh/api/esp_ble_mesh_defs.h

Unions

union esp_ble_mesh_prov_cb_param_t

#include <esp_ble_mesh_defs.h> BLE Mesh Node/Provisioner callback parameters union.

Public Members

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_register_comp_param prov_register_comp
    Event parameter of ESP_BLE_MESH_PROV_REGISTER_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_unprov_dev_name_comp_param
node_set_unprov_dev_name_comp
    Event parameter of ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_enable_comp_param
node_prov_enable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_disable_comp_param
node_prov_disable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_link_open_evt_param node_prov_link_open
    Event parameter of ESP_BLE_MESH_NODE_PROV_LINK_OPEN_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_link_close_evt_param node_prov_link_close
    Event parameter of ESP_BLE_MESH_NODE_PROV_LINK_CLOSE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_output_num_evt_param node_prov_output_num
    Event parameter of ESP_BLE_MESH_NODE_PROV_OUTPUT_NUMBER_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_output_str_evt_param node_prov_output_str
    Event parameter of ESP_BLE_MESH_NODE_PROV_OUTPUT_STRING_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_evt_param node_prov_input
    Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_complete_evt_param node_prov_complete
    Event parameter of ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provision_reset_param node_prov_reset
    Event parameter of ESP_BLE_MESH_NODE_PROV_RESET_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_oob_pub_key_comp_param
node_prov_set_oob_pub_key_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_number_comp_param
node_prov_input_num_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_NUM_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_input_string_comp_param
node_prov_input_str_comp
    Event parameter of ESP_BLE_MESH_NODE_PROV_INPUT_STR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_identity_enable_comp_param
node_proxy_identity_enable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROXY_IDENTITY_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_gatt_enable_comp_param
node_proxy_gatt_enable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_gatt_disable_comp_param
node_proxy_gatt_disable_comp
    Event parameter of ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_node_add_local_net_key_comp_param
node_add_net_key_comp
    Event parameter of ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_node_add_local_app_key_comp_param
node_add_app_key_comp
    Event parameter of ESP_BLE_MESH_NODE_ADD_LOCAL_APP_KEY_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_node_bind_local_mod_app_comp_param
node_bind_app_key_to_model_comp
    Event parameter of ESP_BLE_MESH_NODE_BIND_APP_KEY_TO_MODEL_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_recv_unprov_adv_pkt_param
provisioner_recv_unprov_adv_pkt
    Event parameter of ESP_BLE_MESH_PROVISIONER_RECV_UNPROV_ADV_PKT_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_enable_comp
  provisioner_prov_enable_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_disable_comp
  provisioner_prov_disable_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_open_evt_param
  provisioner_prov_link_open
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_LINK_OPEN_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_read_oob_pub_key_evt_param
  provisioner_prov_read_oob_pub_key
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_input_evt_param
  provisioner_prov_input
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_output_evt_param
  provisioner_prov_output
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_link_close_evt_param
  provisioner_prov_link_close
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_comp_param
  provisioner_prov_complete
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_unprov_dev_comp_param
  provisioner_add_unprov_dev_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_dev_with_addr_comp_param
  provisioner_prov_dev_with_addr_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_DEV_WITH_ADDR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_dev_comp_param
  provisioner_delete_dev_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_dev_uuid_match_comp_param
  provisioner_set_dev_uuid_match_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_SET_DEV_UUID_MATCH_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_prov_data_info_comp_param
  provisioner_set_prov_data_info_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_SET_PROV_DATA_INFO_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_static_oob_val_comp_param
provisioner_set_static_oob_val_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_SET_STATIC_OOB_VALUE_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_primary_elem_addr_comp_param
provisioner_set_primary Elem_addr_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_read_oob_pub_key_comp_param
provisioner_prov_read_oob_pub_key_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_input_num_comp_param
provisioner_prov_input_num_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_input_str_comp_param
provisioner_prov_input_str_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_set_node_name_comp_param
provisioner_set_node_name_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_app_key_comp_param
provisioner_add_app_key_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_update_local_app_key_comp_param
provisioner_update_app_key_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_bind_local_mod_app_comp_param
provisioner_bind_app_key_to_model_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_add_local_net_key_comp_param
provisioner_add_net_key_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_NET_KEY_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_update_local_net_key_comp_param
provisioner_update_net_key_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_store_node_comp_data_comp_param
provisioner_store_node_comp_data_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_uuid_comp_param
provisioner_delete_node_with_uuid_comp
    Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UUID_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_delete_node_with_addr_comp_param
provisioner_delete_node_with_addr_comp
Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT

int err_code
Indicate the result of enabling/disabling to receive heartbeat messages by the Provisioner
Indicate the result of setting the heartbeat filter type by the Provisioner
Indicate the result of setting the heartbeat filter address by the Provisioner
Indicate the result of directly erasing settings by the Provisioner
Indicate the result of opening settings with index by the Provisioner
Indicate the result of opening settings with user id by the Provisioner
Indicate the result of closing settings with index by the Provisioner
Indicate the result of closing settings with user id by the Provisioner
Indicate the result of deleting settings with index by the Provisioner
Indicate the result of deleting settings with user id by the Provisioner

bool enable
Indicate enabling or disabling receiving heartbeat messages

struct esp_ble_mesh_prov_cb_param_t::[anonymous]
provisioner_enable_heartbeat_recv_comp
ESP_BLE_MESH_PROVISIONER_ENABLE_HEARTBEAT_RECV_COMP_EVT.
Event parameters of ESP_BLE_MESH_PROVISIONER_ENABLE_HEARTBEAT_RECV_COMP_EVT

uint8_t type
Type of the filter used for receiving heartbeat messages

struct esp_ble_mesh_prov_cb_param_t::[anonymous]
provisioner_set_heartbeat_filter_type_comp
ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE_COMP_EVT.
Event parameters of ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE_COMP_EVT

uint8_t op
Operation (add, remove, clean)

uint16_t hb_src
Heartbeat source address

uint16_t hb_dst
Heartbeat destination address

struct esp_ble_mesh_prov_cb_param_t::[anonymous]
provisioner_set_heartbeat_filter_info_comp
ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_INFO_COMP_EVT.
Event parameters of ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_INFO_COMP_EVT
uint8_t init_ttl
    Heartbeat InitTTL

uint8_t rx_ttl
    Heartbeat RxTTL

uint8_t hops
    Heartbeat hops (InitTTL - RxTTL + 1)

uint16_t feature
    Bit field of currently active features of the node

int8_t rssi
    RSSI of the heartbeat message

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_recv_heartbeat
    ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT_MESSAGE_EVT.
    Event parameters of ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT_MESSAGE_EVT

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_direct_erase_settings_comp
    ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT.
    Event parameters of ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT

uint8_t index
    Index of Provisioner settings

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_open_settings_with_index_comp
    ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_INDEX_COMP_EVT.
    Event parameter of ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_INDEX_COMP_EVT

char uid[ESP_BLE_MESH_SETTINGS_UID_SIZE + 1]
    Provisioner settings user id

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_open_settings_with_uid_comp
    ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_UID_COMP_EVT.
    Event parameters of ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_UID_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_close_settings_with_index_comp
    ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_INDEX_COMP_EVT.
    Event parameter of ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_INDEX_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::[anonymous] provisioner_close_settings_with_uid_comp
    ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID_COMP_EVT.
    Event parameters of ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID_COMP_EVT
struct esp_ble_mesh_prov_cb_param_t::[anonymous]

provisioner_delete_settings_with_index_comp
  
  ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT.
  
  Event parameter of ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::[anonymous]

provisioner_delete_settings_with_uid_comp
  
  ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT.
  
  Event parameters of ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_fast_prov_info_comp_param

set_fast_prov_info_comp
  
  Event parameter of ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_set_fast_prov_action_comp_param

set_fast_prov_action_comp
  
  Event parameter of ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_heartbeat_msg_recv_param

heartbeat_msg_recv
  
  Event parameter of ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_enable_comp_param

lpn_enable_comp
  
  Event parameter of ESP_BLE_MESH_LPN_ENABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_disable_comp_param

lpn_disable_comp
  
  Event parameter of ESP_BLE_MESH_LPN_DISABLE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_poll_comp_param

lpn_poll_comp
  
  Event parameter of ESP_BLE_MESH_LPN_POLL_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_friendship_establish_param

lpn_friendship_establish
  
  Event parameter of ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_lpn_friendship_terminate_param

lpn_friendship_terminate
  
  Event parameter of ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_friend_friendship_establish_param

frnd_friendship_establish
  
  Event parameter of ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_friend_friendship_terminate_param

frnd_friendship_terminate
  
  Event parameter of ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_recv_adv_pkt_param

proxy_client_recv_adv_pkt
  
  Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connected_param
proxy_client_connected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_disconnected_param
proxy_client_disconnected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_recv_filter_status_param
proxy_client_recv_filter_status
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_connect_comp_param
proxy_client_connect_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_disconnect_comp_param
proxy_client_disconnect_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_set_filter_type_comp_param
proxy_client_set_filter_type_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_add_filter_addr_comp_param
proxy_client_add_filter_addr_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_client_remove_filter_addr_comp_param
proxy_client_remove_filter_addr_comp
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_server_connected_param
proxy_server_connected
Event parameter of ESP_BLE_MESH_PROXY_SERVER_CONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_proxy_server_disconnected_param
proxy_server_disconnected
Event parameter of ESP_BLE_MESH_PROXY_SERVER_DISCONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_model_sub_group_addr_comp_param
model_sub_group_addr_comp
Event parameters of ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_model_unsub_group_addr_comp_param
model_unsub_group_addr_comp
Event parameters of ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_deinit_mesh_comp_param
deinit_mesh_comp
Event parameter of ESP_BLE_MESH_DEINIT_MESH_COMP_EVT

#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_DEINIT_MESH_COMP_EVT.
### Public Members

**int err_code**

Indicate the result of BLE Mesh deinitialization

```c
#include <esp_ble_mesh_defs.h> #define ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT.
```

### Public Members

**uint16_t lpn_addr**

Low Power Node unicast address

```c
#include <esp_ble_mesh_defs.h> #define ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT.
```

### Public Types

```c
enum [anonymous]

This enum value is the reason of friendship termination on the friend node side

**Values:**

- **enumerator ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_ESTABLISH_FAIL**
  
  Friend Offer has been sent, but Friend Offer is not received within 1 second, friendship fails to be established

- **enumerator ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_POLL_TIMEOUT**
  
  Friendship is established, PollTimeout timer expires and no Friend Poll/Sub Add/Sub Remove is received

- **enumerator ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_RECV_FRND_REQ**
  
  Receive Friend Request from existing Low Power Node

- **enumerator ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_RECV_FRND_CLEAR**
  
  Receive Friend Clear from other friend node

- **enumerator ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_DISABLE**
  
  Friend feature disabled or corresponding NetKey is deleted
```

### Public Members

**uint16_t lpn_addr**

Low Power Node unicast address

```c
enum esp_ble_mesh_prov_cb_param_t::ble_mesh_friend_friendship_terminate_param::[anonymous] reason
```
This enum value is the reason of friendship termination on the friend node side Friendship terminated reason

```c
struct ble_mesh_heartbeat_msg_recv_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT.
```

**Public Members**

- `uint8_t hops`
  
  Heartbeat hops (InitTTL - RxTTL + 1)

- `uint16_t feature`
  
  Bit field of currently active features of the node

```c
struct ble_mesh_input_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_INPUT_EVT.
```

**Public Members**

- `esp_ble_mesh_input_action_t action`
  
  Action of Input OOB Authentication

- `uint8_t size`
  
  Size of Input OOB Authentication

```c
struct ble_mesh_input_number_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_INPUT_NUM_COMP_EVT.
```

**Public Members**

- `int err_code`
  
  Indicate the result of inputting number

```c
struct ble_mesh_input_string_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_INPUT_STR_COMP_EVT.
```

**Public Members**

- `int err_code`
  
  Indicate the result of inputting string

```c
struct ble_mesh_link_close_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_LINK_CLOSE_EVT.
```
Public Members

```c
esp_ble_mesh_prov_bearer_t bearer
```
Type of the bearer used when device link is closed

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_LINK_OPEN_EVT.
```

Public Members

```c
esp_ble_mesh_prov_bearer_t bearer
```
Type of the bearer used when device link is open

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_DISABLE_COMP_EVT.
```

Public Members

```c
int err_code
```
Indicate the result of disabling LPN functionality

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_ENABLE_COMP_EVT.
```

Public Members

```c
int err_code
```
Indicate the result of enabling LPN functionality

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT.
```

Public Members

```c
uint16_t friend_addr
```
Friend Node unicast address

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT.
```

Public Members

```c
uint16_t friend_addr
```
Friend Node unicast address
struct ble_mesh_lpn_poll_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_POLL_COMP_EVT.

Public Members

int err_code
Indicate the result of sending Friend Poll

struct ble_mesh_model_sub_group_addr_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT.

Public Members

int err_code
Indicate the result of local model subscribing group address

uint16_t element_addr
Element address

uint16_t company_id
Company ID

uint16_t model_id
Model ID

uint16_t group_addr
Group Address

struct ble_mesh_model_unsub_group_addr_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT.

Public Members

int err_code
Indicate the result of local model unsubscribing group address

uint16_t element_addr
Element address

uint16_t company_id
Company ID

uint16_t model_id
Model ID
uint16_t group_addr
Group Address

struct ble_mesh_node_add_local_app_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_ADD_LOCAL_APP_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of adding local AppKey by the node

uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index

struct ble_mesh_node_add_local_net_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of adding local NetKey by the node

uint16_t net_idx
NetKey Index

struct ble_mesh_node_bind_local_mod_app_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_BIND_APP_KEY_TO_MODEL_COMP_EVT.

Public Members

int err_code
Indicate the result of binding AppKey with model by the node

uint16_t element_addr
Element address

uint16_t app_idx
AppKey Index

uint16_t company_id
Company ID
```c
uint16_t model_id

Model ID

struct ble_mesh_output_num_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_OUTPUT_NUMBER_EVT.

Public Members

esp_ble_mesh_output_action_t action
Action of Output OOB Authentication

uint32_t number
Number of Output OOB Authentication

struct ble_mesh_output_str_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_OUTPUT_STRING_EVT.

Public Members

char string[8]
String of Output OOB Authentication

struct ble_mesh_prov_disable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_DISABLE_COMP_EVT.

Public Members

int err_code
Indicate the result of disabling BLE Mesh device

struct ble_mesh_prov_enable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_ENABLE_COMP_EVT.

Public Members

int err_code
Indicate the result of enabling BLE Mesh device

struct ble_mesh_prov_register_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROV_REGISTER_COMP_EVT.

Public Members

int err_code
Indicate the result of BLE Mesh initialization
```
struct ble_mesh_provision_complete_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT.

Public Members

uint16_t net_idx
NetKey Index

uint8_t net_key[16]
NetKey

uint16_t addr
Primary address

uint8_t flags
Flags

uint32_t iv_index
IV Index

struct ble_mesh_provision_reset_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_RESET_EVT.

struct ble_mesh_provisioner_add_local_app_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of adding local AppKey by the Provisioner

uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index

struct ble_mesh_provisioner_add_local_net_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_NET_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of adding local NetKey by the Provisioner
Chapter 2. API Reference

uint16_t net_idx
   NetKey Index

struct ble_mesh_provisioner_add_unprov_dev_comp_param
   #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT.
   
   Public Members
   
   int err_code
      Indicate the result of adding device into queue by the Provisioner

struct ble_mesh_provisioner_bind_local_mod_app_comp_param
   #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT.
   
   Public Members
   
   int err_code
      Indicate the result of binding AppKey with model by the Provisioner

   uint16_t element_addr
      Element address

   uint16_t app_idx
      AppKey Index

   uint16_t company_id
      Company ID

   uint16_t model_id
      Model ID

struct ble_mesh_provisioner_delete_dev_comp_param
   #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT.
   
   Public Members
   
   int err_code
      Indicate the result of deleting device by the Provisioner

struct ble_mesh_provisioner_delete_node_with_addr_comp_param
   #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT.
   
   Public Members
   
   int err_code
      Indicate the result of deleting node with unicast address by the Provisioner
# ble_mesh_provisioner_delete_node_with_uuid_comp_param

```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UUID_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicates the result of deleting node with uuid by the Provisioner

- `uint8_t uuid[16]`
  - Node device uuid

# ble_mesh_provisioner_link_close_evt_param

```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT.
```

**Public Members**

- `esp_ble_mesh_prov_bearer_t bearer`
  - Type of the bearer used when Provisioner link is closed

- `uint8_t reason`
  - Reason of the closed provisioning link

# ble_mesh_provisioner_link_open_evt_param

```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_PROVISIONER_PROV_LINK_OPEN_EVT.
```

**Public Members**

- `esp_ble_mesh_prov_bearer_t bearer`
  - Type of the bearer used when Provisioner link is opened

# ble_mesh_provisioner_prov_comp_param

```c
#include <esp_ble_mesh_defs.h>
ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT.
```

**Public Members**

- `uint16_t node_idx`
  - Index of the provisioned device

- `esp_ble_mesh_octet16_t device_uuid`
  - Device UUID of the provisioned device

- `uint16_t unicast_addr`
  - Primary address of the provisioned device
**Chapter 2. API Reference**

```
uint8_t element_num
    Element count of the provisioned device

uint16_t netkey_idx
    NetKey Index of the provisioned device

struct ble_mesh_provisioner_prov_dev_with_addr_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_DEV_WITH_ADDR_COMP_EVT.

Public Members

int err_code
    Indicate the result of Provisioner starting to provision a device

struct ble_mesh_provisioner_prov_disable_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT.

Public Members

int err_code
    Indicate the result of disabling BLE Mesh Provisioner

struct ble_mesh_provisioner_prov_enable_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT.

Public Members

int err_code
    Indicate the result of enabling BLE Mesh Provisioner

struct ble_mesh_provisioner_prov_input_evt_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT.

Public Members

esp_ble_mesh_oob_method_t method
    Method of device Output OOB Authentication

esp_ble_mesh_output_action_t action
    Action of device Output OOB Authentication

uint8_t size
    Size of device Output OOB Authentication

uint8_t link_idx
    Index of the provisioning link
```
struct `ble_mesh_provisioner_prov_input_num_comp_param`

```c
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of inputting number by the Provisioner

struct `ble_mesh_provisioner_prov_input_str_comp_param`

```c
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of inputting string by the Provisioner

struct `ble_mesh_provisioner_prov_output(evt)_param`

```c
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT.
```

**Public Members**

- `esp_ble_mesh_oob_method_t method`
  - Method of device Input OOB Authentication

- `esp_ble_mesh_input_action_t action`
  - Action of device Input OOB Authentication

- `uint8_t size`
  - Size of device Input OOB Authentication

- `uint8_t link_idx`
  - Index of the provisioning link

- `char string[8]`
  - String output by the Provisioner

- `uint32_t number`
  - Number output by the Provisioner

union `esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_output_evt_param::[anonymous]`

struct `ble_mesh_provisioner_prov_read_oob_pub_key_comp_param`

```c
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_COMP_EVT.
```

Espressif Systems 550

Release v5.1.2

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Chapter 2  API Reference

**Public Members**

```c
int err_code
```

Indicate the result of setting OOB Public Key by the Provisioner

```c
struct ble_mesh_provisioner_prov_read_oob_pub_key_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_EVT.
```

**Public Members**

```c
uint8_t link_idx
```

Index of the provisioning link

```c
struct ble_mesh_provisioner_recv_unprov_adv_pkt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_RECV_UNPROV_ADV_PKT_EVT.
```

**Public Members**

```c
uint8_t dev_uuid[16]
```

Device UUID of the unprovisioned device

```c
esp_ble_mesh_bd_addr_t addr
```

Device address of the unprovisioned device

```c
esp_ble_mesh_addr_type_t addr_type
```

Device address type

```c
uint16_t oob_info
```

OOB Info of the unprovisioned device

```c
uint8_t adv_type
```

Advertising type of the unprovisioned device

```c
esp_ble_mesh_prov_bearer_t bearer
```

Bearer of the unprovisioned device

```c
int8_t rssi
```

RSSI of the received advertising packet

```c
struct ble_mesh_provisioner_set_dev_uuid_match_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_DEV_UUID_MATCH_COMP_EVT.
```

**Public Members**

```c
int err_code
```

Indicate the result of setting Device UUID match value by the Provisioner
struct **ble_mesh_provisioner_set_node_name_comp_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of setting provisioned device name by the Provisioner

- `uint16_t node_index`
  - Index of the provisioned device

struct **ble_mesh_provisioner_set_primary_elem_addr_comp_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of setting unicast address of primary element by the Provisioner

struct **ble_mesh_provisioner_set_prov_data_info_comp_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_PROV_DATA_INFO_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of setting provisioning info by the Provisioner

struct **ble_mesh_provisioner_set_static_oob_val_comp_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_SET_STATIC_OOB_VALUE_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of setting static oob value by the Provisioner

struct **ble_mesh_provisioner_store_node_comp_data_comp_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT.
```

**Public Members**

- `int err_code`
  - Indicate the result of storing node composition data by the Provisioner

- `uint16_t addr`
  - Node element address
struct ble_mesh_provisioner_update_local_app_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT.

Public Members

int err_code
    Indicate the result of updating local AppKey by the Provisioner

uint16_t net_idx
    NetKey Index

uint16_t app_idx
    AppKey Index

struct ble_mesh_provisioner_update_local_net_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT.

Public Members

int err_code
    Indicate the result of updating local NetKey by the Provisioner

uint16_t net_idx
    NetKey Index

struct ble_mesh_proxy_client_add_filter_addr_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT.

Public Members

int err_code
    Indicate the result of Proxy Client add filter address

uint8_t conn_handle
    Proxy connection handle

uint16_t net_idx
    Corresponding NetKey Index

struct ble_mesh_proxy_client_connect_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT.

Public Members

int err_code
    Indicate the result of Proxy Client connect
```
**esp_ble_mesh_bd_addr_t addr**
Device address of the Proxy Server

**esp_ble_mesh_addr_type_t addr_type**
Device address type

**uint16_t net_idx**
Corresponding NetKey Index

```

### Public Members

```
**esp_ble_mesh_bd_addr_t addr**
Device address of the Proxy Server

**esp_ble_mesh_addr_type_t addr_type**
Device address type

**uint8_t conn_handle**
Proxy connection handle

**uint16_t net_idx**
Corresponding NetKey Index

```

### Public Members

```
**int err_code**
Indicate the result of Proxy Client disconnect

**uint8_t conn_handle**
Proxy connection handle

```

### Public Members

```
**esp_ble_mesh_bd_addr_t addr**
Device address of the Proxy Server
```
**Chapter 2. API Reference**

```c
enum esp_ble_mesh_addr_type_t addr_type
    Device address type

uint8_t conn_handle
    Proxy connection handle

uint16_t net_idx
    Corresponding NetKey Index

uint8_t reason
    Proxy disconnect reason
```

```c
struct ble_mesh_proxy_client_recv_adv_pkt_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT.

Public Members
```

```c
enum esp_ble_mesh_bd_addr_t addr
    Device address

enum esp_ble_mesh_addr_type_t addr_type
    Device address type

uint16_t net_idx
    Network ID related NetKey Index

uint8_t net_id[8]
    Network ID contained in the advertising packet

int8_t rssi
    RSSI of the received advertising packet
```

```c
struct ble_mesh_proxy_client_recv_filter_status_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT.

Public Members
```

```c
uint8_t conn_handle
    Proxy connection handle

uint16_t server_addr
    Proxy Server primary element address

uint16_t net_idx
    Corresponding NetKey Index
```
uint8_t filter_type
    Proxy Server filter type (whitelist or blacklist)

uint16_t list_size
    Number of addresses in the Proxy Server filter list

struct ble_mesh_proxy_client_remove_filter_addr_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT.

Public Members

int err_code
    Indicate the result of Proxy Client remove filter address

uint8_t conn_handle
    Proxy connection handle

uint16_t net_idx
    Corresponding NetKey Index

struct ble_mesh_proxy_client_set_filter_type_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT.

Public Members

int err_code
    Indicate the result of Proxy Client set filter type

uint8_t conn_handle
    Proxy connection handle

uint16_t net_idx
    Corresponding NetKey Index

struct ble_mesh_proxy_gatt_disable_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT.

Public Members

int err_code
    Indicate the result of disabling Mesh Proxy Service

struct ble_mesh_proxy_gatt_enable_comp_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT.
Chapter 2. API Reference

Public Members

int err_code
Indicate the result of enabling Mesh Proxy Service

struct ble_mesh_proxy_identity_enable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROXY_IDENTITY_ENABLE_COMP_EVT.

Public Members

int err_code
Indicate the result of enabling Mesh Proxy advertising

struct ble_mesh_proxy_server_connected_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_SERVER_CONNECTED_EVT.

Public Members

uint8_t conn_handle
Proxy connection handle

struct ble_mesh_proxy_server_disconnected_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_SERVER_DISCONNECTED_EVT.

Public Members

uint8_t conn_handle
Proxy connection handle

uint8_t reason
Proxy disconnect reason

struct ble_mesh_set_fast_prov_action_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT.

Public Members

uint8_t status_action
Indicate the result of setting action of fast provisioning

struct ble_mesh_set_fast_prov_info_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT.
Public Members

uint8_t status_unicast
   Indicate the result of setting unicast address range of fast provisioning

uint8_t status_net_idx
   Indicate the result of setting NetKey Index of fast provisioning

uint8_t status_match
   Indicate the result of setting matching Device UUID of fast provisioning

struct ble_mesh_set_oob_pub_key_comp_param
   #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT.

Public Members

int err_code
   Indicate the result of setting OOB Public Key

struct ble_mesh_set_unprov_dev_name_comp_param
   #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT.

Public Members

int err_code
   Indicate the result of setting BLE Mesh device name

union esp_ble_mesh_server_state_value_t
   #include <esp_ble_mesh_defs.h> Server model state value union.

Public Members

uint8_t onoff
   The value of the Generic OnOff state
   The value of the Light LC Light OnOff state

struct esp_ble_mesh_server_state_value_t::{anonymous} gen_onoff
   The Generic OnOff state

int16_t level
   The value of the Generic Level state

struct esp_ble_mesh_server_state_value_t::{anonymous} gen_level
   The Generic Level state

uint8_t onpowerup
   The value of the Generic OnPowerUp state
struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{gen\_onpowerup}

The Generic OnPowerUp state

\texttt{uint16\_t power}

The value of the Generic Power Actual state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{gen\_power\_actual}

The Generic Power Actual state

\texttt{uint16\_t lightness}

The value of the Light Lightness Actual state

The value of the Light Lightness Linear state

The value of the Light CTL Lightness state

The value of the Light HSL Lightness state

The value of the Light xyl Lightness state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_lightness\_actual}

The Light Lightness Actual state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_lightness\_linear}

The Light Lightness Linear state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_ctl\_lightness}

The Light CTL Lightness state

\texttt{uint16\_t temperature}

The value of the Light CTL Temperature state

\texttt{int16\_t delta\_uv}

The value of the Light CTL Delta UV state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_ctl\_temp\_delta\_uv}

The Light CTL Temperature & Delta UV states

\texttt{uint16\_t hue}

The value of the Light HSL Hue state

\texttt{uint16\_t saturation}

The value of the Light HSL Saturation state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_hsl}

The Light HSL composite state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_hsl\_lightness}

The Light HSL Lightness state

struct \texttt{esp\_ble\_mesh\_server\_state\_value\_t}::{[anonymous]} \texttt{light\_hsl\_hue}

The Light HSL Hue state
struct esp_ble_mesh_server_state_value_t::[anonymous] light_hsl_saturation
    The Light HSL Saturation state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_xyl_lightness
    The Light xyl Lightness state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_lc_light_onoff
    The Light LC Light OnOff state

union esp_ble_mesh_model_cb_param_t
    #include <esp_ble_mesh_defs.h> BLE Mesh model callback parameters union.

**Public Members**

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_operation_evt_param model_operation
    Event parameter of ESP_BLE_MESH_MODEL_OPERATION_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_send_comp_param model_send_comp
    Event parameter of ESP_BLE_MESH_MODEL_SEND_COMP_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_publish_comp_param model_publish_comp
    Event parameter of ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_mod_recv_publish_msg_param
    client_recv_publish_msg
    Event parameter of ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_client_model_send_timeout_param
    client_send_timeout
    Event parameter of ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_model_publish_update_evt_param
    model_publish_update
    Event parameter of ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT

struct esp_ble_mesh_model_cb_param_t::ble_mesh_server_model_update_state_comp_param
    server_model_update_state
    Event parameter of ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT

struct ble_mesh_client_model_send_timeout_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT.

**Public Members**

uint32_t opcode
    Opcode of the previously sent message
`esp_ble_mesh_model_t *model`
Pointer to the model which sends the previous message

`esp_ble_mesh_msg_ctx_t *ctx`
Pointer to the context of the previous message

struct `ble_mesh_mod_recv_publish_msg_param`
```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT.
```

**Public Members**

`uint32_t opcode`
Opcode of the unsolicited received message

`esp_ble_mesh_model_t *model`
Pointer to the model which receives the message

`esp_ble_mesh_msg_ctx_t *ctx`
Pointer to the context of the previous message

`uint16_t length`
Length of the received message

`uint8_t *msg`
Value of the received message

struct `ble_mesh_model_operation_evt_param`
```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_OPERATION_EVT.
```

**Public Members**

`uint32_t opcode`
Opcode of the received message

`esp_ble_mesh_model_t *model`
Pointer to the model which receives the message

`esp_ble_mesh_msg_ctx_t *ctx`
Pointer to the context of the received message

`uint16_t length`
Length of the received message

`uint8_t *msg`
Value of the received message

struct `ble_mesh_model_publish_comp_param`
```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT.
```

**Public Members**


Public Members

`int err_code`
Indicate the result of publishing a message

`esp_ble_mesh_model_t *model`
Pointer to the model which publishes the message

`struct ble_mesh_model_publish_update_evt_param`
`#include <esp_ble_mesh_defs.h>` ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT.

Public Members

`esp_ble_mesh_model_t *model`
Pointer to the model which is going to update its publish message

`struct ble_mesh_model_send_comp_param`
`#include <esp_ble_mesh_defs.h>` ESP_BLE_MESH_MODEL_SEND_COMP_EVT.

Public Members

`int err_code`
Indicate the result of sending a message

`uint32_t opcode`
Opcode of the message

`esp_ble_mesh_model_t *model`
Pointer to the model which sends the message

`esp_ble_mesh_msg_ctx_t *ctx`
Context of the message

`struct ble_mesh_server_model_update_state_comp_param`
`#include <esp_ble_mesh_defs.h>` ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT.

Public Members

`int err_code`
Indicate the result of updating server model state

`esp_ble_mesh_model_t *model`
Pointer to the server model which state value is updated

`esp_ble_mesh_server_state_type_t type`
Type of the updated server state
Structures

struct esp_ble_mesh_deinit_param_t
    BLE Mesh deinit parameters

Public Members

bool erase_flash
    Indicate if erasing flash when deinit mesh stack

struct esp_ble_mesh_elem_t
    Abstraction that describes a BLE Mesh Element. This structure is associated with struct bt_mesh_elem in mesh_access.h

Public Members

uint16_t element_addr
    Element Address, assigned during provisioning.

const uint16_t location
    Location Descriptor (GATT Bluetooth Namespace Descriptors)

const uint8_t sig_model_count
    SIG Model count

const uint8_t vnd_model_count
    Vendor Model count

esp_ble_mesh_model_t *sig_models
    SIG Models

esp_ble_mesh_model_t *vnd_models
    Vendor Models

struct esp_ble_mesh_model_pub_t
    Abstraction that describes a model publication context. This structure is associated with struct bt_mesh_model_pub in mesh_access.h

Public Members

esp_ble_mesh_model_t *model
    Pointer to the model to which the context belongs. Initialized by the stack.

uint16_t publish_addr
    Publish Address.

uint16_t app_idx
    Publish AppKey Index.
uint16_t cred
    Friendship Credentials Flag.

uint16_t send_rel
    Force reliable sending (segment acks)

uint8_t ttl
    Publish Time to Live.

uint8_t retransmit
    Retransmit Count & Interval Steps.

uint8_t period
    Publish Period.

uint8_t period_div
    Divisor for the Period.

uint8_t fast_period
    Use FastPeriodDivisor

uint8_t count
    Retransmissions left.

uint32_t period_start
    Start of the current period.

struct net_buf_simple *msg
    Publication buffer, containing the publication message.
    This will get correctly created when the publication context has been defined using the
    ESP_BLE_MESH_MODEL_PUB_DEFINE macro.
    ESP_BLE_MESH_MODEL_PUB_DEFINE(name, size);

esp_ble_mesh_cb_t update
    Callback used to update publish message. Initialized by the stack.

struct k_delayed_work timer
    Publish Period Timer. Initialized by the stack.

uint8_t dev_role
    Role of the device that is going to publish messages

struct esp_ble_mesh_model_op_t
    Abstraction that describes a model operation context. This structure is associated with struct
    bt_mesh_model_op in mesh_access.h
Public Members

const uint32_t opcode
Message opcode

const size_t min_len
Message minimum length

esp_ble_mesh_cb_t param_cb
Callback used to handle message. Initialized by the stack.

struct esp_ble_mesh_model_cbs_t
Abstraction that describes a model callback structure. This structure is associated with struct bt_mesh_model_cb in mesh_access.h.

Public Members

esp_ble_mesh_cb_t init_cb
Callback used during model initialization. Initialized by the stack.

struct esp_ble_mesh_model
Abstraction that describes a Mesh Model instance. This structure is associated with struct bt_mesh_model in mesh_access.h

Public Members

const uint16_t model_id
16-bit model identifier

uint16_t company_id
16-bit company identifier

uint16_t model_id
16-bit model identifier

struct esp_ble_mesh_model::[anonymous]::[anonymous] vnd
Structure encapsulating a model ID with a company ID

union esp_ble_mesh_model::[anonymous] [anonymous] [anonymous]
Model ID

uint8_t element_idx
Internal information, mainly for persistent storage Belongs to Nth element

uint8_t model_idx
Is the Nth model in the element
uint16_t flags
    Information about what has changed

esp_ble_mesh_elem_t *element
    The Element to which this Model belongs

esp_ble_mesh_model_pub_t *const pub
    Model Publication

uint16_t keys[CONFIG_BLE_MESH_MODEL_KEY_COUNT]
    AppKey List

uint16_t groups[CONFIG_BLE_MESH_MODEL_GROUP_COUNT]
    Subscription List (group or virtual addresses)

esp_ble_mesh_model_op_t *op
    Model operation context

esp_ble_mesh_model_cbs_t *cb
    Model callback structure

void *user_data
    Model-specific user data

struct esp_ble_mesh_msg_ctx_t
    Message sending context. This structure is associated with struct bt_mesh_msg_ctx in mesh_access.h

Public Members

uint16_t net_idx
    NetKey Index of the subnet through which to send the message.

uint16_t app_idx
    AppKey Index for message encryption.

uint16_t addr
    Remote address.

uint16_t recv_dst
    Destination address of a received message. Not used for sending.

int8_t recv_rssi
    RSSI of received packet. Not used for sending.

uint8_t recv_ttl
    Received TTL value. Not used for sending.
uint8_t send_rel
Forcesendingreliablybyusingsegmentacknowledgement

uint8_t send_ttl
TTL,orESP_BLE_MESH_TTL_DEFAULTfordefaultTTL.

uint32_t recv_op
Opcodesofofreceivedmessage.Notusedforsendingmessage.

esp_ble_mesh_model_t *model
Modelcorrespondingtothemessage,noneedtobeenitializedbeforesendingmessage

bool srv_send
Indicateifthemessageissentbyanodemodel,n needtobeenitializedbeforesendingmessage

struct esp_ble_mesh_prov_t
Provisioningproperties&capabilities.Thissstructureisassociatedwithstructbt_mesh_provinemesh_access.h

struct esp_ble_mesh_comp_t
Nodecompositiondatacontext.Thissstructureisassociatedwithstructbt_mesh_compinmesh_access.h

Public Members

uint16_t cid
16-bitSIG-assignedcompanyidentifier

uint16_t pid
16-bitvendor-assignedproductidentifier

uint16_t vid
16-bitvendor-assignedproductversionidentifier

size_t element_count
Elementcount

esp_ble_mesh_elem_t *elements
Asequenceofelements

struct esp_ble_mesh_unprov_dev_add_t
InformationofthedevicewhichisgoingtobeaDDedforprovisioning.

Public Members

esp_ble_mesh_bd_addr_t addr
Deviceaddress
**esp_ble_mesh_addr_type_t addr_type**

Device address type

uint8_t uuid[16]

Device UUID

uint16_t oob_info

Device OOB Info ADD_DEV_START_PROV_NOW_FLAG shall not be set if the bearer has both PB-ADV and PB-GATT enabled

**esp_ble_mesh_prov_bearer_t bearer**

Provisioning Bearer

struct esp_ble_mesh_device_delete_t

Information of the device which is going to be deleted.

**Public Members**

**esp_ble_mesh_bd_addr_t addr**

Device address

**esp_ble_mesh_addr_type_t addr_type**

Device address type

uint8_t uuid[16]

Device UUID

uint8_t flag

BIT0: device address; BIT1: device UUID

struct esp_ble_mesh_prov_data_info_t

Information of the provisioner which is going to be updated.

**Public Members**

uint16_t net_idx

NetKey Index

uint8_t flags

Flags

uint32_t iv_index

IV Index

uint8_t flag

BIT0: net_idx; BIT1: flags; BIT2: iv_index
struct esp_ble_mesh_node_t
    Information of the provisioned node

Public Members

    esp_ble_mesh_bd_addr_t addr
        Node device address

    esp_ble_mesh_addr_type_t addr_type
        Node device address type

    uint8_t dev_uuid[16]
        Device UUID

    uint16_t oob_info
        Node OOB information

    uint16_t unicast_addr
        Node unicast address

    uint8_t element_num
        Node element number

    uint16_t net_idx
        Node NetKey Index

    uint8_t flags
        Node key refresh flag and iv update flag

    uint32_t iv_index
        Node IV Index

    uint8_t dev_key[16]
        Node device key

    char name[ESP_BLE_MESH_NODE_NAME_MAX_LEN + 1]
        Node name

    uint16_t comp_length
        Length of Composition Data

    uint8_t *comp_data
        Value of Composition Data

struct esp_ble_mesh_fast_prov_info_t
    Context of fast provisioning which need to be set.
### Public Members

`uint16_t unicast_min`
- Minimum unicast address used for fast provisioning

`uint16_t unicast_max`
- Maximum unicast address used for fast provisioning

`uint16_t net_idx`
- Netkey index used for fast provisioning

`uint8_t flags`
- Flags used for fast provisioning

`uint32_t iv_index`
- IV Index used for fast provisioning

`uint8_t offset`
- Offset of the UUID to be compared

`uint8_t match_len`
- Length of the UUID to be compared

`uint8_t match_val[16]`
- Value of UUID to be compared

```
struct esp_ble_mesh_heartbeat_filter_info_t
```
- Context of Provisioner heartbeat filter information to be set

### Public Members

`uint16_t hb_src`
- Heartbeat source address (unicast address)

`uint16_t hb_dst`
- Heartbeat destination address (unicast address or group address)

```
struct esp_ble_mesh_client_op_pair_t
```
- BLE Mesh client models related definitions.
- Client model Get/Set message opcode and corresponding Status message opcode

### Public Members

`uint32_t cli_op`
- The client message opcode
uint32_t status_op
    The server status opcode corresponding to the client message opcode

struct esp_ble_mesh_client_t
    Client Model user data context.

**Public Members**

*esp_ble_mesh_model_t* model
    Pointer to the client model. Initialized by the stack.

int op_pair_size
    Size of the op_pair

const *esp_ble_mesh_client_op_pair_t* op_pair
    Table containing get/set message opcode and corresponding status message opcode

uint32_t publish_status
    Callback used to handle the received unsolicited message. Initialized by the stack.

void* internal_data
    Pointer to the internal data of client model

uint8_t msg_role
    Role of the device (Node/Provisioner) that is going to send messages

struct esp_ble_mesh_client_common_param_t
    Common parameters of the messages sent by Client Model.

**Public Members**

*esp_ble_mesh_opcode_t* opcode
    Message opcode

*esp_ble_mesh_model_t* model
    Pointer to the client model structure

*esp_ble_mesh_msg_ctx_t* ctx
    The context used to send message

int32_t msg_timeout
    Timeout value (ms) to get response to the sent message. Note: if using default timeout value in menuconfig, make sure to set this value to 0

uint8_t msg_role
    Role of the device - Node/Provisioner
struct **esp_ble_mesh_state_transition_t**
Parameters of the server model state transition

**Public Functions**

**BLE_MESH_ATOMIC_DEFINE** (flag, `ESP_BLE_MESH_SERVER_FLAG_MAX`)
Flag used to indicate if the transition timer has been started internally.

If the model which contains `esp_ble_mesh_state_transition_t` sets “set_auto_rsp” to ESP_BLE_MESH_SERVER_RSP_BY_APP, the handler of the timer shall be initialized by the users.

And users can use this flag to indicate whether the timer is started or not.

**Public Members**

bool **just_started**
Indicate if the state transition has just started

uint8_t **trans_time**
State transition time

uint8_t **remain_time**
Remaining time of state transition

uint8_t **delay**
Delay before starting state transition

uint32_t **quo_t**
Duration of each divided transition step

uint32_t **counter**
Number of steps which the transition duration is divided

uint32_t **total_duration**
State transition total duration

int64_t **start_timestamp**
Time when the state transition is started

struct **k_delayed_work** **timer**
Timer used for state transition

struct **esp_ble_mesh_last_msg_info_t**
Parameters of the server model received last same set message.

**Public Members**
\textbf{uint8_t \texttt{tid}}
\begin{itemize}
\item Transaction number of the last message
\end{itemize}

\textbf{uint16_t \texttt{src}}
\begin{itemize}
\item Source address of the last message
\end{itemize}

\textbf{uint16_t \texttt{dst}}
\begin{itemize}
\item Destination address of the last message
\end{itemize}

\textbf{int64_t \texttt{timestamp}}
\begin{itemize}
\item Time when the last message is received
\end{itemize}

\textbf{struct \texttt{esp_ble_mesh_server_rsp_ctrl_t}}
\begin{itemize}
\item Parameters of the Server Model response control
\end{itemize}

\textbf{Public Members}

\textbf{uint8_t \texttt{get_auto_rsp}}
\begin{itemize}
\item BLE Mesh Server Response Option.
\end{itemize}

\begin{itemize}
\item i. If \texttt{get_auto_rsp} is set to \texttt{ESP_BLE_MESH_SERVER_RSP_BY_APP}, then the response of Client Get messages need to be replied by the application;
\item ii. If \texttt{get_auto_rsp} is set to \texttt{ESP_BLE_MESH_SERVER_AUTO_RSP}, then the response of Client Get messages will be replied by the server models;
\item iii. If \texttt{set_auto_rsp} is set to \texttt{ESP_BLE_MESH_SERVER_RSP_BY_APP}, then the response of Client Set messages need to be replied by the application;
\item iv. If \texttt{set_auto_rsp} is set to \texttt{ESP_BLE_MESH_SERVER_AUTO_RSP}, then the response of Client Set messages will be replied by the server models;
\item v. If \texttt{status_auto_rsp} is set to \texttt{ESP_BLE_MESH_SERVER_RSP_BY_APP}, then the response of Server Status messages need to be replied by the application;
\item vi. If \texttt{status_auto_rsp} is set to \texttt{ESP_BLE_MESH_SERVER_AUTO_RSP}, then the response of Server Status messages will be replied by the server models; Response control for Client Get messages
\end{itemize}

\textbf{uint8_t \texttt{set_auto_rsp}}
\begin{itemize}
\item Response control for Client Set messages
\end{itemize}

\textbf{uint8_t \texttt{status_auto_rsp}}
\begin{itemize}
\item Response control for Server Status messages
\end{itemize}

\textbf{Macros}

\textbf{ESP_BLE_MESH_SDU_MAX_LEN}
\begin{itemize}
\item The maximum length of a BLE Mesh message, including Opcode, Payload and TransMIC Length of a short Mesh MIC.
\end{itemize}

\textbf{ESP_BLE_MESH_MIC_SHORT}
\begin{itemize}
\item Length of a long Mesh MIC.
\end{itemize}

\textbf{ESP_BLE_MESH_MIC_LONG}
\begin{itemize}
\item The maximum length of a BLE Mesh provisioned node name
\end{itemize}
**ESP_BLE_MESH_NODE_NAME_MAX_LEN**
The maximum length of a BLE Mesh unprovisioned device name

**ESP_BLE_MESH_DEVICE_NAME_MAX_LEN**
The maximum length of settings user id

**ESP_BLE_MESH_SETTINGS_UID_SIZE**
Invalid settings index

**ESP_BLE_MESH_INVALID_SETTINGS_IDX**
Define the BLE Mesh octet 16 bytes size

**ESP_BLE_MESH_OCTET16_LEN**

**ESP_BLE_MESH_OCTET8_LEN**

**ESP_BLE_MESH_CID_NVAL**
Special TTL value to request using configured default TTL

**ESP_BLE_MESH_TTL_DEFAULT**
Maximum allowed TTL value

**ESP_BLE_MESH_TTL_MAX**

**ESP_BLE_MESH_ADDR_UNASSIGNED**

**ESP_BLE_MESH_ADDR_ALL_NODES**

**ESP_BLE_MESH_ADDR_PROXIES**

**ESP_BLE_MESH_ADDR_FRIENDS**

**ESP_BLE_MESH_ADDR_RELAYS**

**ESP_BLE_MESH_KEY_UNUSED**

**ESP_BLE_MESH_KEY_DEV**

**ESP_BLE_MESH_KEY_PRIMARY**

**ESP_BLE_MESH_KEY_ANY**
Primary Network Key index

**ESP_BLE_MESH_NET_PRIMARY**
Relay state value

**ESP_BLE_MESH_RELAY_DISABLED**
Chapter 2. API Reference

ESP_BLE_MESH_RELAY_ENABLED

ESP_BLE_MESH_RELAY_NOT_SUPPORTED
Beacon state value

ESP_BLE_MESH_BEACON_DISABLED

ESP_BLE_MESH_BEACON_ENABLED
GATT Proxy state value

ESP_BLE_MESH_GATT_PROXY_DISABLED

ESP_BLE_MESH_GATT_PROXY_ENABLED

ESP_BLE_MESH_GATT_PROXY_NOT_SUPPORTED
Friend state value

ESP_BLE_MESH_FRIEND_DISABLED

ESP_BLE_MESH_FRIEND_ENABLED

ESP_BLE_MESH_FRIEND_NOT_SUPPORTED
Node identity state value

ESP_BLE_MESH_NODE_IDENTITY_STOPPED

ESP_BLE_MESH_NODE_IDENTITY_RUNNING

ESP_BLE_MESH_NODE_IDENTITY_NOT_SUPPORTED
Supported features

ESP_BLE_MESH_FEATURE_RELAY

ESP_BLE_MESH_FEATURE_PROXY

ESP_BLE_MESH_FEATURE_FRIEND

ESP_BLE_MESH_FEATURE_LOW_POWER

ESP_BLE_MESH_FEATURE_ALL_SUPPORTED

ESP_BLE_MESH_ADDR_IS_UNICAST (addr)

ESP_BLE_MESH_ADDR_IS_GROUP (addr)

ESP_BLE_MESH_ADDR_IS_VIRTUAL (addr)

ESP_BLE_MESH_ADDR_IS_RFU (addr)
ESP_BLE_MESH_INVALID_NODE_INDEX

ESP_BLE_MESH_TRANSMIT (count, int_ms)
Encode transmission count & interval steps.

Note: For example, ESP_BLE_MESH_TRANSMIT(2, 20) means that the message will be sent about 90ms (count is 3, step is 1, interval is 30ms which includes 10ms of advertising interval random delay).

Parameters
• count – Number of retransmissions (first transmission is excluded).
• int_ms – Interval steps in milliseconds. Must be greater than 0 and a multiple of 10.

Returns BLE Mesh transmit value that can be used e.g. for the default values of the Configuration Model data.

ESP_BLE_MESH_GET_TRANSMIT_COUNT (transmit)
Decode transmit count from a transmit value.

Parameters
• transmit – Encoded transmit count & interval value.

Returns Transmission count (actual transmissions equal to N + 1).

ESP_BLE_MESH_GET_TRANSMIT_INTERVAL (transmit)
Decode transmit interval from a transmit value.

Parameters
• transmit – Encoded transmit count & interval value.

Returns Transmission interval in milliseconds.

ESP_BLE_MESH_PUBLISH_TRANSMIT (count, int_ms)
Encode Publish Retransmit count & interval steps.

Parameters
• count – Number of retransmissions (first transmission is excluded).
• int_ms – Interval steps in milliseconds. Must be greater than 0 and a multiple of 50.

Returns BLE Mesh transmit value that can be used e.g. for the default values of the Configuration Model data.

ESP_BLE_MESH_GET_PUBLISH_TRANSMIT_COUNT (transmit)
Decode Publish Retransmit count from a given value.

Parameters
• transmit – Encoded Publish Retransmit count & interval value.

Returns Retransmission count (actual transmissions equal to N + 1).

ESP_BLE_MESH_GET_PUBLISH_TRANSMIT_INTERVAL (transmit)
Decode Publish Retransmit interval from a given value.

Parameters
• transmit – Encoded Publish Retransmit count & interval value.

Returns Transmission interval in milliseconds.

Callbacks which are not needed to be initialized by users (set with 0 and will be initialized internally)

Parameters
• transmit – Encoded Publish Retransmit count & interval value.

Returns Transmission interval in milliseconds.

ESP_BLE_MESH_PROV_STATIC_OOB_MAX_LEN
Maximum length of string used by Output OOB authentication
Chapter 2. API Reference

ESP_BLE_MESH_PROV_OUTPUT_OOB_MAX_LEN
Maximum length of string used by Output OOB authentication

ESP_BLE_MESH_PROV_INPUT_OOB_MAX_LEN
Macros used to define message opcode

ESP_BLE_MESH_MODEL_OP_1 (b0)
ESP_BLE_MESH_MODEL_OP_2 (b0, b1)
ESP_BLE_MESH_MODEL_OP_3 (b0, cid)
This macro is associated with BLE_MESH_MODEL_CB in mesh_access.h

ESP_BLE_MESH_SIG_MODEL (_id, _op, _pub, _user_data)
This macro is associated with BLE_MESH_MODEL_VND_CB in mesh_access.h

ESP_BLE_MESH_VENDOR_MODEL (_company, _id, _op, _pub, _user_data)

ESP_BLE_MESH_ELEMENT (_loc, _mods, _vnd_mods)
Helper to define a BLE Mesh element within an array.
In case the element has no SIG or Vendor models, the helper macro ESP_BLE_MESH_MODEL_NONE can be given instead.

Note: This macro is associated with BLE_MESH_ELEM in mesh_access.h

Parameters
• _loc – Location Descriptor.
• _mods – Array of SIG models.
• _vnd_mods – Array of vendor models.

ESP_BLE_MESH_PROV (uuid, sta_val, sta_val_len, out_size, out_act, in_size, in_act)

BT_OCTET32_LEN

BD_ADDR_LEN

ESP_BLE_MESH_ADDR_TYPE_PUBLIC

ESP_BLE_MESH_ADDR_TYPE_RANDOM

ESP_BLE_MESH_ADDR_TYPE_RPA_PUBLIC

ESP_BLE_MESH_ADDR_TYPE_RPA_RANDOM

ESP_BLE_MESH_MODEL_PUB_DEFINE (_name, _msg_len, _role)
Define a model publication context.

Parameters
• _name – Variable name given to the context.
• _msg_len – Length of the publication message.
• _role – Role of the device which contains the model.
ESP_BLE_MESH_MODEL_OP (_opcode, _min_len)
Define a model operation context.

Parameters
• `_opcode` - Message opcode.
• `_min_len` - Message minimum length.

ESP_BLE_MESH_MODEL_OP_END
Define the terminator for the model operation table. Each model operation struct array must use this terminator as the end tag of the operation unit.

ESP_BLE_MESH_MODEL_NONE
Helper to define an empty model array. This structure is associated with BLE_MESH_MODEL_NONE in mesh_access.h

ADD_DEV_RM_AFTER_PROV_FLAG
Device will be removed from queue after provisioned successfully

ADD_DEV_START_PROV_NOW_FLAG
Start provisioning device immediately

ADD_DEV_FLUSHABLE_DEV_FLAG
Device can be remove when queue is full and new device is going to added

DEL_DEV_ADDR_FLAG

DEL_DEV_UUID_FLAG

PROV_DATA_NET_IDX_FLAG

PROV_DATA_FLAGS_FLAG

PROV_DATA_IV_INDEX_FLAG

ESP_BLE_MESH_HEARTBEAT_FILTER_ACCEPTLIST

ESP_BLE_MESH_HEARTBEAT_FILTER_REJECTLIST
Provisioner heartbeat filter operation

ESP_BLE_MESH_HEARTBEAT_FILTER_ADD

ESP_BLE_MESH_HEARTBEAT_FILTER_REMOVE

ESP_BLE_MESH_MODEL_ID_CONFIG_SRV
BLE Mesh models related Model ID and Opcode definitions.
< Foundation Models

ESP_BLE_MESH_MODEL_ID_CONFIG_CLI
Models from the Mesh Model Specification

ESP_BLE_MESH_MODEL_ID_HEALTH_SRV
ESP_BLE_MESH_MODEL_ID_HEALTH_CLI

ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_SRV
ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_CLI

ESP_BLE_MESH_MODEL_ID_GEN_LEVEL_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LEVEL_CLI

ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_SRV
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_CLI

ESP_BLE_MESH_MODEL_ID_GEN_POWER_ONOFF_SRV
ESP_BLE_MESH_MODEL_ID_GEN_POWER_ONOFF_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_POWER_ONOFF_CLI

ESP_BLE_MESH_MODEL_ID_GEN_POWER_LEVEL_SRV
ESP_BLE_MESH_MODEL_ID_GEN_POWER_LEVEL_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_POWER_LEVEL_CLI

ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_SRV
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_CLI

ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_CLI

ESP_BLE_MESH_MODEL_ID_GEN_ADMIN_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_CLIENT_PROP_SRV

ESP_BLE_MESH_MODEL_ID_GEN_PROP_CLI

ESP_BLE_MESH_MODEL_ID_SENSOR_SRV

ESP_BLE_MESH_MODEL_ID_SENSOR_SETUP_SRV

ESP_BLE_MESH_MODEL_ID_SENSOR_CLI

ESP_BLE_MESH_MODEL_ID_TIME_SRV

ESP_BLE_MESH_MODEL_ID_TIME_SETUP_SRV

ESP_BLE_MESH_MODEL_ID_TIME_CLI

ESP_BLE_MESH_MODEL_ID_SCENE_SRV

ESP_BLE_MESH_MODEL_ID_SCENE_SETUP_SRV

ESP_BLE_MESH_MODEL_ID_SCENE_CLI

ESP_BLE_MESH_MODEL_ID_SCHEDULER_SRV

ESP_BLE_MESH_MODEL_ID_SCHEDULER_SETUP_SRV

ESP_BLE_MESH_MODEL_ID_SCHEDULER_CLI

ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_SRV

ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_SETUP_SRV

ESP_BLE_MESH_MODEL_ID_LIGHT_LIGHTNESS_CLI

ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_SRV

ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_SETUP_SRV

ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_CLI

ESP_BLE_MESH_MODEL_ID_LIGHT_CTL_TEMP_SRV

ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SRV

ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SETUP_SRV
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_HUE_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_HSL_SAT_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_XYL_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_XYL_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_XYL_CLI
ESP_BLE_MESH_MODEL_ID_LIGHT_LC_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_LC_SETUP_SRV
ESP_BLE_MESH_MODEL_ID_LIGHT_LC_CLI

ESP_BLE_MESH_MODEL_OP_BEACON_GET
  Config Beacon Get
ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET
  Config Composition Data Get
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_GET
  Config Default TTL Get
ESP_BLE_MESH_MODEL_OP_GATT_PROXY_GET
  Config GATT Proxy Get
ESP_BLE_MESH_MODEL_OP_RELAY_GET
  Config Relay Get
ESP_BLE_MESH_MODEL_OP_MODEL_PUB_GET
  Config Model Publication Get
ESP_BLE_MESH_MODEL_OP_FRIEND_GET
  Config Friend Get
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_GET
  Config Heartbeat Publication Get
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_GET
  Config Heartbeat Subscription Get
ESP_BLE_MESH_MODEL_OP_NET_KEY_GET
  Config NetKey Get
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_APP_KEY_GET
Config AppKey Get

ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_GET
Config Node Identity Get

ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_GET
Config SIG Model Subscription Get

ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_SUB_GET
Config Vendor Model Subscription Get

ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_GET
Config SIG Model App Get

ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_APP_GET
Config Vendor Model App Get

ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET
Config Key Refresh Phase Get

ESP_BLE_MESH_MODEL_OP_LP_POLLTIMEOUT_GET
Config Low Power Node PollTimeout Get

ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_GET
Config Network Transmit Get

ESP_BLE_MESH_MODEL_OP_BEACON_SET
Config Beacon Set

ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET
Config Default TTL Set

ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET
Config GATT Proxy Set

ESP_BLE_MESH_MODEL_OP_RELAY_SET
Config Relay Set

ESP_BLE_MESH_MODEL_OP_MODEL_PUB_SET
Config Model Publication Set

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_ADD
Config Model Subscription Add

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_ADD
Config Model Subscription Virtual Address Add
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE
Config Model Subscription Delete

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_DELETE
Config Model Subscription Virtual Address Delete

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE
Config Model Subscription Overwrite

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_OVERWRITE
Config Model Subscription Virtual Address Overwrite

ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD
Config NetKey Add

ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD
Config AppKey Add

ESP_BLE_MESH_MODEL_OP_MODEL_APP_BIND
Config Model App Bind

ESP_BLE_MESH_MODEL_OP_NODE_RESET
Config Node Reset

ESP_BLE_MESH_MODEL_OP_FRIEND_SET
Config Friend Set

ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET
Config Heartbeat Publication Set

ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET
Config Heartbeat Subscription Set

ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE
Config NetKey Update

ESP_BLE_MESH_MODEL_OP_NET_KEY_DELETE
Config NetKey Delete

ESP_BLE_MESH_MODEL_OP_APP_KEY_UPDATE
Config AppKey Update

ESP_BLE_MESH_MODEL_OP_APP_KEY_DELETE
Config AppKey Delete

ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_SET
Config Node Identity Set
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_SET
    Config Key Refresh Phase Set

ESP_BLE_MESH_MODEL_OP_MODEL_PUB_VIRTUAL_ADDR_SET
    Config Model Publication Virtual Address Set

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE_ALL
    Config Model Subscription Delete All

ESP_BLE_MESH_MODEL_OP_MODEL_APP_UNBIND
    Config Model App Unbind

ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_SET
    Config Network Transmit Set

ESP_BLE_MESH_MODEL_OP_BEACON_STATUS

ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_STATUS

ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_STATUS

ESP_BLE_MESH_MODEL_OP_GATT_PROXY_STATUS

ESP_BLE_MESH_MODEL_OP_RELAY_STATUS

ESP_BLE_MESH_MODEL_OP_MODEL_PUB_STATUS

ESP_BLE_MESH_MODEL_OP_MODEL_SUB_STATUS

ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_LIST

ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_SUB_LIST

ESP_BLE_MESH_MODEL_OP_NET_KEY_STATUS

ESP_BLE_MESH_MODEL_OP_NET_KEY_LIST

ESP_BLE_MESH_MODEL_OP_APP_KEY_STATUS

ESP_BLE_MESH_MODEL_OP_APP_KEY_LIST

ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_STATUS

ESP_BLE_MESH_MODEL_OP_MODEL_APP_STATUS

ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_LIST
ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_APP_LIST
ESP_BLE_MESH_MODEL_OP_NODE_RESET_STATUS
ESP_BLE_MESH_MODEL_OP_FRIEND_STATUS
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_STATUS
ESP_BLE_MESH_MODEL_OP_LP_POLLTIMEOUT_STATUS
ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_STATUS
ESP_BLE_MESH_CFG_STATUS_SUCCESS
ESP_BLE_MESH_CFG_STATUS_INVALID_ADDRESS
ESP_BLE_MESH_CFG_STATUS_INVALID_MODEL
ESP_BLE_MESH_CFG_STATUS_INVALID_APPKEY
ESP_BLE_MESH_CFG_STATUS_INVALID_NETKEY
ESP_BLE_MESH_CFG_STATUS_INSUFFICIENT_RESOURCES
ESP_BLE_MESH_CFG_STATUS_KEY_INDEX_ALREADY_STORED
ESP_BLE_MESH_CFG_STATUS_INVALID_PUBLISH_PARAMETERS
ESP_BLE_MESH_CFG_STATUS_NOT_A_SUBSCRIBE_MODEL
ESP_BLE_MESH_CFG_STATUS_STORAGE_FAILURE
ESP_BLE_MESH_CFG_STATUS_FEATURE_NOT_SUPPORTED
ESP_BLE_MESH_CFG_STATUS_CANNOT_UPDATE
ESP_BLE_MESH_CFG_STATUS_CANNOT_REMOVE
ESP_BLE_MESH_CFG_STATUS_CANNOT_BIND
ESP_BLE_MESH_CFG_STATUS_TEMP_UNABLE_TO_CHANGE_STATE
Chapter 2. API Reference

ESP_BLE_MESH_CFG_STATUS_CANNOT_SET

ESP_BLE_MESH_CFG_STATUS_UNSPECIFIED_ERROR

ESP_BLE_MESH_CFG_STATUS_INVALID_BINDING

ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET
  Health Fault Get

ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET
  Health Period Get

ESP_BLE_MESH_MODEL_OP_ATTENTION_GET
  Health Attention Get

ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR
  Health Fault Clear

ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK
  Health Fault Clear Unacknowledged

ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST
  Health Fault Test

ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK
  Health Fault Test Unacknowledged

ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET
  Health Period Set

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET
  Health Attention Set

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK
  Health Attention Set Unacknowledged

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_CURRENT_STATUS

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_FAULT_STATUS

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_PERIOD_STATUS

ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_STATUS
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_GET

ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET

ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_STATUS
  Generic Level Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_GET

ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET

ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET

ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET

ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET_UNACK
  Generic Default Transition Time Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_GET

ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_SET

ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_STATUS
  Generic Power OnOff Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_GET

ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_STATUS
  Generic Power OnOff Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET

ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET_UNACK
  Generic Power Level Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_GET
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET

ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_GET

ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_GET

ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_GET

ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_STATUS

Generic Power Level Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET

ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET

ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET_UNACK

Generic Battery Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_BATTERY_GET

ESP_BLE_MESH_MODEL_OP_GEN_BATTERY_STATUS

Generic Location Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_GET

ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_GET

ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_STATUS

Generic Location Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_SET

ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_SET_UNACK
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET

ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET_UNACK
   Generic Manufacturer Property Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTIES_GET

ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTIES_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_GET

ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET

ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_STATUS
   Generic Admin Property Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_GET

ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_GET

ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET

ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_STATUS
   Generic User Property Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_GET

ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_STATUS

ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET

ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET

ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET_UNACK

ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_STATUS
   Generic Client Property Message Opcode

ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_GET
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_STATUS

ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_STATUS

ESP_BLE_MESH_MODEL_OP_SENSOR_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_STATUS

ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_STATUS

ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_STATUS

Sensor Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET

ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET_UNACK

ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_STATUS

ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_STATUS

ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_GET

ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET

ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET_UNACK

ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_STATUS

ESP_BLE_MESH_MODEL_OP_TIME_GET

ESP_BLE_MESH_MODEL_OP_TIME_SET

ESP_BLE_MESH_MODEL_OP_TIME_STATUS
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_TIME_ROLE_GET

ESP_BLE_MESH_MODEL_OP_TIME_ROLE_SET

ESP_BLE_MESH_MODEL_OP_TIME_ROLE_STATUS

ESP_BLE_MESH_MODEL_OP_TIME_ZONE_GET

ESP_BLE_MESH_MODEL_OP_TIME_ZONE_SET

ESP_BLE_MESH_MODEL_OP_TIME_ZONE_STATUS

ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_GET

ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_SET

ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_STATUS

Scene Message Opcode

ESP_BLE_MESH_MODEL_OP_SCENE_GET

ESP_BLE_MESH_MODEL_OP_SCENE_RECALL

ESP_BLE_MESH_MODEL_OP_SCENE_RECALL_UNACK

ESP_BLE_MESH_MODEL_OP_SCENE_STATUS

ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_GET

ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS

Scene Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_SCENE_STORE

ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK

ESP_BLE_MESH_MODEL_OP_SCENE_DELETE

ESP_BLE_MESH_MODEL_OP_SCENE_DELETE_UNACK

Scheduler Message Opcode

ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_GET

ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_STATUS

ESP_BLE_MESH_MODEL_OP_SCHEDULER_GET
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS
Scheduler Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_SET

ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LAST_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LAST_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_STATUS
Light Lightness Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET_UNACK
Light CTL Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET_UNACK

Light CTL Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET

Light HSL Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_TARGET_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_TARGET_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_STATUS
    Light HSL Setup Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET_UNACK
    Light xyL Message Opcode
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_STATUS
Light xyL Setup Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET_UNACK
Light Control Message Opcode

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET_UNACK

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_STATUS

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_GET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET

ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_STATUS

ESP_BLE_MESH_MODEL_STATUS_SUCCESS

ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MIN

ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MAX

ESP_BLE_MESH_SERVER_RSP_BY_APP
    Response need to be sent in the application

ESP_BLE_MESH_SERVER_AUTO_RSP
    Response will be sent internally

Type Definitions

typedef uint8_t esp_ble_mesh_octet16_t[ESP_BLE_MESH_OCTET16_LEN]
    Define the BLE Mesh octet 16 bytes size

typedef uint8_t esp_ble_mesh_octet8_t[ESP_BLE_MESH_OCTET8_LEN]
    Invalid Company ID

typedef uint32_t esp_ble_mesh_cb_t

typedef uint8_t UINT8

typedef uint16_t UINT16

typedef uint32_t UINT32

typedef uint64_t UINT64

typedef UINT8 BT_OCTET32[BT_OCTET32_LEN]

typedef uint8_t BD_ADDR[BD_ADDR_LEN]

typedef uint8_t esp_ble_mesh_bd_addr_t[BD_ADDR_LEN]

typedef uint8_t esp_ble_mesh_addr_type_t
    BLE device address type.

typedef struct esp_ble_mesh_model esp_ble_mesh_model_t

typedef uint8_t esp_ble_mesh_dev_add_flag_t
typedef uint32_t esp_ble_mesh_opcode_config_client_get_t

`esp_ble_mesh_opcode_config_client_get_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by `esp_ble_mesh_config_client_get_state`. The following opcodes will only be used in the `esp_ble_mesh_config_client_get_state` function.

typedef uint32_t esp_ble_mesh_opcode_config_client_set_t

`esp_ble_mesh_opcode_config_client_set_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by `esp_ble_mesh_config_client_set_state`. The following opcodes will only be used in the `esp_ble_mesh_config_client_set_state` function.

typedef uint32_t esp_ble_mesh_opcode_config_status_t

`esp_ble_mesh_opcode_config_status_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by the Config Model messages. The following opcodes are used by the BLE Mesh Config Server Model internally to respond to the Config Client Model’s request messages.

typedef uint8_t esp_ble_mesh_cfg_status_t

This typedef is only used to indicate the status code contained in some of the Configuration Server Model status messages.

typedef uint32_t esp_ble_mesh_opcode_health_client_get_t

`esp_ble_mesh_opcode_health_client_get_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by `esp_ble_mesh_health_client_get_state`. The following opcodes will only be used in the `esp_ble_mesh_health_client_get_state` function.

typedef uint32_t esp_ble_mesh_opcode_health_client_set_t

`esp_ble_mesh_opcode_health_client_set_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by `esp_ble_mesh_health_client_set_state`. The following opcodes will only be used in the `esp_ble_mesh_health_client_set_state` function.

typedef uint32_t esp_ble_mesh_health_model_status_t

`esp_ble_mesh_health_model_status_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by the Health Model messages. The following opcodes are used by the BLE Mesh Health Server Model internally to respond to the Health Client Model’s request messages.

typedef uint32_t esp_ble_mesh_generic_message_opcode_t

`esp_ble_mesh_generic_message_opcode_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by functions `esp_ble_mesh_generic_client_get_state` & `esp_ble_mesh_generic_client_set_state`. Generic OnOff Message Opcode

typedef uint32_t esp_ble_mesh_sensor_message_opcode_t

`esp_ble_mesh_sensor_message_opcode_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by functions `esp_ble_mesh_sensor_client_get_state` & `esp_ble_mesh_sensor_client_set_state`. Sensor Message Opcode

typedef uint32_t esp_ble_mesh_time_scene_message_opcode_t

`esp_ble_mesh_time_scene_message_opcode_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate the opcodes used by functions `esp_ble_mesh_time_scene_client_get_state` & `esp_ble_mesh_time_scene_client_set_state`. Time Message Opcode

typedef uint32_t esp_ble_mesh_light_message_opcode_t

`esp_ble_mesh_light_message_opcode_t` belongs to `esp_ble_mesh_opcode_t`, this typedef is only used to locate
the opcodes used by functions esp_ble_mesh_light_client_get_state & esp_ble_mesh_light_client_set_state.
Light Lightness Message Opcode

typedef uint32_t esp_ble_mesh_opcode_t
End of defines of esp_ble_mesh_opcode_t

typedef uint8_t esp_ble_mesh_model_status_t
This typedef is only used to indicate the status code contained in some of the server models (e.g. Generic Server Model) status message.

Enumerations

enum esp_ble_mesh_cb_type_t
Values:

enumerator ESP_BLE_MESH_TYPE_PROV_CB
enumerator ESP_BLE_MESH_TYPE_OUTPUT_NUM_CB
enumerator ESP_BLE_MESH_TYPE_OUTPUT_STR_CB
enumerator ESP_BLE_MESH_TYPE_INPUT_CB
enumerator ESP_BLE_MESH_TYPE_LINK_OPEN_CB
enumerator ESP_BLE_MESH_TYPE_LINK_CLOSE_CB
enumerator ESP_BLE_MESH_TYPE_COMPLETE_CB
enumerator ESP_BLE_MESH_TYPE_RESET_CB

enum esp_ble_mesh_oob_method_t
Values:

enumerator ESP_BLE_MESH_NO_OOB
enumerator ESP_BLE_MESH_STATIC_OOB
enumerator ESP_BLE_MESH_OUTPUT_OOB
enumerator ESP_BLE_MESH_INPUT_OOB

enum esp_ble_mesh_output_action_t
Values:

enumerator ESP_BLE_MESH_NO_OUTPUT
enumerator ESP_BLE_MESH_BLINK
enumerator ESP_BLE_MESH_BEEP
enumerator ESP_BLE_MESH_VIBRATE
enumerator ESP_BLE_MESH_DISPLAY_NUMBER
enumerator ESP_BLE_MESH_DISPLAY_STRING

enum esp_ble_mesh_input_action_t
  Values:
  enumerator ESP_BLE_MESH_NO_INPUT
  enumerator ESP_BLE_MESH_PUSH
  enumerator ESP_BLE_MESH_TWIST
  enumerator ESP_BLE_MESH_ENTER_NUMBER
  enumerator ESP_BLE_MESH_ENTER_STRING

enum esp_ble_mesh_prov_bearer_t
  Values:
  enumerator ESP_BLE_MESH_PROV_ADV
  enumerator ESP_BLE_MESH_PROV_GATT

enum esp_ble_mesh_prov_oob_info_t
  Values:
  enumerator ESP_BLE_MESH_PROV_OOB_OTHER
  enumerator ESP_BLE_MESH_PROV_OOB_URI
  enumerator ESP_BLE_MESH_PROV_OOB_2D_CODE
  enumerator ESP_BLE_MESH_PROV_OOB_BAR_CODE
  enumerator ESP_BLE_MESH_PROV_OOB_NFC
  enumerator ESP_BLE_MESH_PROV_OOB_NUMBER
  enumerator ESP_BLE_MESH_PROV_OOB_STRING
  enumerator ESP_BLE_MESH_PROV_OOB_ON_BOX
Chapter 2. API Reference

enumerator ESP_BLE_MESH_PROV_OOB_IN_BOX
enumerator ESP_BLE_MESH_PROV_OOB_ON_PAPER
enumerator ESP_BLE_MESH_PROV_OOB_IN_MANUAL
enumerator ESP_BLE_MESH_PROV_OOB_ON_DEV

double esp_ble_mesh_dev_role_t

Values:

enumerator ROLE_NODE
enumerator ROLE_PROVISIONER
enumerator ROLE_FAST_PROV

double esp_ble_mesh_fast_prov_action_t

Values:

enumerator FAST_PROV_ACT_NONE
enumerator FAST_PROV_ACT_ENTER
enumerator FAST_PROV_ACT_SUSPEND
enumerator FAST_PROV_ACT_EXIT
enumerator FAST_PROV_ACT_MAX

double esp_ble_mesh_proxy_filter_type_t

Values:

enumerator PROXY_FILTER_WHITELIST
enumerator PROXY_FILTER_BLACKLIST

double esp_ble_mesh_prov_cb_event_t

Values:

enumerator ESP_BLE_MESH_PROV_REGISTER_COMP_EVT
Initialize BLE Mesh provisioning capabilities and internal data information completion event

enumerator ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT
Set the unprovisioned device name completion event
enumerator **ESP_BLE_MESH_NODE_PROV_ENABLE_COMP_EVT**
Enable node provisioning functionality completion event

enumerator **ESP_BLE_MESH_NODE_PROV_DISABLE_COMP_EVT**
Disable node provisioning functionality completion event

enumerator **ESP_BLE_MESH_NODE_PROV_LINK_OPEN_EVT**
Establish a BLE Mesh link event

enumerator **ESP_BLE_MESH_NODE_PROV_LINK_CLOSE_EVT**
Close a BLE Mesh link event

enumerator **ESP_BLE_MESH_NODE_PROV_OOB_PUB_KEY_EVT**
Generate Node input OOB public key event

enumerator **ESP_BLE_MESH_NODE_PROV_OUTPUT_NUMBER_EVT**
Generate Node Output Number event

enumerator **ESP_BLE_MESH_NODE_PROV_OUTPUT_STRING_EVT**
Generate Node Output String event

enumerator **ESP_BLE_MESH_NODE_PROV_INPUT_EVT**
Event requiring the user to input a number or string

enumerator **ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT**
Provisioning done event

enumerator **ESP_BLE_MESH_NODE_PROV_RESET_EVT**
Provisioning reset event

enumerator **ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT**
Node set oob public key completion event

enumerator **ESP_BLE_MESH_NODE_PROV_INPUT_NUMBER_COMP_EVT**
Node input number completion event

enumerator **ESP_BLE_MESH_NODE_PROV_INPUT_STRING_COMP_EVT**
Node input string completion event

enumerator **ESP_BLE_MESH_NODE_PROXY_IDENTITY_ENABLE_COMP_EVT**
Enable BLE Mesh Proxy Identity advertising completion event

enumerator **ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT**
Enable BLE Mesh GATT Proxy Service completion event

enumerator **ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT**
Disable BLE Mesh GATT Proxy Service completion event
enumerator **ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT**
Node add NetKey locally completion event

enumerator **ESP_BLE_MESH_NODE_ADD_LOCAL_APP_KEY_COMP_EVT**
Node add AppKey locally completion event

enumerator **ESP_BLE_MESH_NODE_BIND_APP_KEY_TO_MODEL_COMP_EVT**
Node bind AppKey to model locally completion event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT**
Provisioner enable provisioning functionality completion event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT**
Provisioner disable provisioning functionality completion event

enumerator **ESP_BLE_MESH_PROVISIONER_RECV_UNPROV_ADV_PKT_EVT**
Provisioner receives unprovisioned device beacon event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_EVT**
Provisioner read unprovisioned device OOB public key event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT**
Provisioner input value for provisioning procedure event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT**
Provisioner output value for provisioning procedure event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_LINK_OPEN_EVT**
Provisioner establish a BLE Mesh link event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT**
Provisioner close a BLE Mesh link event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT**
Provisioner provisioning done event

enumerator **ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT**
Provisioner add a device to the list which contains devices that are waiting/going to be provisioned completion event

enumerator **ESP_BLE_MESH_PROVISIONER_PROV_DEV_WITH_ADDR_COMP_EVT**
Provisioner start to provision an unprovisioned device completion event

enumerator **ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT**
Provisioner delete a device from the list, close provisioning link with the device completion event

enumerator **ESP_BLE_MESH_PROVISIONER_SET_DEV_UUID_MATCH_COMP_EVT**
Provisioner set the value to be compared with part of the unprovisioned device UUID completion event
enumerator ESP_BLE_MESH_PROVISIONER_SET_PROV_DATA_INFO_COMP_EVT
    Provisioner set net_idx/flags/iv_indexused for provisioning completion event

enumerator ESP_BLE_MESH_PROVISIONER_SET_STATIC_OOB_VALUE_COMP_EVT
    Provisioner set static oob value used for provisioning completion event

enumerator ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR_COMP_EVT
    Provisioner set unicast address of primary element completion event

enumerator ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_COMP_EVT
    Provisioner read unprovisioned device OOB public key completion event

enumerator ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT
    Provisioner input number completion event

enumerator ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT
    Provisioner input string completion event

enumerator ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT
    Provisioner set node name completion event

enumerator ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT
    Provisioner add local app key completion event

enumerator ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT
    Provisioner update local app key completion event

enumerator ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT
    Provisioner bind local model with local app key completion event

enumerator ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_NET_KEY_COMP_EVT
    Provisioner add local network key completion event

enumerator ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT
    Provisioner update local network key completion event

enumerator ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT
    Provisioner store node composition data completion event

enumerator ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UUID_COMP_EVT
    Provisioner delete node with uuid completion event

enumerator ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT
    Provisioner delete node with unicast address completion event

enumerator ESP_BLE_MESH_PROVISIONER_ENABLE_HEARTBEAT_RECV_COMP_EVT
    Provisioner start to receive heartbeat message completion event
Chapter 2. API Reference

enumerator **ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE_COMP_EVT**
Provisioner set the heartbeat filter type completion event

enumerator **ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_INFO_COMP_EVT**
Provisioner set the heartbeat filter information completion event

enumerator **ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT_MESSAGE_EVT**
Provisioner receive heartbeat message event

enumerator **ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT**
Provisioner directly erase settings completion event

enumerator **ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGSWITH_INDEX_COMP_EVT**
Provisioner open settings with index completion event

enumerator **ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGSWITH_UID_COMP_EVT**
Provisioner open settings with user id completion event

enumerator **ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGSWITH_INDEX_COMP_EVT**
Provisioner close settings with index completion event

enumerator **ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGSWITH_UID_COMP_EVT**
Provisioner close settings with user id completion event

enumerator **ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGSWITH_INDEX_COMP_EVT**
Provisioner delete settings with index completion event

enumerator **ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGSWITH_UID_COMP_EVT**
Provisioner delete settings with user id completion event

enumerator **ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT**
Set fast provisioning information (e.g. unicast address range, net_idx, etc.) completion event

enumerator **ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT**
Set fast provisioning action completion event

enumerator **ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT**
Receive Heartbeat message event

enumerator **ESP_BLE_MESH_LPN_ENABLE_COMP_EVT**
Enable Low Power Node completion event

enumerator **ESP_BLE_MESH_LPN_DISABLE_COMP_EVT**
Disable Low Power Node completion event

enumerator **ESP_BLE_MESH_LPN_POLL_COMP_EVT**
Low Power Node send Friend Poll completion event
enumerator `ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT`
Low Power Node establishes friendship event

enumerator `ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT`
Low Power Node terminates friendship event

enumerator `ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT`
Friend Node establishes friendship event

enumerator `ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT`
Friend Node terminates friendship event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT`
Proxy Client receives Network ID advertising packet event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT`
Proxy Client establishes connection successfully event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT`
Proxy Client terminates connection successfully event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT`
Proxy Client receives Proxy Filter Status event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT`
Proxy Client connect completion event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT`
Proxy Client disconnect completion event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT`
Proxy Client set filter type completion event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT`
Proxy Client add filter address completion event

enumerator `ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT`
Proxy Client remove filter address completion event

enumerator `ESP_BLE_MESH_PROXY_SERVER_CONNECTED_EVT`
Proxy Server establishes connection successfully event

enumerator `ESP_BLE_MESH_PROXY_SERVER_DISCONNECTED_EVT`
Proxy Server terminates connection successfully event

enumerator `ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT`
Local model subscribes group address completion event
enumerator ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT
   Local model unsubscriptions group address completion event

enumerator ESP_BLE_MESH_DEINIT_MESH_COMP_EVT
   De-initialize BLE Mesh stack completion event

enumerator ESP_BLE_MESH_PROV_EVT_MAX

enum [anonymous]
   BLE Mesh server models related definitions.
   This enum value is the flag of transition timer operation
   Values:

enumerator ESP_BLE_MESH_SERVER_TRANS_TIMER_START

enumerator ESP_BLE_MESH_SERVER_FLAG_MAX

enum esp_ble_mesh_server_state_type_t
   This enum value is the type of server model states
   Values:

enumerator ESP_BLE_MESH_GENERIC_ONOFF_STATE

enumerator ESP_BLE_MESH_GENERIC_LEVEL_STATE

enumerator ESP_BLE_MESH_GENERIC_ONPOWERUP_STATE

enumerator ESP_BLE_MESH_GENERIC_POWER_ACTUAL_STATE

enumerator ESP_BLE_MESH_LIGHT_LIGHTNESS_ACTUAL_STATE

enumerator ESP_BLE_MESH_LIGHT_LIGHTNESS_LINEAR_STATE

enumerator ESP_BLE_MESH_LIGHT_CTL_LIGHTNESS_STATE

enumerator ESP_BLE_MESH_LIGHT_CTL_TEMP_DELTA_UV_STATE

enumerator ESP_BLE_MESH_LIGHT_HSL_STATE

enumerator ESP_BLE_MESH_LIGHT_HSL_LIGHTNESS_STATE

enumerator ESP_BLE_MESH_LIGHT_HSL_HUE_STATE

enumerator ESP_BLE_MESH_LIGHT_HSL_SATURATION_STATE
enumerator **ESP_BLE_MESH_LIGHT_XYL_LIGHTNESS_STATE**

enumerator **ESP_BLE_MESH_LIGHT_LC_LIGHT_ONOFF_STATE**

enumerator **ESP_BLE_MESH_SERVER_MODEL_STATE_MAX**

enum **esp_ble_mesh_model_cb_event_t**

Values:

enumerator **ESP_BLE_MESH_MODEL_OPERATION_EVT**
User-defined models receive messages from peer devices (e.g. get, set, status, etc) event

enumerator **ESP_BLE_MESH_MODEL_SEND_COMP_EVT**
User-defined models send messages completion event

enumerator **ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT**
User-defined models publish messages completion event

enumerator **ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT**
User-defined client models receive publish messages event

enumerator **ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT**
Timeout event for the user-defined client models that failed to receive response from peer server models

enumerator **ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT**
When a model is configured to publish messages periodically, this event will occur during every publish period

enumerator **ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT**
Server models update state value completion event

enumerator **ESP_BLE_MESH_MODEL_EVT_MAX**

ESP-BLE-MESH Core API Reference

This section contains ESP-BLE-MESH Core related APIs, which can be used to initialize ESP-BLE-MESH stack, provision, send/publish messages, etc.

This API reference covers six components:

- **ESP-BLE-MESH Stack Initialization**
- **Reading of Local Data Information**
- **Low Power Operation (Updating)**
- **Send/Publish Messages, add Local AppKey, etc.**
- **ESP-BLE-MESH Node/Provisioner Provisioning**
- **ESP-BLE-MESH GATT Proxy Server**

ESP-BLE-MESH Stack Initialization
Header File

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_common_api.h

Functions

**esp_err_t esp_ble_mesh_init (esp_ble_mesh_prov_t *prov, esp_ble_mesh_comp_t *comp)**

Initialize BLE Mesh module. This API initializes provisioning capabilities and composition data information.

**Note:** After calling this API, the device needs to call esp_ble_mesh_prov_enable() to enable provisioning functionality again.

**Parameters**

- **prov** - [in] Pointer to the device provisioning capabilities. This pointer must remain valid during the lifetime of the BLE Mesh device.
- **comp** - [in] Pointer to the device composition data information. This pointer must remain valid during the lifetime of the BLE Mesh device.

**Returns**

ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_deinit (esp_ble_mesh_deinit_param_t *param)**

De-initialize BLE Mesh module.

**Note:** This function shall be invoked after esp_ble_mesh_client_model_deinit().

**Parameters**

- **param** - [in] Pointer to the structure of BLE Mesh deinit parameters.

**Returns**

ESP_OK on success or error code otherwise.

Reading of Local Data Information

Header File

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_local_data_operation_api.h

Functions

**int32_t esp_ble_mesh_get_model_publish_period (esp_ble_mesh_model_t *model)**

Get the model publish period, the unit is ms.

**Parameters**


**Returns**

Publish period value on success, 0 or (negative) error code from errno.h on failure.

**uint16_t esp_ble_mesh_get_primary_element_address (void)**

Get the address of the primary element.

**Returns**

Address of the primary element on success, or ESP_BLE_MESH_ADDR_UNASSIGNED on failure which means the device has not been provisioned.

**uint16_t *esp_ble_mesh_is_model_subscribed_to_group (esp_ble_mesh_model_t *model, uint16_t group_addr)**

Check if the model has subscribed to the given group address. Note: E.g., once a status message is received and the destination address is a group address, the model uses this API to check if it is successfully subscribed to the given group address.

**Parameters**

- **model** - [in] Pointer to the model.
- **group_addr** - [in] Group address.
Returns Pointer to the group address within the Subscription List of the model on success, or NULL on failure which means the model has not subscribed to the given group address. Note: With the pointer to the group address returned, you can reset the group address to 0x0000 in order to unsubscribe the model from the group.

```c
esp_ble_mesh_elem_t *esp_ble_mesh_find_element (uint16_t element_addr)
```

Find the BLE Mesh element pointer via the element address.

**Parameters**
- `element_addr` - [in] Element address.

**Returns** Pointer to the element on success, or NULL on failure.

```c
uint8_t esp_ble_mesh_get_element_count (void)
```

Get the number of elements that have been registered.

**Returns** Number of elements.

```c
esp_ble_mesh_model_t *esp_ble_mesh_find_vendor_model (const esp_ble_mesh_elem_t *element, uint16_t company_id, uint16_t model_id)
```

Find the Vendor specific model with the given element, the company ID and the Vendor Model ID.

**Parameters**
- `element` - [in] Element to which the model belongs.
- `company_id` - [in] A 16-bit company identifier assigned by the Bluetooth SIG.

**Returns** Pointer to the Vendor Model on success, or NULL on failure which means the Vendor Model is not found.

```c
esp_ble_mesh_model_t *esp_ble_mesh_find_sig_model (const esp_ble_mesh_elem_t *element, uint16_t model_id)
```

Find the SIG model with the given element and Model id.

**Parameters**
- `element` - [in] Element to which the model belongs.
- `model_id` - [in] SIG model identifier.

**Returns** Pointer to the SIG Model on success, or NULL on failure which means the SIG Model is not found.

```c
const esp_ble_mesh_comp_t *esp_ble_mesh_get_composition_data (void)
```

Get the Composition data which has been registered.

**Returns** Pointer to the Composition data on success, or NULL on failure which means the Composition data is not initialized.

```c
esp_err_t esp_ble_mesh_model_subscribe_group_addr (uint16_t element_addr, uint16_t company_id, uint16_t model_id, uint16_t group_addr)
```

A local model of node or Provisioner subscribes a group address.

**Note:** This function shall not be invoked before node is provisioned or Provisioner is enabled.

```c
esp_err_t esp_ble_mesh_model_unsubscribe_group_addr (uint16_t element_addr, uint16_t company_id, uint16_t model_id, uint16_t group_addr)
```

**Parameters**
- `element_addr` - [in] Unicast address of the element to which the model belongs.
- `group_addr` - [in] The group address to be subscribed.

**Returns** ESP_OK on success or error code otherwise.
Chapter 2. API Reference

A local model of node or Provisioner unsubscribes a group address.

**Note:** This function shall not be invoked before node is provisioned or Provisioner is enabled.

### Parameters
- `element_addr` [in] Unicast address of the element to which the model belongs.
- `group_addr` [in] The subscribed group address.

### Returns
- ESP_OK on success or error code otherwise.

```c
const uint8_t* esp_ble_mesh_node_get_local_net_key(uint16_t net_idx)
```

This function is called by Node to get the local NetKey.

**Parameters**

**Returns**
- NetKey on success, or NULL on failure.

```c
const uint8_t* esp_ble_mesh_node_get_local_app_key(uint16_t app_idx)
```

This function is called by Node to get the local AppKey.

**Parameters**

**Returns**
- AppKey on success, or NULL on failure.

```c
esp_err_t esp_ble_mesh_node_add_local_net_key(const uint8_t net_key[16], uint16_t net_idx)
```

This function is called by Node to add a local NetKey.

**Parameters**
- `net_key` [in] NetKey to be added.

**Returns**
- ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_node_add_local_app_key(const uint8_t app_key[16], uint16_t net_idx, uint16_t app_idx)
```

This function is called by Node to add a local AppKey.

**Parameters**
- `app_key` [in] AppKey to be added.

**Returns**
- ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_node_bind_app_key_to_local_model(uint16_t element_addr, uint16_t company_id, uint16_t model_id, uint16_t app_idx)
```

This function is called by Node to bind AppKey to model locally.

**Note:** If going to bind app_key with local vendor model, the company_id shall be set to 0xFFFF. This function can only be called after the device is provisioned.
Parameters

- `element_addr` [in] Node local element address
- `company_id` [in] Node local company id
- `model_id` [in] Node local model id
- `app_idx` [in] Node local appkey index

Returns ESP_OK on success or error code otherwise.

Low Power Operation (Updating)

Header File

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_low_power_api.h

Functions

```c
esp_err_t esp_ble_mesh_lpn_enable (void)
```

Enable BLE Mesh device LPN functionality.

**Note:** This API enables LPN functionality. Once called, the proper Friend Request will be sent.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_lpn_disable (bool force)
```

Disable BLE Mesh device LPN functionality.

**Parameters** `force` [in] when disabling LPN functionality, use this flag to indicate whether
directly clear corresponding information or just send friend clear to disable it if friendship
has already been established.

**Returns** ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_lpn_poll (void)
```

LPN tries to poll messages from the Friend Node.

**Note:** The Friend Poll message is sent by a Low Power node to ask the Friend node to send a message that it
has stored for the Low Power node. Users can call this API to send Friend Poll message manually. If this API
is not invoked, the bottom layer of the Low Power node will send Friend Poll before the PollTimeout timer
expires. If the corresponding Friend Update is received and MD is set to 0, which means there are no messages
for the Low Power node, then the Low Power node will stop scanning.

**Returns** ESP_OK on success or error code otherwise.

Send/Publish Messages, add Local AppKey, etc.

Header File

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_networking_api.h

Functions

```c
esp_err_t esp_ble_mesh_register_custom_model_callback (esp_ble_mesh_model_cb_t callback)
```

Register BLE Mesh callback for user-defined models’ operations. This callback can report the following events
generated for the user-defined models:
Chapter 2.  API Reference

- Call back the messages received by user-defined client and server models to the application layer;
- If users call esp_ble_mesh_server/client_model_send, this callback notifies the application layer of the send_complete event;
- If user-defined client model sends a message that requires response, and the response message is received after the timer expires, the response message will be reported to the application layer as published by a peer device;
- If the user-defined client model fails to receive the response message during a specified period of time, a timeout event will be reported to the application layer.

**Note:** The client models (i.e. Config Client model, Health Client model, Generic Client models, Sensor Client model, Scene Client model and Lighting Client models) that have been realized internally have their specific register functions. For example, esp_ble_mesh_register_config_client_callback is the register function for Config Client Model.

**Parameters**
- **callback**  - [in] Pointer to the callback function.
- **Returns**  ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_model_msg_opcode_init (uint8_t *data, uint32_t opcode)
```

Add the message opcode to the beginning of the model message before sending or publishing the model message.

**Note:** This API is only used to set the opcode of the message.

**Parameters**
- **data**  - [in] Pointer to the message data.
- **opcode**  - [in] The message opcode.
- **Returns**  ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_client_model_init (esp_ble_mesh_model_t *model)
```

Initialize the user-defined client model. All user-defined client models shall call this function to initialize the client model internal data. Node: Before calling this API, the op_pair_size and op_pair variabled within the user_data(defined using esp_ble_mesh_client_t_) of the client model need to be initialized.

**Parameters**
- **model**  - [in] BLE Mesh Client model to which the message belongs.
- **Returns**  ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_client_model_deinit (esp_ble_mesh_model_t *model)
```

De-initialize the user-defined client model.

**Note:** This function shall be invoked before esp_ble_mesh_deinit() is called.

**Parameters**
- **model**  - [in] Pointer of the Client model.
- **Returns**  ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_server_model_send_msg (esp_ble_mesh_model_t *model,
                                            esp_ble_mesh_msg_ctx_t *ctx, uint32_t opcode,
                                            uint16_t length, uint8_t *data)
```

Send server model messages(such as server model status messages).

**Parameters**
- **model**  - [in] BLE Mesh Server Model to which the message belongs.
- **ctx**  - [in] Message context, includes keys, TTL, etc.
- **length**  - [in] Message length (exclude the message opcode).
- **data**  - [in] Parameters of Access Payload (exclude the message opcode) to be sent.
Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_client_model_send_msg(esp_ble_mesh_model_t *model,
                                          esp_ble_mesh_msg_ctx_t *ctx, uint32_t opcode,
                                          uint16_t length, uint8_t *data, int32_t msg_timeout, bool need_rsp,
                                          esp_ble_mesh_dev_role_t device_role)
```

Send client model message (such as model get, set, etc).

Parameters
- `model` - [in] BLE Mesh Client Model to which the message belongs.
- `ctx` - [in] Message context, includes keys, TTL, etc.
- `length` - [in] Message length (exclude the message opcode).
- `data` - [in] Parameters of the Access Payload (exclude the message opcode) to be sent.
- `msg_timeout` - [in] Time to get response to the message (in milliseconds).
- `need_rsp` - [in] TRUE if the opcode requires the peer device to reply, FALSE otherwise.
- `device_role` - [in] Role of the device (Node/Provisioner) that sends the message.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_model_publish(esp_ble_mesh_model_t *model, uint32_t opcode, uint16_t
                                         length, uint8_t *data, esp_ble_mesh_dev_role_t device_role)
```

Send a model publication message.

Note: Before calling this function, the user needs to ensure that the model publication message (esp_ble_mesh_model_pub_t::msg) contains a valid message to be sent. And if users want to update the publishing message, this API should be called in ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT with the message updated.

Parameters
- `length` - [in] Message length (exclude the message opcode).
- `data` - [in] Parameters of the Access Payload (exclude the message opcode) to be sent.
- `device_role` - [in] Role of the device (node/provisioner) publishing the message of the type esp_ble_mesh_dev_role_t.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_server_model_update_state(esp_ble_mesh_model_t *model,
                                                   esp_ble_mesh_server_state_type_t type,
                                                   esp_ble_mesh_server_state_value_t *value)
```

Update a server model state value. If the model publication state is set properly (e.g. publish address is set to a valid address), it will publish corresponding status message.

Note: Currently this API is used to update bound state value, not for all server model states.

Parameters
- `model` - [in] Server model which is going to update the state.
- `type` - [in] Server model state type.
- `value` - [in] Server model state value.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_node_local_reset(void)
```

Reset the provisioning procedure of the local BLE Mesh node.
Note: All provisioning information in this node will be deleted and the node needs to be reprovisioned. The API function esp_ble_mesh_node_prov_enable() needs to be called to start a new provisioning procedure.

Returns  ESP_OK on success or error code otherwise.

esp_err_t esp_ble_mesh_provisioner_set_node_name (uint16_t index, const char *name)
This function is called to set the node (provisioned device) name.

Note: index is obtained from the parameters of ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT.

Parameters
•  index  -[in] Index of the node in the node queue.
•  name  -[in] Name (end by '\0') to be set for the node.

Returns  ESP_OK on success or error code otherwise.

const char *esp_ble_mesh_provisioner_get_node_name (uint16_t index)
This function is called to get the node (provisioned device) name.

Note: index is obtained from the parameters of ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT.

Parameters  index  -[in] Index of the node in the node queue.
            Node name on success, or NULL on failure.

uint16_t esp_ble_mesh_provisioner_get_node_index (const char *name)
This function is called to get the node (provisioned device) index.

Parameters  name  -[in] Name of the node (end by '\0').

Returns  Node index on success, or an invalid value (0xFFFF) on failure.

esp_err_t esp_ble_mesh_provisioner_store_node_comp_data (uint16_t unicast_addr, uint8_t *data, uint16_t length)
This function is called to store the Composition Data of the node.

Parameters
•  unicast_addr  -[in] Element address of the node
•  data  -[in] Pointer of Composition Data
•  length  -[in] Length of Composition Data

Returns  ESP_OK on success or error code otherwise.

esp_ble_mesh_node_t *esp_ble_mesh_provisioner_get_node_with_uuid (const uint8_t uuid[16])
This function is called to get the provisioned node information with the node device uuid.

Parameters  uuid  -[in] Device UUID of the node

Returns  Pointer of the node info struct or NULL on failure.

esp_ble_mesh_node_t *esp_ble_mesh_provisioner_get_node_with_addr (uint16_t unicast_addr)
This function is called to get the provisioned node information with the node unicast address.

Parameters  unicast_addr  -[in] Unicast address of the node

Returns  Pointer of the node info struct or NULL on failure.

esp_ble_mesh_node_t *esp_ble_mesh_provisioner_get_node_with_name (const char *name)
This function is called to get the provisioned node information with the node name.

Parameters  name  -[in] Name of the node (end by '\0').

Returns  Pointer of the node info struct or NULL on failure.
# Chapter 2. API Reference

**uint16_t esp_ble_mesh_provisioner_get_prov_node_count (void)**

This function is called by Provisioner to get provisioned node count.

**Returns**  Number of the provisioned nodes.

**const esp_ble_mesh_node_t ** esp_ble_mesh_provisioner_get_node_table_entry (void)**

This function is called by Provisioner to get the entry of the node table.

**Note:** After invoking the function to get the entry of nodes, users can use the “for” loop combined with the macro `CONFIG_BLE_MESH_MAX_PROV_NODES` to get each node’s information. Before trying to read the node’s information, users need to check if the node exists, i.e. if the `*(esp_ble_mesh_node_t **node)` is NULL. For example:

```c
const esp_ble_mesh_node_t **entry = esp_ble_mesh_provisioner_get_node_table_entry(); for (int i = 0; i < CONFIG_BLE_MESH_MAX_PROV_NODES; i++) { const esp_ble_mesh_node_t *node = entry[i]; if (node) { ...... } }
```

**Returns**  Pointer to the start of the node table.

**esp_err_t esp_ble_mesh_provisioner_delete_node_with_uuid (const uint8_t uuid[16])**

This function is called to delete the provisioned node information with the node device uuid.

**Parameters**  
- **uuid**  -[in]  Device UUID of the node

**Returns**  ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_delete_node_with_addr (uint16_t unicast_addr)**

This function is called to delete the provisioned node information with the node unicast address.

**Parameters**  
- **unicast_addr**  -[in]  Unicast address of the node

**Returns**  ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_add_local_app_key (const uint8_t app_key[16], uint16_t net_idx, uint16_t app_idx)**

This function is called to add a local AppKey for Provisioner.

**Parameters**  
- **app_key**  -[in]  The appkey to be set for the local BLE Mesh stack.
- **net_idx**  -[in]  The network key index.
- **app_idx**  -[in]  The app key index.

**Returns**  ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_update_local_app_key (const uint8_t app_key[16], uint16_t net_idx, uint16_t app_idx)**

This function is used to update a local AppKey for Provisioner.

**Parameters**  
- **app_key**  -[in]  Value of the AppKey.
- **net_idx**  -[in]  Corresponding NetKey Index.
- **app_idx**  -[in]  The AppKey Index

**Returns**  ESP_OK on success or error code otherwise.
const uint8_t *esp_ble_mesh_provisioner_get_local_app_key(uint16_t net_idx, uint16_t app_idx)

This function is called by Provisioner to get the local app key value.

Parameters
• net_idx -[in] Network key index.
• app_idx -[in] Application key index.

Returns App key on success, or NULL on failure.

esp_err_t esp_ble_mesh_provisioner_bind_app_key_to_local_model(uint16_t element_addr, uint16_t app_idx, uint16_t model_id, uint16_t company_id)

This function is called by Provisioner to bind own model with proper app key.

Note: company_id: If going to bind app_key with local vendor model, company_id should be set to 0xFFFF.

Parameters
• element_addr -[in] Provisioner local element address
• app_idx -[in] Provisioner local appkey index
• model_id -[in] Provisioner local model id
• company_id -[in] Provisioner local company id

Returns ESP_OK on success or error code otherwise.

esp_err_t esp_ble_mesh_provisioner_add_local_net_key(const uint8_t net_key[16], uint16_t net_idx)

This function is called by Provisioner to add local network key.

Note: net_key: If set to NULL, net_key will be generated internally. net_idx: If it is going to be generated internally, it should be set to 0xFFFF, and the new net_idx will be reported via an event.

Parameters
• net_key -[in] The network key to be added to the Provisioner local BLE Mesh stack.
• net_idx -[in] The network key index.

Returns ESP_OK on success or error code otherwise.

esp_err_t esp_ble_mesh_provisioner_update_local_net_key(const uint8_t net_key[16], uint16_t net_idx)

This function is called by Provisioner to update a local network key.

Parameters
• net_key -[in] Value of the NetKey.
• net_idx -[in] The NetKey Index.

Returns ESP_OK on success or error code otherwise.

const uint8_t *esp_ble_mesh_provisioner_get_local_net_key(uint16_t net_idx)

This function is called by Provisioner to get the local network key value.

Parameters net_idx -[in] Network key index.

Returns Network key on success, or NULL on failure.

esp_err_t esp_ble_mesh_provisioner_recv_heartbeat(bool enable)

This function is called by Provisioner to enable or disable receiving heartbeat messages.
Parameters `enable` -[in] Enable or disable receiving heartbeat messages.

Returns ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_set_heartbeat_filter_type**(uint8_t `type`)

This function is called by Provisioner to set the heartbeat filter type.

**Note:** 1. If the filter type is not the same with the current value, then all the filter entries will be cleaned.

a. If the previous type is rejectlist, and changed to acceptlist, then the filter will be an empty acceptlist, which means no heartbeat messages will be reported. Users need to add SRC or DST into the filter entry, then heartbeat messages from the SRC or to the DST will be reported.

Parameters `type` -[in] Heartbeat filter type (acceptlist or rejectlist).

Returns ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_set_heartbeat_filter_info**(uint8_t `op`,
**esp_ble_mesh_heartbeat_filter_info_t** *info*)

This function is called by Provisioner to add or remove a heartbeat filter entry.

a. If the operation is “REMOVE”, the “hb_src” can be set to the SRC (can only be a unicast address) of heartbeat messages, and the “hb_dst” can be set to the DST (unicast address or group address), at least one of them needs to be set.

- The filter entry with the same SRC or DST will be removed.

**Note:** 1. If the operation is “ADD”, the “hb_src” can be set to the SRC (can only be a unicast address) of heartbeat messages, and the “hb_dst” can be set to the DST (unicast address or group address), at least one of them needs to be set.

- If only one of them is set, the filter entry will only use the configured SRC or DST to filter heartbeat messages.
- If both of them are set, the SRC and DST will both be used to decide if a heartbeat message will be handled.
- If SRC or DST already exists in some filter entry, then the corresponding entry will be cleaned firstly, then a new entry will be allocated to store the information.

Parameters

- `op` -[in] Add or REMOVE
- `info` -[in] Heartbeat filter entry information, including: hb_src - Heartbeat source address; hb_dst - Heartbeat destination address;

Returns ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_direct_erase_settings**(void)

This function is called by Provisioner to directly erase the mesh information from nvs namespace.

**Note:** This function can be invoked when the mesh stack is not initialized or has been de-initialized.

Returns ESP_OK on success or error code otherwise.
**esp_err_t esp_ble_mesh_provisioner_open_settings_with_index (uint8_t index)**

This function is called by Provisioner to open a nvs namespace for storing mesh information.

**Note:** Before open another nvs namespace, the previously opened nvs namespace must be closed firstly.

**Parameters**
- `index` - [in] Settings index.

**Returns**
- ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_open_settings_with_uid (const char *uid)**

This function is called by Provisioner to open a nvs namespace for storing mesh information.

**Note:** Before open another nvs namespace, the previously opened nvs namespace must be closed firstly.

**Parameters**
- `uid` - [in] Settings userid.

**Returns**
- ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_close_settings_with_index (uint8_t index, bool erase)**

This function is called by Provisioner to close a nvs namespace which is opened previously for storing mesh information.

**Note:**
1. Before closing the nvs namespace, it must be open.
   a. When the function is invoked, the Provisioner functionality will be disabled firstly, and:  
      a) If the “erase” flag is set to false, the mesh information will be cleaned (e.g. removing NetKey, AppKey, nodes, etc) from the mesh stack.  
      b) If the “erase” flag is set to true, the mesh information stored in the nvs namespace will also be erased besides been cleaned from the mesh stack.  
   b. If Provisioner tries to work properly again, we can invoke the open function to open a new nvs namespace or a previously added one, and restore the mesh information from it if not erased.  
   c. The working process shall be as following:  
      a) Open settings A  
      b) Start to provision and control nodes  
      c) Close settings A  
      d) Open settings B  
      e) Start to provision and control other nodes  
      f) Close settings B  
      g) ... ...

**Parameters**
- `index` - [in] Settings index.  
- `erase` - [in] Indicate if erasing mesh information.  

**Returns**
- ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_close_settings_with_uid (const char *uid, bool erase)**

This function is called by Provisioner to close a nvs namespace which is opened previously for storing mesh information.

**Note:**
1. Before closing the nvs namespace, it must be open.
   a. When the function is invoked, the Provisioner functionality will be disabled firstly, and:  
      a) If the “erase” flag is set to false, the mesh information will be cleaned (e.g. removing NetKey, AppKey, nodes, etc) from the mesh stack.  
      b) If the “erase” flag is set to true, the mesh information stored in the nvs namespace will also be erased besides been cleaned from the mesh stack.  
   b. If Provisioner tries to work properly again, we can invoke the open function to open a new nvs namespace or a previously added one, and restore the mesh information from it if not erased.  
   c. The working process shall be as following:  
      a) Open settings A  
      b) Start to provision and control nodes  
      c) Close settings A  
      d) Open settings B  
      e) Start to provision and control other nodes  
      f) Close settings B  
      g) ... ...
Parameters

- **uid** – [in] Settings user id.
- **erase** – [in] Indicate if erasing mesh information.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_provisioner_delete_settings_with_index(uint8_t index)
```

This function is called by Provisioner to erase the mesh information and settings user id from a nvs namespace.

**Note:** When this function is called, the nvs namespace must not be open. This function is used to erase the mesh information and settings user id which are not used currently.

```c
Parameters index -[in] Settings index.
Returns ESP_OK on success or error code otherwise.
```

```c
esp_err_t esp_ble_mesh_provisioner_delete_settings_with_uid(const char* uid)
```

This function is called by Provisioner to erase the mesh information and settings user id from a nvs namespace.

**Note:** When this function is called, the nvs namespace must not be open. This function is used to erase the mesh information and settings user id which are not used currently.

```c
Parameters uid -[in] Settings user id.
Returns ESP_OK on success or error code otherwise.
```

```c
const char* esp_ble_mesh_provisioner_get_settings_uid(uint8_t index)
```

This function is called by Provisioner to get settings user id.

```c
Parameters index -[in] Settings index.
Returns Setting userid on success or NULL on failure.
```

```c
uint8_t esp_ble_mesh_provisioner_get_settings_index(const char* uid)
```

This function is called by Provisioner to get settings index.

```c
Parameters uid -[in] Settings user id.
Returns Settings index.
```

```c
uint8_t esp_ble_mesh_provisioner_get_free_settings_count(void)
```

This function is called by Provisioner to get the number of free settings user id.

```c
Returns Number of free settings user id.
```

```c
const uint8_t* esp_ble_mesh_get_fast_prov_app_key(uint16_t net_idx, uint16_t app_idx)
```

This function is called to get fast provisioning application key.

```c
Parameters

- **app_idx** – [in] Application key index.

Returns Application key on success, or NULL on failure.
```

**Type Definitions**

typedef void (*esp_ble_mesh_model_cb_t)(esp_ble_mesh_model_cb_event_t event, esp_ble_mesh_model_cb_param_t *param)

: event, event code of user-defined model events; param, parameters of user-defined model events

**ESP-BLE-MESH Node/Provisioner Provisioning**
Header File

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_provisioning_api.h

Functions

**esp_err_t esp_ble_mesh_register_prov_callback** *(esp_ble_mesh_prov_cb_t callback)*

Register BLE Mesh provisioning callback.

**Parameters**

- *callback* - [in] Pointer to the callback function.

**Returns**

- ESP_OK on success or error code otherwise.

**bool esp_ble_mesh_node_is_provisioned** *(void)*

Check if a device has been provisioned.

**Parameters**

- *void* - 

**Returns**

- TRUE if the device is provisioned, FALSE if the device is unprovisioned.

**esp_err_t esp_ble_mesh_node_prov_enable** *(esp_ble_mesh_prov_bearer_t bearers)*

Enable specific provisioning bearers to get the device ready for provisioning.

**Parameters**

- *bearers* - Bit-wise OR of provisioning bearers.

**Returns**

- ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_node_prov_disable** *(esp_ble_mesh_prov_bearer_t bearers)*

Disable specific provisioning bearers to make a device inaccessible for provisioning.

**Parameters**

- *bearers* - Bit-wise OR of provisioning bearers.

**Returns**

- ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_node_set_oob_pub_key** *(uint8_t pub_key_x[32], uint8_t pub_key_y[32], uint8_t private_key[32])*

Unprovisioned device set own OOB public key & private key pair.

**Note:** In order to avoid suffering brute-forcing attack (CVE-2020-26559). The Bluetooth SIG recommends that potentially vulnerable mesh provisioners use an out-of-band mechanism to exchange the public keys. So as an unprovisioned device, it should use this function to input the Public Key exchanged through the out-of-band mechanism.

**Parameters**

- *pub_key_x* - [in] Unprovisioned device’s Public Key X
- *pub_key_y* - [in] Unprovisioned device’s Public Key Y
- *private_key* - [in] Unprovisioned device’s Private Key

**Returns**

- ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_node_input_number** *(uint32_t number)*

Provide provisioning input OOB number.

**Note:** This is intended to be called if the user has received ESP_BLE_MESH_NODE_PROV_INPUT_EVT with ESP_BLE_MESH_ENTER_NUMBER as the action.

**Parameters**

- *number* - [in] Number input by device.

**Returns**

- ESP_OK on success or error code otherwise.
Chapter 2. API Reference

**esp_err_t esp_ble_mesh_node_input_string** (const char *string)

Provide provisioning input OOB string.

**Note:** This is intended to be called if the user has received ESP_BLE_MESH_NODE_PROV_INPUT_EVT with ESP_BLE_MESH_ENTER_STRING as the action.

**Parameters** string - [in] String input by device.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_set_unprovisioned_device_name** (const char *name)

Using this function, an unprovisioned device can set its own device name, which will be broadcasted in its advertising data.

**Note:** This API applicable to PB-GATT mode only by setting the name to the scan response data, it doesn’t apply to PB-ADV mode.

**Parameters** name - [in] Unprovisioned device name

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_read_oob_pub_key** (uint8_t link_idx, uint8_t pub_key_x[32], uint8_t pub_key_y[32])

Provisioner inputs unprovisioned device’s oob public key.

**Note:** In order to avoid suffering brute-forcing attack (CVE-2020-26559). The Bluetooth SIG recommends that potentially vulnerable mesh provisioners use an out-of-band mechanism to exchange the public keys.

**Parameters**

- link_idx - [in] The provisioning link index
- pub_key_x - [in] Unprovisioned device’s Public Key X
- pub_key_y - [in] Unprovisioned device’s Public Key Y

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_input_string** (const char *string, uint8_t link_idx)

Provide provisioning input OOB string.

**This is intended to be called after the esp_ble_mesh_prov_t prov_input_num callback has been called with ESP_BLE_MESH_ENTER_STRING as the...**

**Parameters**

- string - [in] String input by Provisioner.
- link_idx - [in] The provisioning link index.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_provisioner_input_number** (uint32_t number, uint8_t link_idx)

Provide provisioning input OOB number.
This is intended to be called after the esp_ble_mesh_prov_t prov_input_num callback has been called with ESP_BLE_MESH_ENTER_NUMBER as the action.

Parameters
- **number** [in] Number input by Provisioner.
- **link_idx** [in] The provisioning link index.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_provisioner_prov_enable(esp_ble_mesh_prov_bearer_t bearers)
```
Enable one or more provisioning bearers.

Note: PB-ADV: Enable BLE scan. PB-GATT: Initialize corresponding BLE Mesh Proxy info.

```c
esp_err_t esp_ble_mesh_provisioner_prov_disable(esp_ble_mesh_prov_bearer_t bearers)
```
Disable one or more provisioning bearers.

Note: PB-ADV: Disable BLE scan. PB-GATT: Break any existing BLE Mesh Provisioning connections.

```c
esp_err_t esp_ble_mesh_provisioner_add_unprov_dev(esp_ble_mesh_unprov_dev_add_t *add_dev, esp_ble_mesh_dev_add_flag_t flags)
```
Add unprovisioned device info to the unprov_dev queue.

Note: 1. Currently address type only supports public address and static random address.

   a. If device UUID and/or device address as well as address type already exist in the device queue, but the bearer is different from the existing one, add operation will also be successful and it will update the provision bearer supported by the device.

   b. For example, if the Provisioner wants to add an unprovisioned device info before receiving its unprovisioned device beacon or Mesh Provisioning advertising packets, the Provisioner can use this API to add the device info with each one or both of device UUID and device address added. When the Provisioner gets the device’s advertising packets, it will start provisioning the device internally.

   - In this situation, the Provisioner can set bearers with each one or both of ESP_BLE_MESH_PROV_ADV and ESP_BLE_MESH_PROV_GATT enabled, and cannot set flags with ADD_DEV_START_PROV_NOW_FLAG enabled.

   c. Another example is when the Provisioner receives the unprovisioned device’s beacon or Mesh Provisioning advertising packets, the advertising packets will be reported on to the application layer using the callback registered by the function esp_ble_mesh_register_prov_callback. And in the callback, the Provisioner can call this API to start provisioning the device.

   - If the Provisioner uses PB-ADV to provision, either one or both of device UUID and device address can be added, bearers shall be set with ESP_BLE_MESH_PROV_ADV enabled and the flags shall be set with ADD_DEV_START_PROV_NOW_FLAG enabled.

   - If the Provisioner uses PB-GATT to provision, both the device UUID and device address need to be added, bearers shall be set with ESP_BLE_MESH_PROV_GATT enabled, and the flags shall be set with ADD_DEV_START_PROV_NOW_FLAG enabled.
• If the Provisioner just wants to store the unprovisioned device info when receiving its advertising packets and start to provision it the next time (e.g., after receiving its advertising packets again), then it can add the device info with either one or both of device UUID and device address included. Bearers can be set with either one or both of ESP_BLE_MESH_PROV_ADV and ESP_BLE_MESH_PROV_GATT enabled (recommend to enable the bearer which will receive its advertising packets, because if the other bearer is enabled, the Provisioner is not aware if the device supports the bearer), and flags cannot be set with ADD_DEV_START_PROV_NOW_FLAG enabled.

• Note: ESP_BLE_MESH_PROV_ADV, ESP_BLE_MESH_PROV_GATT and ADD_DEV_START_PROV_NOW_FLAG can not be enabled at the same time.

Parameters

• add_dev –[in] Pointer to a struct containing the device information
• flags –[in] Flags indicate several operations on the device information
  – Remove device information from queue after device has been provisioned (BIT0)
  – Start provisioning immediately after device is added to queue (BIT1)
  – Device can be removed if device queue is full (BIT2)

Returns ESP_OK on success or error code otherwise.

esp_err_t esp_ble_mesh_provisioner_prov_device_with_addr (const uint8_t uuid[16], esp_ble_mesh_bd_addr_t addr, esp_ble_mesh_addr_type_t addr_type, esp_ble_mesh_prov_bearer_t bearer, uint16_t oob_info, uint16_t unicast_addr)

Provision an unprovisioned device and assign a fixed unicast address for it in advance.

Note: : 1. Currently address type only supports public address and static random address.

a. Bearer must be equal to ESP_BLE_MESH_PROV_ADV or ESP_BLE_MESH_PROV_GATT, since Provisioner will start to provision a device immediately once this function is invoked. And the input bearer must be identical with the one within the parameters of the ESP_BLE_MESH_PROVISIONER_RECV_UNPROV_ADV_PKT_EVT event.
b. If this function is used by a Provisioner to provision devices, the application should take care of the assigned unicast address and avoid overlap of the unicast addresses of different nodes.
c. Recommend to use only one of the functions “esp_ble_mesh_provisioner_add_unprov_dev” and “esp_ble_mesh_provisioner_prov_device_with_addr” by a Provisioner.

Parameters

• uuid –[in] Device UUID of the unprovisioned device
• addr –[in] Device address of the unprovisioned device
• addr_type –[in] Device address type of the unprovisioned device
• bearer –[in] Provisioning bearer going to be used by Provisioner
• oob_info –[in] OOB info of the unprovisioned device
• unicast_addr –[in] Unicast address going to be allocated for the unprovisioned device

Returns Zero on success or (negative) error code otherwise.

esp_err_t esp_ble_mesh_provisioner_delete_dev (esp_ble_mesh_device_delete_t *del_dev)

Delete device from queue, and reset current provisioning link with the device.

Note: If the device is in the queue, remove it from the queue; if the device is being provisioned, terminate the provisioning procedure. Either one of the device address or device UUID can be used as input.
**Parameters**

`del_dev` **[in]** Pointer to a struct containing the device information.

**Returns**

ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_provisioner_set_dev_uuid_match(const uint8_t* match_val, uint8_t match_len, uint8_t offset, bool prov_after_match)
```

This function is called by Provisioner to set the part of the device UUID to be compared before starting to provision.

**Parameters**

- `match_val` **[in]** Value to be compared with the part of the device UUID.
- `match_len` **[in]** Length of the compared match value.
- `offset` **[in]** Offset of the device UUID to be compared (based on zero).
- `prov_after_match` **[in]** Flag used to indicate whether provisioner should start to provision the device immediately if the part of the UUID matches.

**Returns**

ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_provisioner_set_prov_data_info(esp_ble_mesh_prov_data_info_t *prov_data_info)
```

This function is called by Provisioner to set provisioning data information before starting to provision.

**Parameters**

`prov_data_info` **[in]** Pointer to a struct containing net_idx or flags or iv_index.

**Returns**

ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_provisioner_set_static_oob_value(const uint8_t* value, uint8_t length)
```

This function is called by Provisioner to set static oob value used for provisioning.

AuthValues selected using a cryptographically secure random or pseudorandom number generator and having the maximum permitted entropy (128-bits) will be most difficult to brute-force. AuthValues with reduced entropy or generated in a predictable manner will not grant the same level of protection against this vulnerability. Selecting a new AuthValue with each provisioning attempt can also make it more difficult to launch a brute-force attack by requiring the attacker to restart the search with each provisioning attempt (CVE-2020-26556).

**Note:** The Bluetooth SIG recommends that mesh implementations enforce a randomly selected AuthValue using all of the available bits, where permitted by the implementation. A large entropy helps ensure that a brute-force of the AuthValue, even a static AuthValue, cannot normally be completed in a reasonable time (CVE-2020-26557).

**Parameters**

- `value` **[in]** Pointer to the static oob value.
- `length` **[in]** Length of the static oob value.

**Returns**

ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_provisioner_set_primary_elem_addr(uint16_t addr)
```

This function is called by Provisioner to set own Primary element address.

**Note:** This API must be invoked when BLE Mesh initialization is completed successfully, and can be invoked before Provisioner functionality is enabled. Once this API is invoked successfully, the prov_unicast_addr value in the struct `esp_ble_mesh_prov_t` will be ignored, and Provisioner will use this address as its own primary element address. And if the unicast address going to assigned for the next unprovisioned device is smaller than the input address + element number of Provisioner, then the address for the next unprovisioned device will be recalculated internally.

**Parameters**

`addr` **[in]** Unicast address of the Primary element of Provisioner.
Returns ESP_OK on success or error code otherwise.

```
// Returns ESP_OK on success or error code otherwise.
```

```
// esp_err_t esp_ble_mesh_set_fast_prov_info(esp_ble_mesh_fast_prov_info_t *fast_prov_info)
// This function is called to set provisioning data information before starting fast provisioning.

Parameters fast_prov_info – [in] Pointer to a struct containing unicast address range, net_idx, etc.

Returns ESP_OK on success or error code otherwise.
```

```
// Returns ESP_OK on success or error code otherwise.
```

```
// esp_err_t esp_ble_mesh_set_fast_prov_action(esp_ble_mesh_fast_prov_action_t action)
// This function is called to start/suspend/exit fast provisioning.

Parameters action – [in] fast provisioning action (i.e. enter, suspend, exit).

Returns ESP_OK on success or error code otherwise.
```

### Type Definitions

```
typedef void (*esp_ble_mesh_prov_cb_t)(esp_ble_mesh_prov_cb_event_t event, esp_ble_mesh_prov_cb_param_t *param)
: event, event code of provisioning events; param, parameters of provisioning events
```

```
typedef void (*esp_ble_mesh_prov_adv_cb_t)(const esp_ble_mesh_bd_addr_t addr, const esp_ble_mesh_addr_type_t addr_type, const uint8_t adv_type, const uint8_t *dev_uuid, uint16_t oob_info, esp_ble_mesh_prov_bearer_t bearer)

Callback for Provisioner that received advertising packets from unprovisioned devices which are not in the unprovisioned device queue.

Report on the unprovisioned device beacon and mesh provisioning service adv data to application.

Param addr [in] Pointer to the unprovisioned device address.
Param addr_type [in] Unprovisioned device address type.
Param adv_type [in] Adv packet type(ADV_IND or ADV_NONCONN_IND).
Param dev_uuid [in] Unprovisioned device UUID pointer.
Param oob_info [in] OOB information of the unprovisioned device.
Param bearer [in] Adv packet received from PB-GATT or PB-ADV bearer.
```

### ESP-BLE-MESH GATT Proxy Server

#### Header File

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_proxy_api.h

#### Functions

```
// esp_err_t esp_ble_mesh_proxy_identity_enable(void)
// Enable advertising with Node Identity.

Note: This API requires that GATT Proxy support be enabled. Once called, each subnet starts advertising using Node Identity for the next 60 seconds, and after 60s Network ID will be advertised. Under normal conditions, the BLE Mesh Proxy Node Identity and Network ID advertising will be enabled automatically by BLE Mesh stack after the device is provisioned.
```

```
// Returns ESP_OK on success or error code otherwise.
```

```
// esp_err_t esp_ble_mesh_proxy_gatt_enable(void)
// Enable BLE Mesh GATT Proxy Service.

Returns ESP_OK on success or error code otherwise.
```

---

Espressif Systems 625 Release v5.1.2

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**esp_err_t** **esp_ble_mesh_proxy_gatt_disable**(void)

Disconnect the BLE Mesh GATT Proxy connection if there is any, and disable the BLE Mesh GATT Proxy Service.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t** **esp_ble_mesh_proxy_client_connect**(esp_ble_mesh_bd_addr_t \*addr, esp_ble_mesh_addr_type_t addr_type, uint16_t net_idx)

Proxy Client creates a connection with the Proxy Server.

**Parameters**
- addr - [in] Device address of the Proxy Server.
- addr_type - [in] Device address type (public or static random).
- net_idx - [in] NetKey Index related with Network ID in the Mesh Proxy advertising packet.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t** **esp_ble_mesh_proxy_client_disconnect**(uint8_t conn_handle)

Proxy Client terminates a connection with the Proxy Server.

**Parameters** conn_handle - [in] Proxy connection handle.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t** **esp_ble_mesh_proxy_client_set_filter_type**(uint8_t conn_handle, uint16_t net_idx, esp_ble_mesh_proxy_filter_type_t filter_type)

Proxy Client sets the filter type of the Proxy Server.

**Parameters**
- conn_handle - [in] Proxy connection handle.
- net_idx - [in] Corresponding NetKey Index.
- filter_type - [in] whitelist or blacklist.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t** **esp_ble_mesh_proxy_client_add_filter_addr**(uint8_t conn_handle, uint16_t net_idx, uint16_t \*addr, uint16_t addr_num)

Proxy Client adds address to the Proxy Server filter list.

**Parameters**
- conn_handle - [in] Proxy connection handle.
- net_idx - [in] Corresponding NetKey Index.
- addr - [in] Pointer to the filter address.
- addr_num - [in] Number of the filter address.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t** **esp_ble_mesh_proxy_client_remove_filter_addr**(uint8_t conn_handle, uint16_t net_idx, uint16_t \*addr, uint16_t addr_num)

Proxy Client removes address from the Proxy Server filter list.

**Parameters**
- conn_handle - [in] Proxy connection handle.
- net_idx - [in] Corresponding NetKey Index.
- addr - [in] Pointer to the filter address.
- addr_num - [in] Number of the filter address.

**Returns** ESP_OK on success or error code otherwise.

**ESP-BLE-MESH Models API Reference**

This section contains ESP-BLE-MESH Model related APIs, event types, event parameters, etc.
There are six categories of models:

- **Configuration Client/Server Models**
- **Health Client/Server Models**
- **Generic Client/Server Models**
- **Sensor Client/Server Models**
- **Time and Scenes Client/Server Models**
- **Lighting Client/Server Models**

**Note:** Definitions related to Server Models are being updated, and will be released soon.

### Configuration Client/Server Models

**Header File**

```
components/bt/esp_ble_mesh/api/models/include/esp_ble_mesh_config_model_api.h
```

**Functions**

```c
esp_err_t esp_ble_mesh_register_config_client_callback(esp_ble_mesh_cfg_client_cb_t callback)
```

Register BLE Mesh Config Client Model callback.

- **Parameters**
  - `callback` - [in] Pointer to the callback function.
  - **Returns**
    - ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_register_config_server_callback(esp_ble_mesh_cfg_server_cb_t callback)
```

Register BLE Mesh Config Server Model callback.

- **Parameters**
  - `callback` - [in] Pointer to the callback function.
  - **Returns**
    - ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_config_client_get_state(esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_cfg_client_get_state_t *get_state)
```

Get the value of Config Server Model states using the Config Client Model get messages.

- **Parameters**
  - `params` - [in] Pointer to BLE Mesh common client parameters.
  - `get_state` - [in] Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.
  - **Returns**
    - ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_config_client_set_state(esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_cfg_client_set_state_t *set_state)
```

Set the value of the Configuration Server Model states using the Config Client Model set messages.

- **Note:** If you want to find the opcodes and corresponding meanings accepted by this API, please refer to `esp_ble_mesh_opcode_config_client_get_t` in `esp_ble_mesh_defs.h`
## Parameters

- **params**  
  Pointer to BLE Mesh common client parameters.
- **set_state**  
  Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.

### Returns

ESP_OK on success or error code otherwise.

---

### Unions

**union esp_ble_mesh_cfg_client_get_state_t**

```c
#include <esp_ble_mesh_config_model_api.h>

For ESP_BLE_MESH_MODEL_OP_BEACON_GET
ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_GET
ESP_BLE_MESH_MODEL_OP_GATT_PROXY_GET ESP_BLE_MESH_MODEL_OP_RELAY_GET
ESP_BLE_MESH_MODEL_OP_MODEL_PUB_GET ESP_BLE_MESH_MODEL_OP_FRIEND_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_GET ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_GET
```

The `get_state` parameter in the esp_ble_mesh_config_client_get_state function should not be set to NULL.

---

### Public Members

**esp_ble_mesh_cfg_model_pub_get_t model_pub_get**

For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_GET.

**esp_ble_mesh_cfg_composition_data_get_t comp_data_get**

For ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET.

**esp_ble_mesh_cfg_sig_model_sub_get_t sig_model_sub_get**

For ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_GET

**esp_ble_mesh_cfg_vnd_model_sub_get_t vnd_model_sub_get**

For ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_SUB_GET

**esp_ble_mesh_cfg_app_key_get_t app_key_get**

For ESP_BLE_MESH_MODEL_OP_APP_KEY_GET.

**esp_ble_mesh_cfg_node_identity_get_t node_identity_get**

For ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_GET.

**esp_ble_mesh_cfg_sig_model_app_get_t sig_model_app_get**

For ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_GET

**esp_ble_mesh_cfg_vnd_model_app_get_t vnd_model_app_get**

For ESP_BLE_MESH_MODEL_OP_VENDOR_MODEL_APP_GET

**esp_ble_mesh_cfg_kr_phase_get_t kr_phase_get**

For ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET

**esp_ble_mesh_cfg_lpn_polltimeout_get_t lpn_pollto_get**

For ESP_BLE_MESH_MODEL_OP_LPN_POLLTIMEOUT_GET

---

**union esp_ble_mesh_cfg_client_set_state_t**

```c
#include <esp_ble_mesh_config_model_api.h>

For ESP_BLE_MESH_MODEL_OP_BEACON_SET
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET
```
Chapter 2. API Reference

The `esp_ble_mesh_config_client_set_state` function should not be set to `NULL`.

### Public Members

- `esp_ble_mesh_cfg_beacon_set_t beacon_set`
  For `ESP_BLE_MESH_MODEL_OP_BEACON_SET`

- `esp_ble_mesh_cfg_default_ttl_set_t default_ttl_set`
  For `ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET`

- `esp_ble_mesh_cfg_friend_set_t friend_set`
  For `ESP_BLE_MESH_MODEL_OP_FRIEND_SET`

- `esp_ble_mesh_cfg_gatt_proxy_set_t gatt_proxy_set`
  For `ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET`

- `esp_ble_mesh_cfg_relay_set_t relay_set`
  For `ESP_BLE_MESH_MODEL_OP_RELAY_SET`

- `esp_ble_mesh_cfg_net_key_add_t net_key_add`
  For `ESP_BLE_MESH_MODEL_OP_NET_KEY_ADD`

- `esp_ble_mesh_cfg_app_key_add_t app_key_add`
  For `ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD`

- `esp_ble_mesh_cfg_model_app_bind_t model_app_bind`
  For `ESP_BLE_MESH_MODEL_OP_MODEL_APP_BIND`

- `esp_ble_mesh_cfg_model_pub_set_t model_pub_set`
  For `ESP_BLE_MESH_MODEL_OP_MODEL_PUB_SET`

- `esp_ble_mesh_cfg_model_sub_add_t model_sub_add`
  For `ESP_BLE_MESH_MODEL_OP_MODEL_SUB_ADD`

- `esp_ble_mesh_cfg_model_sub_delete_t model_sub_delete`
  For `ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE`

- `esp_ble_mesh_cfg_model_sub_overwrite_t model_sub_overwrite`
  For `ESP_BLE_MESH_MODEL_OP_MODEL_SUB_OVERWRITE`

- `esp_ble_mesh_cfg_model_sub_va_add_t model_sub_va_add`
  For `ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_ADD`
configuration_client_common_cb_param_t

union

#include <esp_ble_mesh_config_model_api.h> Configuration Client Model received message union.

Public Members
Chapter 2. API Reference

```c
exp_ble_mesh_cfg_beacon_status_cb_t beacon_status
    The beacon status value

exp_ble_mesh_cfg_comp_data_status_cb_t comp_data_status
    The composition data status value

exp_ble_mesh_cfg_default_ttl_status_cb_t default_ttl_status
    The default_ttl status value

exp_ble_mesh_cfg_gatt_proxy_status_cb_t gatt_proxy_status
    The gatt_proxy status value

exp_ble_mesh_cfg_relay_status_cb_t relay_status
    The relay status value

exp_ble_mesh_cfg_model_pub_status_cb_t model_pub_status
    The model publication status value

exp_ble_mesh_cfg_model_sub_status_cb_t model_sub_status
    The model subscription status value

exp_ble_mesh_cfg_net_key_status_cb_t netkey_status
    The netkey status value

exp_ble_mesh_cfg_app_key_status_cb_t appkey_status
    The appkey status value

exp_ble_mesh_cfg_mod_app_status_cb_t model_app_status
    The model app status value

exp_ble_mesh_cfg_friend_status_cb_t friend_status
    The friend status value

exp_ble_mesh_cfg_hb_pub_status_cb_t heartbeat_pub_status
    The heartbeat publication status value

exp_ble_mesh_cfg_hb_sub_status_cb_t heartbeat_sub_status
    The heartbeat subscription status value

exp_ble_mesh_cfg_net_trans_status_cb_t net_transmit_status
    The network transmit status value

exp_ble_mesh_cfg_model_sub_list_cb_t model_sub_list
    The model subscription list value

exp_ble_mesh_cfg_net_key_list_cb_t netkey_list
    The network key index list value
```
esp_ble_mesh_cfg_app_key_list_cb_t appkey_list
The application key index list value

esp_ble_mesh_cfg_node_id_status_cb_t node_identity_status
The node identity status value

esp_ble_mesh_cfg_model_app_list_cb_t model_app_list
The model application key index list value

esp_ble_mesh_cfg_kr_phase_status_cb_t kr_phase_status
The key refresh phase status value

esp_ble_mesh_cfg_lpn_pollto_status_cb_t lpn_timeout_status
The low powernode polltimeout status value

union esp_ble_mesh_cfg_server_state_change_t
#include <esp_ble_mesh_config_model_api.h> Configuration Server model state change value union.

Public Members

esp_ble_mesh_state_change_cfg_mod_pub_set_t mod_pub_set
The recv_op in ctx can be used to decide which state is changed. Config Model Publication Set

esp_ble_mesh_state_change_cfg_mod_sub_add_t mod_sub_add
Config Model Subscription Add

esp_ble_mesh_state_change_cfg_mod_sub_delete_t mod_sub_delete
Config Model Subscription Delete

esp_ble_mesh_state_change_cfg_netkey_add_t netkey_add
Config NetKey Add

esp_ble_mesh_state_change_cfg_netkey_update_t netkey_update
Config NetKey Update

esp_ble_mesh_state_change_cfg_netkey_delete_t netkey_delete
Config NetKey Delete

esp_ble_mesh_state_change_cfg_appkey_add_t appkey_add
Config AppKey Add

esp_ble_mesh_state_change_cfg_appkey_update_t appkey_update
Config AppKey Update

esp_ble_mesh_state_change_cfg_appkey_delete_t appkey_delete
Config AppKey Delete
Chapter 2. API Reference

`esp_ble_mesh_state_change_cfg_model_app_bind_t mod_app_bind`
Config Model App Bind

`esp_ble_mesh_state_change_cfg_model_app_unbind_t mod_app_unbind`
Config Model App Unbind

`esp_ble_mesh_state_change_cfg_kr_phase_set_t kr_phase_set`
Config Key Refresh Phase Set

union `esp_ble_mesh_cfg_server_cb_value_t`  
#include <esp_ble_mesh_config_model_api.h> Configuration Server model callback value union.

Public Members

`esp_ble_mesh_cfg_server_state_change_t state_change`
ESP_BLE_MESH_CFG_SERVER_STATE_CHANGE_EVT

Structures
struct `esp_ble_mesh_cfg_srv`  
Configuration Server Model context

Public Members

`esp_ble_mesh_model_t *model`
Pointer to Configuration Server Model

uint8_t net_transmit  
Network Transmit state

uint8_t relay  
Relay Mode state

uint8_t relay_retransmit  
Relay Retransmit state

uint8_t beacon  
Secure Network Beacon state

uint8_t gatt_proxy  
GATT Proxy state

uint8_t friend_state  
Friend state

uint8_t default_ttl  
Default TTL
Chapter 2. API Reference

```c
struct k_delayed_work timer
    Heartbeat Publication timer

uint16_t dst
    Destination address for Heartbeat messages

uint16_t count
    Number of Heartbeat messages to be sent
    Number of Heartbeat messages received

uint8_t period
    Period for sending Heartbeat messages

uint8_t ttl
    TTL to be used when sending Heartbeat messages

uint16_t feature
    Bit field indicating features that trigger Heartbeat messages when changed

uint16_t net_idx
    NetKey Index used by Heartbeat Publication

struct esp_ble_mesh_cfg_srv::[anonymous] heartbeat_pub
    Heartbeat Publication

int64_t expiry
    Timestamp when Heartbeat subscription period is expired

uint16_t src
    Source address for Heartbeat messages

uint8_t min_hops
    Minimum hops when receiving Heartbeat messages

uint8_t max_hops
    Maximum hops when receiving Heartbeat messages

esp_ble_mesh_cb_t heartbeat_recv_cb
    Optional heartbeat subscription tracking function

struct esp_ble_mesh_cfg_srv::[anonymous] heartbeat_sub
    Heartbeat Subscription

struct esp_ble_mesh_cfg_composition_data_get_t
    Parameters of Config Composition Data Get.
```

Public Members
uint8_t page
    Page number of the Composition Data.

struct esp_ble_mesh_cfg_model_pub_get_t
    Parameters of Config Model Publication Get.

    Public Members

    uint16_t element_addr
        The element address

    uint16_t model_id
        The model id

    uint16_t company_id
        The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_sig_model_sub_get_t
    Parameters of Config SIG Model Subscription Get.

    Public Members

    uint16_t element_addr
        The element address

    uint16_t model_id
        The model id

struct esp_ble_mesh_cfg_vnd_model_sub_get_t
    Parameters of Config Vendor Model Subscription Get.

    Public Members

    uint16_t element_addr
        The element address

    uint16_t model_id
        The model id

    uint16_t company_id
        The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_app_key_get_t
    Parameters of Config AppKey Get.
Public Members

uint16_t net_idx
    The network key index

struct esp_ble_mesh_cfg_node_identity_get_t
Parameters of Config Node Identity Get.

Public Members

uint16_t net_idx
    The network key index

struct esp_ble_mesh_cfg_sig_model_app_get_t
Parameters of Config SIG Model App Get.

Public Members

uint16_t element_addr
    The element address

uint16_t model_id
    The model id

struct esp_ble_mesh_cfg_vnd_model_app_get_t
Parameters of Config Vendor Model App Get.

Public Members

uint16_t element_addr
    The element address

uint16_t model_id
    The model id

uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_kr_phase_get_t
Parameters of Config Key Refresh Phase Get.

Public Members

uint16_t net_idx
    The network key index
struct esp_ble_mesh_cfg_lpn_polltimeout_get_t
Parameters of Config Low Power Node PollTimeout Get.

Public Members

uint16_t lpn_addr
The unicast address of the Low Power node

struct esp_ble_mesh_cfg_beacon_set_t
Parameters of Config Beacon Set.

Public Members

uint8_t beacon
New Secure Network Beacon state

struct esp_ble_mesh_cfg_default_ttl_set_t
Parameters of Config Default TTL Set.

Public Members

uint8_t ttl
The default TTL state value

struct esp_ble_mesh_cfg_friend_set_t
Parameters of Config Friend Set.

Public Members

uint8_t friend_state
The friend state value

struct esp_ble_mesh_cfg_gatt_proxy_set_t
Parameters of Config GATT Proxy Set.

Public Members

uint8_t gatt_proxy
The GATT Proxy state value

struct esp_ble_mesh_cfg_relay_set_t
Parameters of Config Relay Set.
Public Members

uint8_t relay
The relay value

uint8_t relay_retransmit
The relay retransmit value

struct esp_ble_mesh_cfg_net_key_add_t
Parameters of Config NetKey Add.

Public Members

uint16_t net_idx
The network key index

uint8_t net_key[16]
The network key value

struct esp_ble_mesh_cfg_app_key_add_t
Parameters of Config AppKey Add.

Public Members

uint16_t net_idx
The network key index

uint16_t app_idx
The app key index

uint8_t app_key[16]
The app key value

struct esp_ble_mesh_cfg_model_app_bind_t
Parameters of Config Model App Bind.

Public Members

uint16_t element_addr
The element address

uint16_t model_app_idx
Index of the app key to bind with the model

uint16_t model_id
The model id
Chapter 2. API Reference

```c
uint16_t company_id
     The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_model_pub_set_t
     Parameters of Config Model Publication Set.

     Public Members

     uint16_t element_addr
             The element address

     uint16_t publish_addr
             Value of the publish address

     uint16_t publish_app_idx
             Index of the application key

     bool cred_flag
             Value of the Friendship Credential Flag

     uint8_t publish_ttl
             Default TTL value for the publishing messages

     uint8_t publish_period
             Period for periodic status publishing

     uint8_t publish_retransmit
             Number of retransmissions and number of 50-millisecond steps between retransmissions

     uint16_t model_id
             The model id

     uint16_t company_id
             The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_model_sub_add_t
     Parameters of Config Model Subscription Add.

     Public Members

     uint16_t element_addr
             The element address

     uint16_t sub_addr
             The address to be added to the Subscription List
```
uint16_t **model_id**
The model id

uint16_t **company_id**
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_delete_t**
Parameters of Config Model Subscription Delete.

**Public Members**

uint16_t **element_addr**
The element address

uint16_t **sub_addr**
The address to be removed from the Subscription List

uint16_t **model_id**
The model id

uint16_t **company_id**
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_overwrite_t**
Parameters of Config Model Subscription Overwrite.

**Public Members**

uint16_t **element_addr**
The element address

uint16_t **sub_addr**
The address to be added to the Subscription List

uint16_t **model_id**
The model id

uint16_t **company_id**
The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_va_add_t**
Parameters of Config Model Subscription Virtual Address Add.

**Public Members**
uint16_t element_addr
    The element address

uint8_t label_uuid[16]
    The Label UUID of the virtual address to be added to the Subscription List

uint16_t model_id
    The model id

uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_model_sub_va_delete_t
    Parameters of Config Model Subscription Virtual Address Delete.

Public Members

uint16_t element_addr
    The element address

uint8_t label_uuid[16]
    The Label UUID of the virtual address to be removed from the Subscription List

uint16_t model_id
    The model id

uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_model_sub_va_overwrite_t
    Parameters of Config Model Subscription Virtual Address Overwrite.

Public Members

uint16_t element_addr
    The element address

uint8_t label_uuid[16]
    The Label UUID of the virtual address to be added to the Subscription List

uint16_t model_id
    The model id

uint16_t company_id
    The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_model_pub_va_set_t
    Parameters of Config Model Publication Virtual Address Set.
Public Members

`uint16_t element_addr`
- The element address

`uint8_t label_uuid[16]`
- Value of the Label UUID publish address

`uint16_t publish_app_idx`
- Index of the application key

`bool cred_flag`
- Value of the Friendship Credential Flag

`uint8_t publish_ttl`
- Default TTL value for the publishing messages

`uint8_t publish_period`
- Period for periodic status publishing

`uint8_t publish_retransmit`
- Number of retransmissions and number of 50-millisecond steps between retransmissions

`uint16_t model_id`
- The model id

`uint16_t company_id`
- The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_model_sub_delete_all_t**
- Parameters of Config Model Subscription Delete All.

Public Members

`uint16_t element_addr`
- The element address

`uint16_t model_id`
- The model id

`uint16_t company_id`
- The company id, if not a vendor model, shall set to 0xFFFF

**struct esp_ble_mesh_cfg_net_key_update_t**
- Parameters of Config NetKey Update.
Chapter 2. API Reference

Public Members

```c
uint16_t net_idx
    The network key index
```

```c
uint8_t net_key[16]
    The network key value
```

```c
struct esp_ble_mesh_cfg_net_key_delete_t
    Parameters of Config NetKey Delete.
```

Public Members

```c
uint16_t net_idx
    The network key index
```

```c
struct esp_ble_mesh_cfg_app_key_update_t
    Parameters of Config AppKey Update.
```

Public Members

```c
uint16_t net_idx
    The network key index
```

```c
uint16_t app_idx
    The app key index
```

```c
uint8_t app_key[16]
    The app key value
```

```c
struct esp_ble_mesh_cfg_app_key_delete_t
    Parameters of Config AppKey Delete.
```

Public Members

```c
uint16_t net_idx
    The network key index
```

```c
uint16_t app_idx
    The app key index
```

```c
struct esp_ble_mesh_cfg_node_identity_set_t
    Parameters of Config Node Identity Set.
```
Public Members

uint16_t net_idx
  The network key index

uint8_t identity
  New Node Identity state

struct esp_ble_mesh_cfg_model_app_unbind_t
  Parameters of Config Model App Unbind.

Public Members

uint16_t element_addr
  The element address

uint16_t model_app_idx
  Index of the app key to bind with the model

uint16_t model_id
  The model id

uint16_t company_id
  The company id, if not a vendor model, shall set to 0xFFFF

struct esp_ble_mesh_cfg_kr_phase_set_t
  Parameters of Config Key Refresh Phase Set.

Public Members

uint16_t net_idx
  The network key index

uint8_t transition
  New Key Refresh Phase Transition

struct esp_ble_mesh_cfg_net_transmit_set_t
  Parameters of Config Network Transmit Set.

Public Members

uint8_t net_transmit
  Network Transmit State

struct esp_ble_mesh_cfg_heartbeat_pub_set_t
  Parameters of Config Model Heartbeat Publication Set.
**Public Members**

`uint16_t dst`
Destination address for Heartbeat messages

`uint8_t count`
Number of Heartbeat messages to be sent

`uint8_t period`
Period for sending Heartbeat messages

`uint8_t ttl`
TTL to be used when sending Heartbeat messages

`uint16_t feature`
Bit field indicating features that trigger Heartbeat messages when changed

`uint16_t net_idx`
NetKey Index

**struct esp_ble_mesh_cfg_heartbeat_sub_set_t**
Parameters of Config Model Heartbeat Subscription Set.

**Public Members**

`uint16_t src`
Source address for Heartbeat messages

`uint16_t dst`
Destination address for Heartbeat messages

`uint8_t period`
Period for receiving Heartbeat messages

**struct esp_ble_mesh_cfg_beacon_status_cb_t**
Parameter of Config Beacon Status

**Public Members**

`uint8_t beacon`
Secure Network Beacon state value

**struct esp_ble_mesh_cfg_comp_data_status_cb_t**
Parameters of Config Composition Data Status
Chapter 2. API Reference

Public Members

uint8_t \texttt{page}

Page number of the Composition Data

struct net_buf_simple *\texttt{composition_data}

Pointer to Composition Data for the identified page

struct \texttt{esp_ble_mesh_cfg_default_ttl_status_cb_t}

Parameter of Config Default TTL Status

Public Members

uint8_t \texttt{default_ttl}

Default TTL state value

struct \texttt{esp_ble_mesh_cfg_gatt_proxy_status_cb_t}

Parameter of Config GATT Proxy Status

Public Members

uint8_t \texttt{gatt_proxy}

GATT Proxy state value

struct \texttt{esp_ble_mesh_cfg_relay_status_cb_t}

Parameters of Config Relay Status

Public Members

uint8_t \texttt{relay}

Relay state value

uint8_t \texttt{retransmit}

Relay retransmit value (number of retransmissions and number of 10-millisecond steps between retransmissions)

struct \texttt{esp_ble_mesh_cfg_model_pub_status_cb_t}

Parameters of Config Model Publication Status

Public Members

uint8_t \texttt{status}

Status Code for the request message

uint16_t \texttt{element_addr}

Address of the element
uint16_t publish_addr
    Value of the publish address

uint16_t app_idx
    Index of the application key

bool cred_flag
    Value of the Friendship Credential Flag

uint8_t ttl
    Default TTL value for the outgoing messages

uint8_t period
    Period for periodic status publishing

uint8_t transmit
    Number of retransmissions and number of 50-millisecond steps between retransmissions

uint16_t company_id
    Company ID

uint16_t model_id
    Model ID

struct esp_ble_mesh_cfg_model_sub_status_cb_t
    Parameters of Config Model Subscription Status

Public Members

uint8_t status
    Status Code for the request message

uint16_t element_addr
    Address of the element

uint16_t sub_addr
    Value of the address

uint16_t company_id
    Company ID

uint16_t model_id
    Model ID

struct esp_ble_mesh_cfg_net_key_status_cb_t
    Parameters of Config NetKey Status
Chapter 2. API Reference

**Public Members**

```c
uint8_t status
    Status Code for the request message
```

```c
uint16_t net_idx
    Index of the NetKey
```

```c
struct esp_ble_mesh_cfg_app_key_status_cb_t
    Parameters of Config AppKey Status
```

**Public Members**

```c
uint8_t status
    Status Code for the request message
```

```c
uint16_t net_idx
    Index of the NetKey
```

```c
uint16_t app_idx
    Index of the application key
```

```c
struct esp_ble_mesh_cfg_mod_app_status_cb_t
    Parameters of Config Model App Status
```

**Public Members**

```c
uint8_t status
    Status Code for the request message
```

```c
uint16_t element_addr
    Address of the element
```

```c
uint16_t app_idx
    Index of the application key
```

```c
uint16_t company_id
    Company ID
```

```c
uint16_t model_id
    Model ID
```

```c
struct esp_ble_mesh_cfg_friend_status_cb_t
    Parameter of Config Friend Status
```
Public Members

uint8_t friend_state
Friend state value

struct esp_ble_mesh_cfg hb_pub_status_cb_t
Parameters of Config Heartbeat Publication Status

Public Members

uint8_t status
Status Code for the request message

uint16_t dst
Destination address for Heartbeat messages

uint8_t count
Number of Heartbeat messages remaining to be sent

uint8_t period
Period for sending Heartbeat messages

uint8_t ttl
TTL to be used when sending Heartbeat messages

uint16_t features
Features that trigger Heartbeat messages when changed

uint16_t net_idx
Index of the NetKey

struct esp_ble_mesh_cfg hb_sub_status_cb_t
Parameters of Config Heartbeat Subscription Status

Public Members

uint8_t status
Status Code for the request message

uint16_t src
Source address for Heartbeat messages

uint16_t dst
Destination address for Heartbeat messages

uint8_t period
Remaining Period for processing Heartbeat messages
uint8_t count
    Number of Heartbeat messages received

uint8_t min_hops
    Minimum hops when receiving Heartbeat messages

uint8_t max_hops
    Maximum hops when receiving Heartbeat messages

struct esp_ble_mesh_cfg_net_trans_status_cb_t
    Parameters of Config Network Transmit Status

Public Members

uint8_t net_trans_count
    Number of transmissions for each Network PDU originating from the node

uint8_t net_trans_step
    Maximum hops when receiving Heartbeat messages

struct esp_ble_mesh_cfg_model_sub_list_cb_t
    Parameters of Config SIG/Vendor Subscription List

Public Members

uint8_t status
    Status Code for the request message

uint16_t element_addr
    Address of the element

uint16_t company_id
    Company ID

uint16_t model_id
    Model ID

struct net_buf_simple *sub_addr
    A block of all addresses from the Subscription List

struct esp_ble_mesh_cfg_net_key_list_cb_t
    Parameter of Config NetKey List

Public Members
struct net_buf_simple *net_idx
A list of NetKey Indexes known to the node

struct esp_ble_mesh_cfg_app_key_list_cb_t
Parameters of Config AppKey List

**Public Members**

uint8_t status
Status Code for the request message

uint16_t net_idx
NetKey Index of the NetKey that the AppKeys are bound to

struct net_buf_simple *app_idx
A list of AppKey indexes that are bound to the NetKey identified by NetKeyIndex

struct esp_ble_mesh_cfg_node_id_status_cb_t
Parameters of Config Node Identity Status

**Public Members**

uint8_t status
Status Code for the request message

uint16_t net_idx
Index of the NetKey

uint8_t identity
Node Identity state

struct esp_ble_mesh_cfg_model_app_list_cb_t
Parameters of Config SIG/Vendor Model App List

**Public Members**

uint8_t status
Status Code for the request message

uint16_t element_addr
Address of the element

uint16_t company_id
Company ID
uint16_t model_id
Model ID

struct net_buf_simple *app_idx
All AppKey indexes bound to the Model

struct esp_ble_mesh_cfg_kr_phase_status_cb_t
Parameters of Config Key Refresh Phase Status

Public Members

uint8_t status
Status Code for the request message

uint16_t net_idx
Index of the NetKey

uint8_t phase
Key Refresh Phase state

struct esp_ble_mesh_cfg_lpn_pollto_status_cb_t
Parameters of Config Low Power Node PollTimeout Status

Public Members

uint16_t lpn_addr
The unicast address of the Low Power node

int32_t poll_timeout
The current value of the PollTimeout timer of the Low Power node

struct esp_ble_mesh_cfg_client_cb_param_t
Configuration Client Model callback parameters

Public Members

int error_code
Appropriate error code

esp_ble_mesh_client_common_param_t *params
The client common parameters

esp_ble_mesh_cfg_client_common_cb_param_t status_cb
The config status message callback values

struct esp_ble_mesh_state_change_cfg_mod_pub_set_t
Configuration Server model related context.
Public Members

```c
uint16_t element_addr
   Element Address

uint16_t pub_addr
   Publish Address

uint16_t app_idx
   AppKey Index

bool cred_flag
   Friendship Credential Flag

uint8_t pub_ttl
   Publish TTL

uint8_t pub_period
   Publish Period

uint8_t pub_retransmit
   Publish Retransmit

uint16_t company_id
   Company ID

uint16_t model_id
   Model ID
```

```c
struct esp_ble_mesh_state_change_cfg_model_sub_add_t
   Parameters of Config Model Subscription Add
```

Public Members

```c
uint16_t element_addr
   Element Address

uint16_t sub_addr
   Subscription Address

uint16_t company_id
   Company ID

uint16_t model_id
   Model ID
```

```c
struct esp_ble_mesh_state_change_cfg_model_sub_delete_t
   Parameters of Config Model Subscription Delete
```
Public Members

`uint16_t element_addr`
Element Address

`uint16_t sub_addr`
Subscription Address

`uint16_t company_id`
Company ID

`uint16_t model_id`
Model ID

struct `esp_ble_mesh_state_change_cfg_netkey_add_t`
Parameters of Config NetKey Add

Public Members

`uint16_t net_idx`
NetKey Index

`uint8_t net_key[16]`
NetKey

struct `esp_ble_mesh_state_change_cfg_netkey_update_t`
Parameters of Config NetKey Update

Public Members

`uint16_t net_idx`
NetKey Index

`uint8_t net_key[16]`
NetKey

struct `esp_ble_mesh_state_change_cfg_netkey_delete_t`
Parameter of Config NetKey Delete

Public Members

`uint16_t net_idx`
NetKey Index

struct `esp_ble_mesh_state_change_cfg_appkey_add_t`
Parameters of Config AppKey Add
Public Members

```c
uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index

uint8_t app_key[16]
AppKey

struct esp_ble_mesh_state_change_cfg_appkey_update_t
Parameters of Config AppKey Update

Public Members

uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index

uint8_t app_key[16]
AppKey

struct esp_ble_mesh_state_change_cfg_appkey_delete_t
Parameters of Config AppKey Delete

Public Members

uint16_t net_idx
NetKey Index

uint16_t app_idx
AppKey Index

struct esp_ble_mesh_state_change_cfg_model_app_bind_t
Parameters of Config Model App Bind

Public Members

uint16_t element_addr
Element Address

uint16_t app_idx
AppKey Index
Chapter 2. API Reference

```c
uint16_t company_id
    Company ID

uint16_t model_id
    Model ID
```

```c
struct esp_ble_mesh_state_change_cfg_model_app_unbind_t
    Parameters of Config Model App Unbind
```

**Public Members**

```c
uint16_t element_addr
    Element Address

uint16_t app_idx
    AppKey Index
```

```c
uint16_t company_id
    Company ID

uint16_t model_id
    Model ID
```

```c
struct esp_ble_mesh_state_change_cfg_kr_phase_set_t
    Parameters of Config Key Refresh Phase Set
```

**Public Members**

```c
uint16_t net_idx
    NetKey Index
```

```c
uint8_t kr_phase
    New Key Refresh Phase Transition
```

```c
struct esp_ble_mesh_cfg_server_cb_param_t
    Configuration Server model callback parameters
```

**Public Members**

```c
esp_ble_mesh_model_t *model
    Pointer to the server model structure
```

```c
esp_ble_mesh_msg_ctx_t ctx
    Context of the received message
```

```c
esp_ble_mesh_cfg_server_cb_value_t value
    Value of the received configuration messages
```
Chapter 2. API Reference

**Macros**

**ESP_BLE_MESH_MODEL_CFG_SRV (srv_data)**

Define a new Config Server Model.

**Note:** The Config Server Model can only be included by a Primary Element.

**Parameters**

- **srv_data** - Pointer to a unique Config Server Model user_data.

**Returns** New Config Server Model instance.

**ESP_BLE_MESH_MODEL_CFG_CLI (cli_data)**

Define a new Config Client Model.

**Note:** The Config Client Model can only be included by a Primary Element.

**Parameters**

- **cli_data** - Pointer to a unique struct *esp_ble_mesh_client_t*.

**Returns** New Config Client Model instance.

**Type Definitions**

typedef struct *esp_ble_mesh_cfg_srv* esp_ble_mesh_cfg_srv_t

Configuration Server Model context

typedef void (*esp_ble_mesh_cfg_client_cb_t)(esp_ble_mesh_cfg_client_cb_event_t event, esp_ble_mesh_cfg_client_cb_param_t *param)

Bluetooth Mesh Config Client and Server Model functions.

Configuration Client Model callback function type

- **Param event** Event type
- **Param param** Pointer to callback parameter

typedef void (*esp_ble_mesh_cfg_server_cb_t)(esp_ble_mesh_cfg_server_cb_event_t event, esp_ble_mesh_cfg_server_cb_param_t *param)

Configuration Server Model callback function type.

- **Param event** Event type
- **Param param** Pointer to callback parameter

**Enumerations**

enum esp_ble_mesh_cfg_client_cb_event_t

This enum value is the event of Configuration Client Model

**Values:**

- **enumerator ESP_BLE_MESH_CFG_CLIENT_GET_STATE_EVT**
- **enumerator ESP_BLE_MESH_CFG_CLIENT_SET_STATE_EVT**
- **enumerator ESP_BLE_MESH_CFG_CLIENT_PUBLISH_EVT**
enumerator **ESP_BLE_MESH_CFG_CLIENT_TIMEOUT_EVT**

enumerator **ESP_BLE_MESH_CFG_CLIENT_EVT_MAX**

enum **esp_ble_mesh_cfg_server_cb_event_t**

This enum value is the event of Configuration Server model.

*Values:*

enumerator **ESP_BLE_MESH_CFG_SERVER_STATE_CHANGE_EVT**

enumerator **ESP_BLE_MESH_CFG_SERVER_EVT_MAX**

---

**Health Client/Server Models**

**Header File**

- components/bt/esp_ble_mesh/api/models/include/esp_ble_mesh_health_model_api.h

**Functions**

`esp_err_t esp_ble_mesh_register_health_client_callback(esp_ble_mesh_health_client_cb_t callback)`

Register BLE Mesh Health Model callback, the callback will report Health Client & Server Model events.

*Parameters* callback — [in] Pointer to the callback function.

*Returns* ESP_OK on success or error code otherwise.

`esp_err_t esp_ble_mesh_register_health_server_callback(esp_ble_mesh_health_server_cb_t callback)`

Register BLE Mesh Health Server Model callback.

*Parameters* callback — [in] Pointer to the callback function.

*Returns* ESP_OK on success or error code otherwise.

`esp_err_t esp_ble_mesh_health_client_get_state(esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_health_client_get_state_t *get_state)`

This function is called to get the Health Server states using the Health Client Model get messages.

*Note:* If you want to find the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_opcode_health_client_get_t in esp_ble_mesh_defs.h

*Parameters*

- *get_state* — [in] Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.

*Returns* ESP_OK on success or error code otherwise.

`esp_err_t esp_ble_mesh_health_client_set_state(esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_health_client_set_state_t *set_state)`

This function is called to set the Health Server states using the Health Client Model set messages.
Chapter 2. API Reference

Note: If you want to find the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_opcode_health_client_set_t in esp_ble_mesh_defs.h

Parameters

- **params** - [in] Pointer to BLE Mesh common client parameters.
- **set_state** - [in] Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.

Returns ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_health_server_fault_update (esp_ble_mesh_elem_t *element)
```

This function is called by the Health Server Model to update the context of its Health Current status.

Parameters **element** - [in] The element to which the Health Server Model belongs.

Returns ESP_OK on success or error code otherwise.

Unions

```c
union esp_ble_mesh_health_client_get_state_t
#include<esp_ble_mesh_health_model_api.h> For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET ESP_BLE_MESH_MODEL_OP_ATTENTION_GET ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET the get_state parameter in the esp_ble_mesh_health_client_get_state function should not be set to NULL.
```

Public Members

```c
esp_ble_mesh_health_fault_get_t fault_get
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET.
```

```c
union esp_ble_mesh_health_client_set_state_t
#include<esp_ble_mesh_health_model_api.h> For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK ESP_BLE_MESH_MODEL_OP_ATTENTION_SET ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK ESP_BLE_MESH_MODEL_OP_ATTENTION_SET the set_state parameter in the esp_ble_mesh_health_client_set_state function should not be set to NULL.
```

Public Members

```c
esp_ble_mesh_health_attention_set_t attention_set
For ESP_BLE_MESH_MODEL_OP_ATTENTION_SET or ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK.
```

```c
esp_ble_mesh_health_period_set_t period_set
For ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET or ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK.
```

```c
esp_ble_mesh_health_fault_test_t fault_test
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST or ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK.
```

```c
esp_ble_mesh_health_fault_clear_t fault_clear
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR or ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK.
```
union esp_ble_mesh_health_client_common_cb_param_t
#include <esp_ble_mesh_health_model_api.h> Health Client Model received message union.

Public Members

esp_ble_mesh_health_current_status_cb_t current_status
The health current status value

esp_ble_mesh_health_fault_status_cb_t fault_status
The health fault status value

esp_ble_mesh_health_period_status_cb_t period_status
The health period status value

esp_ble_mesh_health_attention_status_cb_t attention_status
The health attention status value

union esp_ble_mesh_health_server_cb_param_t
#include <esp_ble_mesh_health_model_api.h> Health Server Model callback parameters union.

Public Members

esp_ble_mesh_health_fault_update_comp_cb_t fault_update_comp
ESP_BLE_MESH_HEALTH_SERVER_FAULT_UPDATE_COMP_EVT

esp_ble_mesh_health_fault_clear_cb_t fault_clear
ESP_BLE_MESH_HEALTH_SERVER_FAULT_CLEAR_EVT

esp_ble_mesh_health_fault_test_cb_t fault_test
ESP_BLE_MESH_HEALTH_SERVER_FAULT_TEST_EVT

esp_ble_mesh_health_attention_on_cb_t attention_on
ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_ON_EVT

esp_ble_mesh_health_attention_off_cb_t attention_off
ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_OFF_EVT

Structures

struct esp_ble_mesh_health_srv_cb_t
ESP BLE Mesh Health Server callback

Public Members

esp_ble_mesh_cb_t fault_clear
Clear health registered faults. Initialized by the stack.
**esp_ble_mesh_cb_t fault_test**
Run a specific health test. Initialized by the stack.

**esp_ble_mesh_cb_t attention_on**
Health attention on callback. Initialized by the stack.

**esp_ble_mesh_cb_t attention_off**
Health attention off callback. Initialized by the stack.

**struct esp_ble_mesh_health_test_t**
ESP BLE Mesh Health Server test Context

### Public Members

- `uint8_t id_count`
  Number of Health self-test ID

- `const uint8_t *test_ids`
  Array of Health self-test IDs

- `uint16_t company_id`
  Company ID used to identify the Health Fault state

- `uint8_t prev_test_id`
  Current test ID of the health fault test

- `uint8_t current faults[ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE]`
  Array of current faults

- `uint8_t registered faults[ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE]`
  Array of registered faults

**struct esp_ble_mesh_health_srv_t**
ESP BLE Mesh Health Server Model Context

### Public Members

- `esp_ble_mesh_model_t *model`
  Pointer to Health Server Model

- `esp_ble_mesh_health_srv_cb_t health_cb`
  Health callback struct

- `struct k_delayed_work attention_timer`
  Attention Timer state

- `bool attention_timer_start`
  Attention Timer start flag
Chapter 2. API Reference

`esp_ble_mesh_health_test_t health_test`

Health Server fault test

`struct esp_ble_mesh_health_fault_get_t`

Parameter of Health Fault Get

**Public Members**

`uint16_t company_id`

Bluetooth assigned 16-bit Company ID

`struct esp_ble_mesh_health_attention_set_t`

Parameter of Health Attention Set

**Public Members**

`uint8_t attention`

Value of the Attention Timer state

`struct esp_ble_mesh_health_period_set_t`

Parameter of Health Period Set

**Public Members**

`uint8_t fast_period_divisor`

Divider for the Publish Period

`struct esp_ble_mesh_health_fault_test_t`

Parameter of Health Fault Test

**Public Members**

`uint16_t company_id`

Bluetooth assigned 16-bit Company ID

`uint8_t test_id`

ID of a specific test to be performed

`struct esp_ble_mesh_health_fault_clear_t`

Parameter of Health Fault Clear

**Public Members**

`uint16_t company_id`

Bluetooth assigned 16-bit Company ID
struct esp_ble_mesh_health_current_status_cb_t
Parameters of Health Current Status

Public Members

uint8_t test_id
ID of a most recently performed test

uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct net_buf_simple *fault_array
FaultArray field contains a sequence of 1-octet fault values

struct esp_ble_mesh_health_fault_status_cb_t
Parameters of Health Fault Status

Public Members

uint8_t test_id
ID of a most recently performed test

uint16_t company_id
Bluetooth assigned 16-bit Company ID

struct net_buf_simple *fault_array
FaultArray field contains a sequence of 1-octet fault values

struct esp_ble_mesh_health_period_status_cb_t
Parameter of Health Period Status

Public Members

uint8_t fast_period_divisor
Divider for the Publish Period

struct esp_ble_mesh_health_attention_status_cb_t
Parameter of Health Attention Status

Public Members

uint8_t attention
Value of the Attention Timer state

struct esp_ble_mesh_health_client_cb_param_t
Health Client Model callback parameters
Public Members

`int error_code`
Appropriate error code

`esp_ble_mesh_client_common_param_t *params`
The client common parameters.

`esp_ble_mesh_health_client_common_cb_param_t status_cb`
The health message status callback values

struct `esp_ble_mesh_health_fault_update_comp_cb_t`
Parameter of publishing Health Current Status completion event

Public Members

`int error_code`
The result of publishing Health Current Status

`esp_ble_mesh_elem_t *element`
Pointer to the element which contains the Health Server Model

struct `esp_ble_mesh_health_fault_clear_cb_t`
Parameters of Health Fault Clear event

Public Members

`esp_ble_mesh_model_t *model`
Pointer to the Health Server Model

`uint16_t company_id`
Bluetooth assigned 16-bit Company ID

struct `esp_ble_mesh_health_fault_test_cb_t`
Parameters of Health Fault Test event

Public Members

`esp_ble_mesh_model_t *model`
Pointer to the Health Server Model

`uint8_t test_id`
ID of a specific test to be performed

`uint16_t company_id`
Bluetooth assigned 16-bit Company ID
struct `esp_ble_mesh_health_attention_on_cb_t`
    Parameter of Health Attention On event

    **Public Members**

    `esp_ble_mesh_model_t * model`
    Pointer to the Health Server Model

    `uint8_t time`
    Duration of attention timer on (in seconds)

struct `esp_ble_mesh_health_attention_off_cb_t`
    Parameter of Health Attention Off event

    **Public Members**

    `esp_ble_mesh_model_t * model`
    Pointer to the Health Server Model

**Macros**

`ESP_BLE_MESH_MODEL_HEALTH_SRV(srv, pub)`
Define a new Health Server Model.

**Note:** The Health Server Model can only be included by a Primary Element.

**Parameters**

- `srv` – Pointer to the unique struct `esp_ble_mesh_health_srv_t`.
- `pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.

**Returns** New Health Server Model instance.

`ESP_BLE_MESH_MODEL_HEALTH_CLI(cli_data)`
Define a new Health Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Health Client Model.

**Parameters**

- `cli_data` – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Health Client Model instance.

`ESP_BLE_MESH_HEALTH_PUB_DEFINE(_name, _max, _role)`
A helper to define a health publication context

**Parameters**

- `_name` – Name given to the publication context variable.
- `_max` – Maximum number of faults the element can have.
- `_role` – Role of the device which contains the model.
Chapter 2. API Reference

ESP_BLE_MESH_HEALTH_STANDARD_TEST
SIG identifier of Health Fault Test. 0x01 ~ 0xFF: Vendor Specific Test.

ESP_BLE_MESH_NO_FAULT
Fault values of Health Fault Test. 0x33 ~ 0x7F: Reserved for Future Use. 0x80 ~ 0xFF: Vendor Specific Warning/Error.

ESP_BLE_MESH_BATTERY_LOW_WARNING

ESP_BLE_MESH_BATTERY_LOW_ERROR

ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_WARNING

ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_LOW_ERROR

ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_WARNING

ESP_BLE_MESH_SUPPLY_VOLTAGE_TOO_HIGH_ERROR

ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_WARNING

ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_ERROR

ESP_BLE_MESH_NO_LOAD_WARNING

ESP_BLE_MESH_NO_LOAD_ERROR

ESP_BLE_MESH_OVERLOAD_WARNING

ESP_BLE_MESH_OVERLOAD_ERROR

ESP_BLE_MESH_OVERHEAT_WARNING

ESP_BLE_MESH_OVERHEAT_ERROR

ESP_BLE_MESH_CONDENSATION_WARNING

ESP_BLE_MESH_CONDENSATION_ERROR

ESP_BLE_MESH_VIBRATION_WARNING

ESP_BLE_MESH_VIBRATION_ERROR

ESP_BLE_MESH_CONFIGURATION_WARNING

ESP_BLE_MESH_CONFIGURATION_ERROR
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_WARNING
ESP_BLE_MESH_ELEMENT_NOT_CALIBRATED_ERROR
ESP_BLE_MESH_MEMORY_WARNING
ESP_BLE_MESH_MEMORY_ERROR
ESP_BLE_MESH_SELF_TEST_WARNING
ESP_BLE_MESH_SELF_TEST_ERROR
ESP_BLE_MESH_INPUT_TOO_LOW_WARNING
ESP_BLE_MESH_INPUT_TOO_LOW_ERROR
ESP_BLE_MESH_INPUT_TOO_HIGH_WARNING
ESP_BLE_MESH_INPUT_TOO_HIGH_ERROR
ESP_BLE_MESH_INPUT_NO_CHANGE_WARNING
ESP_BLE_MESH_INPUT_NO_CHANGE_ERROR
ESP_BLE_MESH_ACTUATOR_BLOCKED_WARNING
ESP_BLE_MESH_ACTUATOR_BLOCKED_ERROR
ESP_BLE_MESH_HOUSING_OPENED_WARNING
ESP_BLE_MESH_HOUSING_OPENED_ERROR
ESP_BLE_MESH_TAMPER_WARNING
ESP_BLE_MESH_TAMPER_ERROR
ESP_BLE_MESH_DEVICE_MOVED_WARNING
ESP_BLE_MESH_DEVICE_MOVED_ERROR
ESP_BLE_MESH_DEVICE_DROPPED_WARNING
ESP_BLE_MESH_DEVICE_DROPPED_ERROR
ESP_BLE_MESH_OVERFLOW_WARNING
Chapter 2. API Reference

ESP_BLE_MESH_OVERFLOW_ERROR

ESP_BLE_MESH_EMPTY_WARNING

ESP_BLE_MESH_EMPTY_ERROR

ESP_BLE_MESH_INTERNAL_BUS_WARNING

ESP_BLE_MESH_INTERNAL_BUS_ERROR

ESP_BLE_MESH_MECHANISM_JAMMED_WARNING

ESP_BLE_MESH_MECHANISM_JAMMED_ERROR

ESP_BLE_MESH_HEALTH_FAULT_ARRAY_SIZE

Type Definitions

typedef void (*esp_ble_mesh_health_client_cb_t)(esp_ble_mesh_health_client_cb_event_t event,
        esp_ble_mesh_health_client_cb_param_t *param)

    Bluetooth Mesh Health Client and Server Model function.
    Health Client Model callback function type
    
    Param event Event type
    Param param Pointer to callback parameter

typedef void (*esp_ble_mesh_health_server_cb_t)(esp_ble_mesh_health_server_cb_event_t event,
        esp_ble_mesh_health_server_cb_param_t *param)

    Health Server Model callback function type.
    Param event Event type
    Param param Pointer to callback parameter

Enumerations

enum esp_ble_mesh_health_client_cb_event_t

This enum value is the event of Health Client Model

Values:

enumerator ESP_BLE_MESH_HEALTH_CLIENT_GET_STATE_EVT

enumerator ESP_BLE_MESH_HEALTH_CLIENT_SET_STATE_EVT

enumerator ESP_BLE_MESH_HEALTH_CLIENT_PUBLISH_EVT

enumerator ESP_BLE_MESH_HEALTH_CLIENT_TIMEOUT_EVT

enumerator ESP_BLE_MESH_HEALTH_CLIENT_EVT_MAX
enum esp_ble_mesh_health_server_cb_event_t
This enum values is the event of Health Server Model

Values:

enumerator ESP_BLE_MESH_HEALTH_SERVER_FAULT_UPDATE_COMP_EVT
enumerator ESP_BLE_MESH_HEALTH_SERVER_FAULT_CLEAR_EVT
enumerator ESP_BLE_MESH_HEALTH_SERVER_FAULT_TEST_EVT
enumerator ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_ON_EVT
enumerator ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_OFF_EVT
enumerator ESP_BLE_MESH_HEALTH_SERVER_EVT_MAX

Generic Client/Server Models

Header File

- components/bt/esp_ble_mesh/api/models/include/esp_ble_mesh_generic_model_api.h

Functions

esp_err_t esp_ble_mesh_register_generic_client_callback(esp_ble_mesh_generic_client_cb_t callback)

Register BLE Mesh Generic Client Model callback.

Parameters

Returns
ESP_OK on success or error code otherwise.

esp_err_t esp_ble_mesh_generic_client_get_state(esp_ble_mesh_client_common_param_t *params,
    esp_ble_mesh_generic_client_get_state_t *get_state)

Get the value of Generic Server Model states using the Generic Client Model get messages.

Note: If you want to find the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_generic_message_opcode_t in esp_ble_mesh_defs.h

Parameters
- get_state – [in] Pointer to generic get message value. Shall not be set to NULL.

Returns
ESP_OK on success or error code otherwise.

esp_err_t esp_ble_mesh_generic_client_set_state(esp_ble_mesh_client_common_param_t *params,
    esp_ble_mesh_generic_client_set_state_t *set_state)

Set the value of Generic Server Model states using the Generic Client Model set messages.
Chapter 2. API Reference

**Note:** If you want to find the opcodes and corresponding meanings accepted by this API, please refer to `esp_ble_mesh_generic_message_opcode_t` in `esp_ble_mesh_defs.h`

---

**Parameters**
- **params** - [in] Pointer to BLE Mesh common client parameters.
- **set_state** - [in] Pointer to generic set message value. Shall not be set to NULL.

**Returns**
- ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_register_generic_server_callback(esp_ble_mesh_generic_server_cb_t callback)
```

Register BLE Mesh Generic Server Model callback.

- **Parameters**
  - callback - [in] Pointer to the callback function.
- **Returns**
  - ESP_OK on success or error code otherwise.

---

### Unions

**union esp_ble_mesh_generic_client_get_state_t**

```c
#include <esp_ble_mesh_generic_model_api.h>
```

Generic Client Model get message union.

#### Public Members

- **esp_ble_mesh_gen_user_property_get_t**
  - **user_property_get**
    - For ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET

- **esp_ble_mesh_gen_admin_property_get_t**
  - **admin_property_get**
    - For ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_GET

- **esp_ble_mesh_gen_manufacturer_property_get_t**
  - **manufacturer_property_get**
    - For ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET

- **esp_ble_mesh_gen_client_properties_get_t**
  - **client_properties_get**
    - For ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_GET

**union esp_ble_mesh_generic_client_set_state_t**

```c
#include <esp_ble_mesh_generic_model_api.h>
```

Generic Client Model set message union.

#### Public Members

- **esp_ble_mesh_gen_onoff_set_t**
  - **onoff_set**
    - For ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET & ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET_UNACK

- **esp_ble_mesh_gen_level_set_t**
  - **level_set**
    - For ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET & ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET_UNACK

- **esp_ble_mesh_gen_delta_set_t**
  - **delta_set**
    - For ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET & ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET_UNACK
Chapter 2. API Reference

\textit{esp\_ble\_mesh\_gen\_move\_set\_t move\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_MOVE\_SET & ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_MOVE\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_def\_trans\_time\_set\_t def\_trans\_time\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_DEF\_TRANS\_TIME\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_DEF\_TRANS\_TIME\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_onpowerup\_set\_t power\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_ONPOWERUP\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_ONPOWERUP\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_power\_level\_set\_t power\_level\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_POWER\_LEVEL\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_POWER\_LEVEL\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_power\_default\_set\_t power\_default\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_POWER\_DEFAULT\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_POWER\_DEFAULT\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_power\_range\_set\_t power\_range\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_POWER\_RANGE\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_POWER\_RANGE\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_loc\_global\_set\_t loc\_global\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_LOC\_GLOBAL\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_LOC\_GLOBAL\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_loc\_local\_set\_t loc\_local\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_LOC\_LOCAL\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_LOC\_LOCAL\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_user\_property\_set\_t user\_property\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_USER\_PROPERTY\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_USER\_PROPERTY\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_admin\_property\_set\_t admin\_property\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_ADMIN\_PROPERTY\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_ADMIN\_PROPERTY\_SET\_UNACK

\textit{esp\_ble\_mesh\_gen\_manufacturer\_property\_set\_t manufacturer\_property\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_MANUFACTURER\_PROPERTY\_SET &
ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_MANUFACTURER\_PROPERTY\_SET\_UNACK

union \textit{esp\_ble\_mesh\_gen\_client\_status\_cb\_t}
#include &lt;esp\_ble\_mesh\_generic\_model\_api\_h&gt; Generic Client Model received message union.

\textbf{Public Members}

\textit{esp\_ble\_mesh\_gen\_onoff\_status\_cb\_t onoff\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_GEN\_ONOFF\_STATUS
esp_ble_mesh_gen_level_status_cb_t level_status
For ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_STATUS

esp_ble_mesh_gen_def_trans_time_status_cb_t def_trans_time_status
For ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_STATUS

esp_ble_mesh_gen_onpowerup_status_cb_t onpowerup_status
For ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_STATUS

esp_ble_mesh_gen_power_level_status_cb_t power_level_status
For ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_STATUS

esp_ble_mesh_gen_power_last_status_cb_t power_last_status
For ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_STATUS

esp_ble_mesh_gen_power_default_status_cb_t power_default_status
For ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_STATUS

esp_ble_mesh_gen_power_range_status_cb_t power_range_status
For ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_STATUS

esp_ble_mesh_gen_battery_status_cb_t battery_status
For ESP_BLE_MESH_MODEL_OP_GEN_BATTERY_STATUS

esp_ble_mesh_gen_loc_global_status_cb_t location_global_status
For ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_STATUS

esp_ble_mesh_gen_loc_local_status_cb_t location_local_status
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_STATUS

esp_ble_mesh_gen_user_properties_status_cb_t user_properties_status
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_STATUS

esp_ble_mesh_gen_user_property_status_cb_t user_property_status
ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_STATUS

esp_ble_mesh_gen_admin_properties_status_cb_t admin_properties_status
ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_STATUS

esp_ble_mesh_gen_admin_property_status_cb_t admin_property_status
ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_STATUS

esp_ble_mesh_gen_manufacturer_properties_status_cb_t manufacturer_properties_status
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTIES_STATUS

esp_ble_mesh_gen_manufacturer_property_status_cb_t manufacturer_property_status
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_STATUS
**Chapter 2. API Reference**

```c
esp_ble_mesh_gen_client_properties_status cb_t client_properties_status
ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_STATUS
```

**union esp_ble_mesh_generic_server_state_change_t**

#include `<esp_ble_mesh_generic_model_api.h>` Generic Server Model state change value union.

**Public Members**

```c
esp_ble_mesh_state_change_gen_onoff_set_t onoff_set
   The recv_op in ctx can be used to decide which state is changed. Generic OnOff Set

esp_ble_mesh_state_change_gen_level_set_t level_set
   Generic Level Set

esp_ble_mesh_state_change_gen_delta_set_t delta_set
   Generic Delta Set

esp_ble_mesh_state_change_gen_move_set_t move_set
   Generic Move Set

esp_ble_mesh_state_change_gen_def_trans_time_set_t def_trans_time_set
   Generic Default Transition Time Set

esp_ble_mesh_state_change_gen_onpowerup_set_t onpowerup_set
   Generic OnPowerUp Set

esp_ble_mesh_state_change_gen_power_level_set_t power_level_set
   Generic Power Level Set

esp_ble_mesh_state_change_gen_power_default_set_t power_default_set
   Generic Power Default Set

esp_ble_mesh_state_change_gen_power_range_set_t power_range_set
   Generic Power Range Set

esp_ble_mesh_state_change_gen_loc_global_set_t loc_global_set
   Generic Location Global Set

esp_ble_mesh_state_change_gen_loc_local_set_t loc_local_set
   Generic Location Local Set

esp_ble_mesh_state_change_gen_user_property_set_t user_property_set
   Generic User Property Set

esp_ble_mesh_state_change_gen_admin_property_set_t admin_property_set
   Generic Admin Property Set
```
```c
union esp_ble_mesh_state_change_gen_manu_property_set_t manu_property_set
    Generic Manufacturer Property Set

union esp_ble_mesh_generic_server_recv_get_msg_t
    #include <esp_ble_mesh_generic_model_api.h> Generic Server Model received get message union.

Public Members

esp_ble_mesh_server_recv_gen_user_property_get_t user_property
    Generic User Property Get

esp_ble_mesh_server_recv_gen_admin_property_get_t admin_property
    Generic Admin Property Get

esp_ble_mesh_server_recv_gen_manufacturer_property_get_t manu_property
    Generic Manufacturer Property Get

esp_ble_mesh_server_recv_gen_client_properties_get_t client_properties
    Generic Client Properties Get

union esp_ble_mesh_generic_server_recv_set_msg_t
    #include <esp_ble_mesh_generic_model_api.h> Generic Server Model received set message union.

Public Members

esp_ble_mesh_server_recv_gen_onoff_set_t onoff
    Generic OnOff Set/Generic OnOff Set Unack

esp_ble_mesh_server_recv_gen_level_set_t level
    Generic Level Set/Generic Level Set Unack

esp_ble_mesh_server_recv_gen_delta_set_t delta
    Generic Delta Set/Generic Delta Set Unack

esp_ble_mesh_server_recv_gen_move_set_t move
    Generic Move Set/Generic Move Set Unack

esp_ble_mesh_server_recv_gen_def_trans_time_set_t def_trans_time
    Generic Default Transition Time Set/Generic Default Transition Time Set Unack

esp_ble_mesh_server_recv_gen_onpowerup_set_t onpowerup
    Generic OnPowerUp Set/Generic OnPowerUp Set Unack

esp_ble_mesh_server_recv_gen_power_level_set_t power_level
    Generic Power Level Set/Generic Power Level Set Unack
```
Chapter 2. API Reference

```c
#include <esp_ble_mesh_generic_model_api.h>

struct esp_ble_mesh_gen_onoff_set_t
{
    bool op_en
        Indicate if optional parameters are included
};
```

---

## Public Members

```c
struct esp_ble_mesh_gen_onoff_set_t
{
    bool op_en
        Indicate if optional parameters are included
};
```
**Chapter 2. API Reference**

**uint8_t onoff**
Target value of Generic OnOff state

**uint8_t tid**
Transaction ID

**uint8_t trans_time**
Time to complete state transition (optional)

**uint8_t delay**
Indicate message execution delay (C.1)

**struct esp_ble_mesh_gen_level_set_t**
Parameters of Generic Level Set.

**Public Members**

**bool op_en**
Indicate if optional parameters are included

**int16_t level**
Target value of Generic Level state

**uint8_t tid**
Transaction ID

**uint8_t trans_time**
Time to complete state transition (optional)

**uint8_t delay**
Indicate message execution delay (C.1)

**struct esp_ble_mesh_gen_delta_set_t**
Parameters of Generic Delta Set.

**Public Members**

**bool op_en**
Indicate if optional parameters are included

**int32_t level**
Delta change of Generic Level state

**uint8_t tid**
Transaction ID

**uint8_t trans_time**
Time to complete state transition (optional)
uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_gen_move_set_t
   Parameters of Generic Move Set.

   **Public Members**

   bool op_en
      Indicate if optional parameters are included

   int16_t delta_level
      Delta Level step to calculate Move speed for Generic Level state

   uint8_t tid
      Transaction ID

   uint8_t trans_time
      Time to complete state transition (optional)

   uint8_t delay
      Indicate message execution delay (C.1)

struct esp_ble_mesh_gen_def_trans_time_set_t
   Parameter of Generic Default Transition Time Set.

   **Public Members**

   uint8_t trans_time
      The value of the Generic Default Transition Time state

struct esp_ble_mesh_gen_onpowerup_set_t
   Parameter of Generic OnPowerUp Set.

   **Public Members**

   uint8_t onpowerup
      The value of the Generic OnPowerUp state

struct esp_ble_mesh_gen_power_level_set_t
   Parameters of Generic Power Level Set.

   **Public Members**

   bool op_en
      Indicate if optional parameters are included
uint16_t **power**
Target value of Generic Power Actual state

uint8_t **tid**
Transaction ID

uint8_t **trans_time**
Time to complete state transition (optional)

uint8_t **delay**
Indicate message execution delay (C.1)

struct **esp_ble_mesh_gen_power_default_set_t**
Parameter of Generic Power Default Set.

**Public Members**

uint16_t **power**
The value of the Generic Power Default state

struct **esp_ble_mesh_gen_power_range_set_t**
Parameters of Generic Power Range Set.

**Public Members**

uint16_t **range_min**
Value of Range Min field of Generic Power Range state

uint16_t **range_max**
Value of Range Max field of Generic Power Range state

struct **esp_ble_mesh_gen_loc_global_set_t**
Parameters of Generic Location Global Set.

**Public Members**

int32_t **global_latitude**
Global Coordinates (Latitude)

int32_t **global_longitude**
Global Coordinates (Longitude)

int16_t **global_altitude**
Global Altitude

struct **esp_ble_mesh_gen_loc_local_set_t**
Parameters of Generic Location Local Set.
Public Members

int16_t local_north
Local Coordinates (North)

int16_t local_east
Local Coordinates (East)

int16_t local_altitude
Local Altitude

uint8_t floor_number
Floor Number

uint16_t uncertainty
Uncertainty

struct esp_ble_mesh_gen_user_property_get_t
Parameter of Generic User Property Get.

Public Members

uint16_t property_id
Property ID identifying a Generic User Property

struct esp_ble_mesh_gen_user_property_set_t
Parameters of Generic User Property Set.

Public Members

uint16_t property_id
Property ID identifying a Generic User Property

struct net_buf_simple *property_value
Raw value for the User Property

struct esp_ble_mesh_gen_admin_property_get_t
Parameter of Generic Admin Property Get.

Public Members

uint16_t property_id
Property ID identifying a Generic Admin Property

struct esp_ble_mesh_gen_admin_property_set_t
Parameters of Generic Admin Property Set.
Public Members

uint16_t property_id
Property ID identifying a Generic Admin Property

uint8_t user_access
Enumeration indicating user access

struct net_buf_simple *property_value
Raw value for the Admin Property

struct esp_ble_mesh_gen_manufacturer_property_get_t
Parameter of Generic Manufacturer Property Get.

Public Members

uint16_t property_id
Property ID identifying a Generic Manufacturer Property

struct esp_ble_mesh_gen_manufacturer_property_set_t
Parameters of Generic Manufacturer Property Set.

Public Members

uint16_t property_id
Property ID identifying a Generic Manufacturer Property

uint8_t user_access
Enumeration indicating user access

struct esp_ble_mesh_gen_client_properties_get_t
Parameter of Generic Client Properties Get.

Public Members

uint16_t property_id
A starting Client Property ID present within an element

struct esp_ble_mesh_gen_onoff_status_cb_t
Bluetooth Mesh Generic Client Model Get and Set callback parameters structure.
Parameters of Generic OnOff Status.

Public Members
bool op_en
Indicate if optional parameters are included

uint8_t present_onoff
Current value of Generic OnOff state

uint8_t target_onoff
Target value of Generic OnOff state (optional)

uint8_t remain_time
Time to complete state transition (C.1)

struct esp_ble_mesh_gen_level_status_cb_t
Parameters of Generic Level Status.

**Public Members**

bool op_en
Indicate if optional parameters are included

int16_t present_level
Current value of Generic Level state

int16_t target_level
Target value of the Generic Level state (optional)

uint8_t remain_time
Time to complete state transition (C.1)

struct esp_ble_mesh_gen_def_trans_time_status_cb_t
Parameter of Generic Default Transition Time Status.

**Public Members**

uint8_t trans_time
The value of the Generic Default Transition Time state

struct esp_ble_mesh_gen_onpowerup_status_cb_t

**Public Members**

uint8_t onpowerup
The value of the Generic OnPowerUp state

struct esp_ble_mesh_gen_power_level_status_cb_t
Parameters of Generic Power Level Status.
### Public Members

**bool op_en**

Indicate if optional parameters are included

**uint16_t** present_power

Current value of Generic Power Actual state

**uint16_t** target_power

Target value of Generic Power Actual state (optional)

**uint8_t** remain_time

Time to complete state transition (C.1)

**struct esp_ble_mesh_gen_power_last_status_cb_t**

Parameter of Generic Power Last Status.

---

### Public Members

**uint16_t** power

The value of the Generic Power Last state

**struct esp_ble_mesh_gen_power_default_status_cb_t**

Parameter of Generic Power Default Status.

---

### Public Members

**uint16_t** power

The value of the Generic Default Last state

**struct esp_ble_mesh_gen_power_range_status_cb_t**

Parameters of Generic Power Range Status.

---

### Public Members

**uint8_t** status_code

Status Code for the request message

**uint16_t** range_min

Value of Range Min field of Generic Power Range state

**uint16_t** range_max

Value of Range Max field of Generic Power Range state

**struct esp_ble_mesh_gen_battery_status_cb_t**

Parameters of Generic Battery Status.
Public Members

uint32_t `battery_level`
Value of Generic Battery Level state

uint32_t `time_to_discharge`
Value of Generic Battery Time to Discharge state

uint32_t `time_to_charge`
Value of Generic Battery Time to Charge state

uint32_t `flags`
Value of Generic Battery Flags state

struct `esp_ble_mesh_gen_loc_global_status_cb_t`
Parameters of Generic Location Global Status.

Public Members

int32_t `global_latitude`
Global Coordinates (Latitude)

int32_t `global_longitude`
Global Coordinates (Longitude)

int16_t `global_altitude`
Global Altitude

struct `esp_ble_mesh_gen_loc_local_status_cb_t`
Parameters of Generic Location Local Status.

Public Members

int16_t `local_north`
Local Coordinates (North)

int16_t `local_east`
Local Coordinates (East)

int16_t `local_altitude`
Local Altitude

uint8_t `floor_number`
Floor Number

uint16_t `uncertainty`
Uncertainty
struct esp_ble_mesh_gen_user_properties_status_cb_t
Parameter of Generic User Properties Status.

Public Members

struct net_buf_simple *property_ids
Buffer contains a sequence of N User Property IDs

struct esp_ble_mesh_gen_user_property_status_cb_t
Parameters of Generic User Property Status.

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t property_id
Property ID identifying a Generic User Property

uint8_t user_access
Enumeration indicating user access (optional)

struct net_buf_simple *property_value
Raw value for the User Property (C.1)

struct esp_ble_mesh_gen_admin_properties_status_cb_t
Parameter of Generic Admin Properties Status.

Public Members

struct net_buf_simple *property_ids
Buffer contains a sequence of N Admin Property IDs

struct esp_ble_mesh_gen_admin_property_status_cb_t
Parameters of Generic Admin Property Status.

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t property_id
Property ID identifying a Generic Admin Property

uint8_t user_access
Enumeration indicating user access (optional)
struct net_buf_simple *property_value
Raw value for the Admin Property (C.1)

struct esp_ble_mesh_gen_manufacturer_properties_status_cb_t
Parameter of Generic Manufacturer Properties Status.

Public Members

struct net_buf_simple *property_ids
Buffer contains a sequence of N Manufacturer Property IDs

struct esp_ble_mesh_gen_manufacturer_property_status_cb_t
Parameters of Generic Manufacturer Property Status.

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t property_id
Property ID identifying a Generic Manufacturer Property

uint8_t user_access
Enumeration indicating user access (optional)

struct net_buf_simple *property_value
Raw value for the Manufacturer Property (C.1)

struct esp_ble_mesh_gen_client_properties_status_cb_t
Parameter of Generic Client Properties Status.

Public Members

struct net_buf_simple *property_ids
Buffer contains a sequence of N Client Property IDs

struct esp_ble_mesh_generic_client_cb_param_t
Generic Client Model callback parameters

Public Members

int error_code
Appropriate error code

esp_ble_mesh_client_common_param_t *params
The client common parameters.
**Chapter 2. API Reference**

```c
esp_ble_mesh_gen_client_status_cb_t status_cb
```

The generic status message callback values

**struct esp_ble_mesh_gen_onoff_state_t**

Parameters of Generic OnOff state

**Public Members**

```c
uint8_t onoff
```

The present value of the Generic OnOff state

```c
uint8_t target_onoff
```

The target value of the Generic OnOff state

**struct esp_ble_mesh_gen_onoff_srv_t**

User data of Generic OnOff Server Model

**Public Members**

```c
esp_ble_mesh_model_t *model
```

Pointer to the Generic OnOff Server Model. Initialized internally.

```c
esp_ble_mesh_server_rsp_ctrl_t rsp_ctrl
```

Response control of the server model received messages

```c
esp_ble_mesh_gen_onoff_state_t state
```

Parameters of the Generic OnOff state

```c
esp_ble_mesh_last_msg_info_t last
```

Parameters of the last received set message

```c
esp_ble_mesh_state_transition_t transition
```

Parameters of state transition

**struct esp_ble_mesh_gen_level_state_t**

Parameters of Generic Level state

**Public Members**

```c
int16_t level
```

The present value of the Generic Level state

```c
int16_t target_level
```

The target value of the Generic Level state
int16_t last_level
When a new transaction starts, level should be set to last_last, and use “level + incoming delta” to calculate the target level. In another word, “last_level” is used to record “level” of the last transaction, and “last_delta” is used to record the previously received delta_level value. The last value of the Generic Level state

int32_t last_delta
The last delta change of the Generic Level state

bool move_start
Indicate if the transition of the Generic Level state has been started

bool positive
Indicate if the transition is positive or negative

struct esp_ble_mesh_gen_level_srv_t
User data of Generic Level Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Level Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_gen_level_state_t state
Parameters of the Generic Level state

esp_ble_mesh_last_msg_info_t last
Parameters of the last received set message

esp_ble_mesh_state_transition_t transition
Parameters of state transition

int32_t tt_delta_level
Delta change value of level state transition

struct esp_ble_mesh_gen_def_trans_time_state_t
Parameter of Generic Default Transition Time state

Public Members

uint8_t trans_time
The value of the Generic Default Transition Time state

struct esp_ble_mesh_gen_def_trans_time_srv_t
User data of Generic Default Transition Time Server Model
**Public Members**

```c
esp_ble_mesh_model_t *model
// Pointer to the Generic Default Transition Time Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
// Response control of the server model received messages
```

```c
esp_ble_mesh_gen_def_trans_time_state_t state
// Parameters of the Generic Default Transition Time state
```

```c
struct esp_ble_mesh_gen_onpowerup_state_t
// Parameter of Generic OnPowerUp state
```

**Public Members**

```c
uint8_t onpowerup
// The value of the Generic OnPowerUp state
```

```c
struct esp_ble_mesh_gen_power_onoff_srv_t
// User data of Generic Power OnOff Server Model
```

**Public Members**

```c
esp_ble_mesh_model_t *model
// Pointer to the Generic Power OnOff Server Model. Initialized internally.
```

```c
esp_BLE_mesh_server_rsp_ctrl_t *rsp_ctrl
// Response control of the server model received messages
```

```c
esp_ble_mesh_gen_onpowerup_state_t *state
// Parameters of the Generic OnPowerUp state
```

```c
struct esp_ble_mesh_gen_power_onoff_setup_srv_t
// User data of Generic Power OnOff Setup Server Model
```

**Public Members**

```c
esp_ble_mesh_model_t *model
```

```c
esp_BLE_mesh_server_rsp_ctrl_t *rsp_ctrl
// Response control of the server model received messages
```

```c
esp_ble_mesh_gen_onpowerup_state_t *state
// Parameters of the Generic OnPowerUp state
```
Chapter 2. API Reference

**struct esp_ble_mesh_gen_power_level_state_t**

Parameters of Generic Power Level state

**Public Members**

**uint16_t power_actual**

The present value of the Generic Power Actual state

**uint16_t target_power_actual**

The target value of the Generic Power Actual state

**uint16_t power_last**

The value of the Generic Power Last state

**uint16_t power_default**

The value of the Generic Power Default state

**uint8_t status_code**

The status code of setting Generic Power Range state

**uint16_t power_range_min**

The minimum value of the Generic Power Range state

**uint16_t power_range_max**

The maximum value of the Generic Power Range state

**struct esp_ble_mesh_gen_power_level_srv_t**

User data of Generic Power Level Server Model

**Public Members**

**esp_ble_mesh_model_t *model**

Pointer to the Generic Power Level Server Model. Initialized internally.

**esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl**

Response control of the server model received messages

**esp_ble_mesh_gen_power_level_state_t *state**

Parameters of the Generic Power Level state

**esp_ble_mesh_last_msg_info_t last**

Parameters of the last received set message

**esp_ble_mesh_state_transition_t transition**

Parameters of state transition
Chapter 2. API Reference

int32_t tt_delta_level
Delta change value of level state transition

struct esp_ble_mesh_gen_power_level_setup_srv_t
User data of Generic Power Level Setup Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Power Level Setup Server Model. Initialized internally.

esp_ble_mesh_server rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_gen_power_level_state_t *state
Parameters of the Generic Power Level state

struct esp_ble_mesh_gen_battery_state_t
Parameters of Generic Battery state

Public Members

uint32_t battery_level
The value of the Generic Battery Level state

uint32_t time_to_discharge
The value of the Generic Battery Time to Discharge state

uint32_t time_to_charge
The value of the Generic Battery Time to Charge state

uint32_t battery_flags
The value of the Generic Battery Flags state

struct esp_ble_mesh_gen_battery_srv_t
User data of Generic Battery Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Generic Battery Server Model. Initialized internally.

esp_ble_mesh_server rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages
**Chapter 2. API Reference**

```c
esp_ble_mesh_gen_battery_state_t state
Parameters of the Generic Battery state
```

```c
struct esp_ble_mesh_gen_location_state_t
Parameters of Generic Location state
```

### Public Members

```c
int32_t global_latitude
The value of the Global Latitude field
```

```c
int32_t global_longitude
The value of the Global Longitude field
```

```c
int16_t global_altitude
The value of the Global Altitude field
```

```c
int16_t local_north
The value of the Local North field
```

```c
int16_t local_east
The value of the Local East field
```

```c
int16_t local_altitude
The value of the Local Altitude field
```

```c
uint8_t floor_number
The value of the Floor Number field
```

```c
uint16_t uncertainty
The value of the Uncertainty field
```

```c
struct esp_ble_mesh_gen_location_srv_t
User data of Generic Location Server Model
```

### Public Members

```c
esp_ble_mesh_model_t *model
Pointer to the Generic Location Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages
```

```c
esp_ble_mesh_gen_location_state_t *state
Parameters of the Generic Location state
```

```c
struct esp_ble_mesh_gen_location_setup_srv_t
User data of Generic Location Setup Server Model
```
Public Members

*esp_ble_mesh_model_t* model

Pointer to the Generic Location Setup Server Model. Initialized internally.

*esp_ble_mesh_server_rsp_ctrl_t* rsp_ctrl

Response control of the server model received messages

*esp_ble_mesh_gen_location_state_t* state

Parameters of the Generic Location state

struct esp_ble_mesh_gen_location_state_t

Parameters of Generic Property states

Public Members

uint16_t id

The value of User/Admin/Manufacturer Property ID

uint8_t user_access

The value of User Access field

uint8_t admin_access

The value of Admin Access field

uint8_t manu_access

The value of Manufacturer Access field

struct net_buf_simple* val

The value of User/Admin/Manufacturer Property

struct esp_ble_mesh_gen_user_prop_srv_t

User data of Generic User Property Server Model

Public Members

*esp_ble_mesh_model_t* model

Pointer to the Generic User Property Server Model. Initialized internally.

*esp_ble_mesh_server_rsp_ctrl_t* rsp_ctrl

Response control of the server model received messages

uint8_t property_count

Generic User Property count

*esp_ble_mesh_generic_property_t* properties

Parameters of the Generic User Property state
struct `esp_ble_mesh_gen_admin_prop_srv_t`
User data of Generic Admin Property Server Model

**Public Members**

`esp_ble_mesh_model_t *model`
Pointer to the Generic Admin Property Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages

`uint8_t property_count`
Generic Admin Property count

`esp_ble_mesh_generic_property_t *properties`
Parameters of the Generic Admin Property state

struct `esp_ble_mesh_gen_manu_prop_srv_t`
User data of Generic Manufacturer Property Server Model

**Public Members**

`esp_ble_mesh_model_t *model`
Pointer to the Generic Manufacturer Property Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages

`uint8_t property_count`
Generic Manufacturer Property count

`esp_ble_mesh_generic_property_t *properties`
Parameters of the Generic Manufacturer Property state

struct `esp_ble_mesh_gen_client_prop_srv_t`
User data of Generic Client Property Server Model

**Public Members**

`esp_ble_mesh_model_t *model`
Pointer to the Generic Client Property Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages
uint8_t id_count
    Generic Client Property ID count

uint16_t *property_ids
    Parameters of the Generic Client Property state

struct esp_ble_mesh_state_change_gen_onoff_set_t
    Parameter of Generic OnOff Set state change event

Public Members

uint8_t onoff
    The value of Generic OnOff state

struct esp_ble_mesh_state_change_gen_level_set_t
    Parameter of Generic Level Set state change event

Public Members

int16_t level
    The value of Generic Level state

struct esp_ble_mesh_state_change_gen_delta_set_t
    Parameter of Generic Delta Set state change event

Public Members

int16_t level
    The value of Generic Level state

struct esp_ble_mesh_state_change_gen_move_set_t
    Parameter of Generic Move Set state change event

Public Members

int16_t level
    The value of Generic Level state

struct esp_ble_mesh_state_change_gen_def_trans_time_set_t
    Parameter of Generic Default Transition Time Set state change event

Public Members

uint8_t trans_time
    The value of Generic Default Transition Time state
struct esp_ble_mesh_state_change_gen_onpowerup_set_t
    Parameter of Generic OnPowerUp Set state change event

    Public Members

    uint8_t onpowerup
        The value of Generic OnPowerUp state

struct esp_ble_mesh_state_change_gen_power_level_set_t
    Parameter of Generic Power Level Set state change event

    Public Members

    uint16_t power
        The value of Generic Power Actual state

struct esp_ble_mesh_state_change_gen_power_default_set_t
    Parameter of Generic Power Default Set state change event

    Public Members

    uint16_t power
        The value of Generic Power Default state

struct esp_ble_mesh_state_change_gen_power_range_set_t
    Parameters of Generic Power Range Set state change event

    Public Members

    uint16_t range_min
        The minimum value of Generic Power Range state

    uint16_t range_max
        The maximum value of Generic Power Range state

struct esp_ble_mesh_state_change_gen_loc_global_set_t
    Parameters of Generic Location Global Set state change event

    Public Members

    int32_t latitude
        The Global Latitude value of Generic Location state

    int32_t longitude
        The Global Longitude value of Generic Location state
int16_t **\texttt{altitude}
\hspace{1em} The Global Altitude value of Generic Location state

\textbf{struct} esp\_ble\_mesh\_state\_change\_gen\_loc\_local\_set\_t
\hspace{1em} Parameters of Generic Location Local Set state change event

\textbf{Public Members}

int16_t **\texttt{north}
\hspace{1em} The Local North value of Generic Location state

int16_t **\texttt{east}
\hspace{1em} The Local East value of Generic Location state

int16_t **\texttt{altitude}
\hspace{1em} The Local Altitude value of Generic Location state

uint8_t **\texttt{floor\_number}
\hspace{1em} The Floor Number value of Generic Location state

uint16_t **\texttt{uncertainty}
\hspace{1em} The Uncertainty value of Generic Location state

\textbf{struct} esp\_ble\_mesh\_state\_change\_gen\_user\_property\_set\_t
\hspace{1em} Parameters of Generic User Property Set state change event

\textbf{Public Members}

uint16_t **\texttt{id}
\hspace{1em} The property id of Generic User Property state

struct net\_buf\_simple\_*\texttt{value}
\hspace{1em} The property value of Generic User Property state

\textbf{struct} esp\_ble\_mesh\_state\_change\_gen\_admin\_property\_set\_t
\hspace{1em} Parameters of Generic Admin Property Set state change event

\textbf{Public Members}

uint16_t **\texttt{id}
\hspace{1em} The property id of Generic Admin Property state

uint8_t **\texttt{access}
\hspace{1em} The property access of Generic Admin Property state
struct net_buf_simple *value
    The property value of Generic Admin Property state

struct esp_ble_mesh_state_change_gen_manu_property_set_t
    Parameters of Generic Manufacturer Property Set state change event

Public Members

uint16_t id
    The property id of Generic Manufacturer Property state

uint8_t access
    The property value of Generic Manufacturer Property state

struct esp_ble_mesh_server_recv_gen_user_property_get_t
    Context of the received Generic User Property Get message

Public Members

uint16_t property_id
    Property ID identifying a Generic User Property

struct esp_ble_mesh_server_recv_gen_admin_property_get_t
    Context of the received Generic Admin Property Get message

Public Members

uint16_t property_id
    Property ID identifying a Generic Admin Property

struct esp_ble_mesh_server_recv_gen_manufacturer_property_get_t
    Context of the received Generic Manufacturer Property message

Public Members

uint16_t property_id
    Property ID identifying a Generic Manufacturer Property

struct esp_ble_mesh_server_recv_gen_client_properties_get_t
    Context of the received Generic Client Properties Get message

Public Members

uint16_t property_id
    A starting Client Property ID present within an element
struct esp_ble_mesh_server_recv_gen_onoff_set_t

Context of the received Generic OnOff Set message

Public Members

bool op_en
    Indicate if optional parameters are included

uint8_t onoff
    Target value of Generic OnOff state

uint8_t tid
    Transaction ID

uint8_t trans_time
    Time to complete state transition (optional)

uint8_t delay
    Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_gen_level_set_t

Context of the received Generic Level Set message

Public Members

bool op_en
    Indicate if optional parameters are included

int16_t level
    Target value of Generic Level state

uint8_t tid
    Transaction ID

uint8_t trans_time
    Time to complete state transition (optional)

uint8_t delay
    Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_gen_delta_set_t

Context of the received Generic Delta Set message

Public Members
bool op_en
   Indicate if optional parameters are included

int32_t delta_level
   Delta change of Generic Level state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_gen_move_set_t
   Context of the received Generic Move Set message

**Public Members**

bool op_en
   Indicate if optional parameters are included

int16_t delta_level
   Delta Level step to calculate Move speed for Generic Level state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_gen_def_trans_time_set_t
   Context of the received Generic Default Transition Time Set message

**Public Members**

uint8_t trans_time
   The value of the Generic Default Transition Time state

struct esp_ble_mesh_server_recv_gen_onpowerup_set_t
   Context of the received Generic OnPowerUp Set message
Chapter 2. API Reference

Public Members

```c
uint8_t onpowerup
```
The value of the Generic OnPowerUp state

```c
struct esp_ble_mesh_server_recv_gen_power_level_set_t
```
Context of the received Generic Power Level Set message

Public Members

```c
bool op_en
```
Indicate if optional parameters are included

```c
uint16_t power
```
Target value of Generic Power Actual state

```c
uint8_t tid
```
Transaction ID

```c
uint8_t trans_time
```
Time to complete state transition (optional)

```c
uint8_t delay
```
Indicate message execution delay (C.1)

```c
struct esp_ble_mesh_server_recv_gen_power_default_set_t
```
Context of the received Generic Power Default Set message

Public Members

```c
uint16_t power
```
The value of the Generic Power Default state

```c
struct esp_ble_mesh_server_recv_gen_power_range_set_t
```
Context of the received Generic Power Range Set message

Public Members

```c
uint16_t range_min
```
Value of Range Min field of Generic Power Range state

```c
uint16_t range_max
```
Value of Range Max field of Generic Power Range state

```c
struct esp_ble_mesh_server_recv_gen_loc_global_set_t
```
Context of the received Generic Location Global Set message
Chapter 2. API Reference

Public Members

int32_t \texttt{global_latitude}
Global Coordinates (Latitude)

int32_t \texttt{global_longitude}
Global Coordinates (Longitude)

int16_t \texttt{global_altitude}
Global Altitude

struct \texttt{esp\_ble\_mesh\_server\_recv\_gen\_loc\_local\_set\_t}
Context of the received Generic Location Local Set message

Public Members

int16_t \texttt{local_north}
Local Coordinates (North)

int16_t \texttt{local_east}
Local Coordinates (East)

int16_t \texttt{local_altitude}
Local Altitude

uint8_t \texttt{floor\_number}
Floor Number

uint16_t \texttt{uncertainty}
Uncertainty

struct \texttt{esp\_ble\_mesh\_server\_recv\_gen\_user\_property\_set\_t}
Context of the received Generic User Property Set message

Public Members

uint16_t \texttt{property\_id}
Property ID identifying a Generic User Property

struct net_buf_simple *\texttt{property\_value}
Raw value for the User Property

struct \texttt{esp\_ble\_mesh\_server\_recv\_gen\_admin\_property\_set\_t}
Context of the received Generic Admin Property Set message
Public Members

uint16_t property_id
   Property ID identifying a Generic Admin Property

uint8_t user_access
   Enumeration indicating user access

struct net_buf_simple *property_value
   Raw value for the Admin Property

struct esp_ble_mesh_server_recv_gen_manufacturer_property_set_t
   Context of the received Generic Manufacturer Property Set message

Public Members

uint16_t property_id
   Property ID identifying a Generic Manufacturer Property

uint8_t user_access
   Enumeration indicating user access

struct esp_ble_mesh_generic_server_cb_param_t
   Generic Server Model callback parameters

Public Members

esp_ble_mesh_model_t *model
   Pointer to Generic Server Models

esp_ble_mesh_msg_ctx_t ctx
   Context of the received messages

esp_ble_mesh_generic_server_cb_value_t value
   Value of the received Generic Messages

Macros

ESP_BLE_MESH_MODEL_GEN_ONOFF_CLI (cli_pub, cli_data)
   Define a new Generic OnOff Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic OnOff Client Model.

Parameters

- cli_pub - Pointer to the unique struct esp_ble_mesh_model_pub_t.
- cli_data - Pointer to the unique struct esp_ble_mesh_client_t.

Returns New Generic OnOff Client Model instance.
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_GEN_LEVEL_CLI (cli_pub, cli_data)
Define a new Generic Level Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Level Client Model.

Parameters
• cli_pub – Pointer to the unique struct esp_ble_mesh_model_pub_t.
• cli_data – Pointer to the unique struct esp_ble_mesh_client_t.
Returns New Generic Level Client Model instance.

ESP_BLE_MESH_MODEL_GEN_DEF_TRANS_TIME_CLI (cli_pub, cli_data)
Define a new Generic Default Transition Time Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Default Transition Time Client Model.

Parameters
• cli_pub – Pointer to the unique struct esp_ble_mesh_model_pub_t.
• cli_data – Pointer to the unique struct esp_ble_mesh_client_t.
Returns New Generic Default Transition Time Client Model instance.

ESP_BLE_MESH_MODEL_GEN_POWER_ONOFF_CLI (cli_pub, cli_data)
Define a new Generic Power OnOff Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Power OnOff Client Model.

Parameters
• cli_pub – Pointer to the unique struct esp_ble_mesh_model_pub_t.
• cli_data – Pointer to the unique struct esp_ble_mesh_client_t.
Returns New Generic Power OnOff Client Model instance.

ESP_BLE_MESH_MODEL_GEN_POWER_LEVEL_CLI (cli_pub, cli_data)
Define a new Generic Power Level Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Power Level Client Model.

Parameters
• cli_pub – Pointer to the unique struct esp_ble_mesh_model_pub_t.
• cli_data – Pointer to the unique struct esp_ble_mesh_client_t.
Returns New Generic Power Level Client Model instance.

ESP_BLE_MESH_MODEL_GEN_BATTERY_CLI (cli_pub, cli_data)
Define a new Generic Battery Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Battery Client Model.
Chapter 2. API Reference

Parameters

- **cli_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** - Pointer to the unique struct `esp_ble_mesh_client_t`.

Returns New Generic Battery Client Model instance.

**ESP_BLE_MESH_MODEL_GEN_LOCATION_CLI** (cli_pub, cli_data)
Define a new Generic Location Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Location Client Model.

Parameters

- **cli_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** - Pointer to the unique struct `esp_ble_mesh_client_t`.

Returns New Generic Location Client Model instance.

**ESP_BLE_MESH_MODEL_GEN_PROPERTY_CLI** (cli_pub, cli_data)
Define a new Generic Property Client Model.

Note: This API needs to be called for each element on which the application needs to have a Generic Property Client Model.

Parameters

- **cli_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** - Pointer to the unique struct `esp_ble_mesh_client_t`.

Returns New Generic Location Client Model instance.

**ESP_BLE_MESH_MODEL_GEN_ONOFF_SRV** (srv_pub, srv_data)
Generic Server Models related context.
Define a new Generic OnOff Server Model.

Note: 1. The Generic OnOff Server Model is a root model.
   a. This model shall support model publication and model subscription.

Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_gen_onoff_srv_t`.

Returns New Generic OnOff Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_LEVEL_SRV** (srv_pub, srv_data)
Define a new Generic Level Server Model.

Note: 1. The Generic Level Server Model is a root model.
   a. This model shall support model publication and model subscription.
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_GEN_DEF_TRANS_TIME_SRV (srv_pub, srv_data)
Define a new Generic Default Transition Time Server Model.

**Note:** 1. The Generic Default Transition Time Server Model is a root model.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_def_trans_time_srv_t`.

**Returns** New Generic Default Transition Time Server Model instance.

ESP_BLE_MESH_MODEL_GEN_POWER_ONOFF_SRV (srv_pub, srv_data)
Define a new Generic Power OnOff Server Model.

**Note:** 1. The Generic Power OnOff Server model extends the Generic OnOff Server model. When this model is present on an element, the corresponding Generic Power OnOff Setup Server model shall also be present.
   a. This model may be used to represent a variety of devices that do not fit any of the model descriptions that have been defined but support the generic properties of On/Off.
   b. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_power_onoff_srv_t`.

**Returns** New Generic Power OnOff Server Model instance.

ESP_BLE_MESH_MODEL_GEN_POWER_ONOFF_SETUP_SRV (srv_pub, srv_data)
Define a new Generic Power OnOff Setup Server Model.

   a. This model shall support model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_power_onoff_setup_srv_t`.


ESP_BLE_MESH_MODEL_GEN_POWER_LEVEL_SRV (srv_pub, srv_data)
Define a new Generic Power Level Server Model.

**Note:** 1. The Generic Power Level Server model extends the Generic Power OnOff Server model and the Generic Level Server model. When this model is present on an Element, the corresponding Generic Power Level Setup Server model shall also be present.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_power_level_srv_t`.

**Returns** New Generic Power Level Server Model instance.
Chapter 2. API Reference

**ESP_BLE_MESH_MODEL_GEN_POWER_LEVEL_SETUP_SRV** (srv_pub, srv_data)

Define a new Generic Power Level Setup Server Model.

**Note:**
   a. This model shall support model subscription.

**Parameters**
   - **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
   - **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_power_level_setup_srv_t`.

**Returns** New Generic Power Level Setup Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_BATTERY_SRV** (srv_pub, srv_data)

Define a new Generic Battery Server Model.

**Note:**
1. The Generic Battery Server Model is a root model.
   a. This model shall support model publication and model subscription.
   b. The model may be used to represent an element that is powered by a battery.

**Parameters**
   - **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
   - **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_battery_srv_t`.

**Returns** New Generic Battery Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_LOCATION_SRV** (srv_pub, srv_data)

Define a new Generic Location Server Model.

**Note:**
1. The Generic Location Server model is a root model. When this model is present on an Element, the corresponding Generic Location Setup Server model shall also be present.
   a. This model shall support model publication and model subscription.
   b. The model may be used to represent an element that knows its location (global or local).

**Parameters**
   - **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
   - **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_location_srv_t`.

**Returns** New Generic Location Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_LOCATION_SETUP_SRV** (srv_pub, srv_data)

Define a new Generic Location Setup Server Model.

**Note:**
1. The Generic Location Setup Server model extends the Generic Location Server model.
   a. This model shall support model subscription.

**Parameters**
   - **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
   - **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_location_setup_srv_t`.

**Returns** New Generic Location Setup Server Model instance.
**ESP_BLE_MESH_MODEL_GEN_USER_PROP_SRV** (srv_pub, srv_data)
Define a new Generic User Property Server Model.

**Note:** 1. The Generic User Property Server model is a root model.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_user_prop_srv_t`.

**Returns** New Generic User Property Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_ADMIN_PROP_SRV** (srv_pub, srv_data)
Define a new Generic Admin Property Server Model.

**Note:** 1. The Generic Admin Property Server model extends the Generic User Property Server model.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_admin_prop_srv_t`.

**Returns** New Generic Admin Property Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_MANUFACTURER_PROP_SRV** (srv_pub, srv_data)
Define a new Generic Manufacturer Property Server Model.

**Note:** 1. The Generic Manufacturer Property Server model extends the Generic User Property Server model.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_manu_prop_srv_t`.

**Returns** New Generic Manufacturer Property Server Model instance.

**ESP_BLE_MESH_MODEL_GEN_CLIENT_PROP_SRV** (srv_pub, srv_data)
Define a new Generic Client Property Server Model.

**Note:** 1. The Generic Client Property Server model is a root model.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_gen_client_prop_srv_t`.

**Returns** New Generic Client Property Server Model instance.

**Type Definitions**
typedef void (esp_ble_mesh_generic_client_cb_t)(esp_ble_mesh_generic_client_cb_event_t event, esp_ble_mesh_generic_client_cb_param_t *param)

Bluetooth Mesh Generic Client Model function.

Generic Client Model callback function type

Param event Event type
Param param Pointer to callback parameter

typedef void (esp_ble_mesh_generic_server_cb_t)(esp_ble_mesh_generic_server_cb_event_t event, esp_ble_mesh_generic_server_cb_param_t *param)

Bluetooth Mesh Generic Server Model function.

Generic Server Model callback function type

Param event Event type
Param param Pointer to callback parameter

Enumerations

defined enum esp_ble_mesh_generic_client_cb_event_t

This enum value is the event of Generic Client Model

Values:

enumerator ESP_BLE_MESH_GENERIC_CLIENT_GET_STATE_EVT
enumerator ESP_BLE_MESH_GENERIC_CLIENT_SET_STATE_EVT
enumerator ESP_BLE_MESH_GENERIC_CLIENT_PUBLISH_EVT
enumerator ESP_BLE_MESH_GENERIC_CLIENT_TIMEOUT_EVT
enumerator ESP_BLE_MESH GENERIC_CLIENT_EVT_MAX

defined enum esp_ble_mesh_gen_user_prop_access_t

This enum value is the access value of Generic User Property

Values:

enumerator ESP_BLE_MESH GEN_USER_ACCESS_PROHIBIT
enumerator ESP_BLE_MESH GEN_USER_ACCESS_READ
enumerator ESP_BLE_MESH GEN_USER_ACCESS_WRITE
enumerator ESP_BLE_MESH GEN_USER_ACCESS_READ_WRITE

defined enum esp_ble_mesh_gen_admin_prop_access_t

This enum value is the access value of Generic Admin Property

Values:

enumerator ESP_BLE_MESH_GEN_ADMIN NOT USER_PROP
enumerator ESP_BLE_MESH_GEN_ADMIN_ACCESS_READ

enumerator ESP_BLE_MESH_GEN_ADMIN_ACCESS_WRITE

enumerator ESP_BLE_MESH_GEN_ADMIN_ACCESS_READ_WRITE

enum esp_ble_mesh_gen_manu_prop_access_t
This enum value is the access value of Generic Manufacturer Property

Values:

enumerator ESP_BLE_MESH_GEN_MANU_NOT_USER_PROP

enumerator ESP_BLE_MESH_GEN_MANU_ACCESS_READ

enum esp_ble_mesh_generic_server_cb_event_t
This enum value is the event of Generic Server Model

Values:

enumerator ESP_BLE_MESH_GENERIC_SERVER_STATE_CHANGE_EVT
  i. When get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, no event will be callback
     to the application layer when Generic Get messages are received.
  ii. When set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, this event will be callback
     to the application layer when Generic Set/Set Unack messages are received.

enumerator ESP_BLE_MESH_GENERIC_SERVER_RECV_GET_MSG_EVT
  When get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to
  the application layer when Generic Get messages are received.

enumerator ESP_BLE_MESH_GENERIC_SERVER_RECV_SET_MSG_EVT
  When set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to
  the application layer when Generic Set/Set Unack messages are received.

enumerator ESP_BLE_MESH_GENERIC_SERVER_EVT_MAX

Sensor Client/Server Models

Header File

- components/bt/esp_ble_mesh/api/models/include/esp_ble_mesh_sensor_model_api.h

Functions

esp_err_t esp_ble_mesh_register_sensor_client_callback (esp_ble_mesh_sensor_client_cb_t
  callback)

Register BLE Mesh Sensor Client Model callback.

Parameters callback  [in] Pointer to the callback function.

Returns ESP_OK on success or error code otherwise.
Chapter 2. API Reference

```c
esp_err_t esp_ble_mesh_sensor_client_get_state(esp_ble_mesh_client_common_param_t *params,
                                                esp_ble_mesh_sensor_client_get_state_t *get_state)
```

Get the value of Sensor Server Model states using the Sensor Client Model get messages.

**Note:** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_sensor_message_opcode_tinesp_ble_mesh_defs.h

**Parameters**
- `params` - [in] Pointer to BLE Mesh common client parameters.
- `get_state` - [in] Pointer to sensor get message value. Shall not be set to NULL.

**Returns** ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_sensor_client_set_state(esp_ble_mesh_client_common_param_t *params,
                                                 esp_ble_mesh_sensor_client_set_state_t *set_state)
```

Set the value of Sensor Server Model states using the Sensor Client Model set messages.

**Note:** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_sensor_message_opcode_tinesp_ble_mesh_defs.h

**Parameters**
- `params` - [in] Pointer to BLE Mesh common client parameters.
- `set_state` - [in] Pointer to sensor set message value. Shall not be set to NULL.

**Returns** ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_register_sensor_server_callback(esp_ble_mesh_sensor_server_cb_t *callback)
```

Register BLE Mesh Sensor Server Model callback.

**Parameters** `callback` - [in] Pointer to the callback function.

**Returns** ESP_OK on success or error code otherwise.

**Unions**

```c
union esp_ble_mesh_sensor_client_get_state_t
    #include <esp_ble_mesh_sensor_model_api.h> Sensor Client Model get message union.
```

**Public Members**

```c
esp_ble_mesh_sensor_descriptor_get_t descriptor_get
    For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_GET
```

```c
esp_ble_mesh_sensor_cadence_get_t cadence_get
    For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_GET
```

```c
esp_ble_mesh_sensor_settings_get_t settings_get
    For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_GET
```
Chapter 2. API Reference

`esp_ble_mesh_sensor_setting_get_t` `setting_get`
For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_GET

`esp_ble_mesh_sensor_get_t` `sensor_get`
For ESP_BLE_MESH_MODEL_OP_SENSOR_GET

`esp_ble_mesh_sensor_column_get_t` `column_get`
For ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET

`esp_ble_mesh_sensor_series_get_t` `series_get`
For ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_GET

union `esp_ble_mesh_sensor_client_set_state_t`
#include `<esp_ble_mesh_sensor_model_api.h>` Sensor Client Model set message union.

Public Members

`esp_ble_mesh_sensor_cadence_set_t` `cadence_set`
For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET &
ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET_UNACK

`esp_ble_mesh_sensor_setting_set_t` `setting_set`
For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET &
ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET_UNACK

union `esp_ble_mesh_sensor_client_status_cb_t`
#include `<esp_ble_mesh_sensor_model_api.h>` Sensor Client Model received message union.

Public Members

`esp_ble_mesh_sensor_descriptor_status_cb_t` `descriptor_status`
For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_STATUS

`esp_ble_mesh_sensor_cadence_status_cb_t` `cadence_status`
For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_STATUS

`esp_ble_mesh_sensor_settings_status_cb_t` `settings_status`
For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_STATUS

`esp_ble_mesh_sensor_setting_status_cb_t` `setting_status`
For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_STATUS

`esp_ble_mesh_sensor_status_cb_t` `sensor_status`
For ESP_BLE_MESH_MODEL_OP_SENSOR_STATUS

`esp_ble_mesh_sensor_column_status_cb_t` `column_status`
For ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_STATUS
**Chapter 2. API Reference**

\[\text{esp_ble_mesh_sensor_series_status_cb_t} \text{ series_status}\]

For ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_STATUS

union \[\text{esp_ble_mesh_sensor_server_state_change_t}\]

\#include <esp_ble_mesh_sensor_model_api.h> Sensor Server Model state change value union.

**Public Members**

\[\text{esp_ble_mesh_state_change_sensor_cadence_set_t} \text{ sensor_cadence_set}\]

The recv op in ctx can be used to decide which state is changed. Sensor Cadence Set

\[\text{esp_ble_mesh_state_change_sensor_setting_set_t} \text{ sensor_setting_set}\]

Sensor Setting Set

union \[\text{esp_ble_mesh_sensor_server_recv_get_msg_t}\]

\#include <esp_ble_mesh_sensor_model_api.h> Sensor Server Model received get message union.

**Public Members**

\[\text{esp_ble_mesh_server_recv_sensor_descriptor_get_t} \text{ sensor_descriptor}\]

Sensor Descriptor Get

\[\text{esp_ble_mesh_server_recv_sensor_cadence_get_t} \text{ sensor_cadence}\]

Sensor Cadence Get

\[\text{esp_ble_mesh_server_recv_sensor_settings_get_t} \text{ sensor_settings}\]

Sensor Settings Get

\[\text{esp_ble_mesh_server_recv_sensor_setting_get_t} \text{ sensor_setting}\]

Sensor Setting Get

\[\text{esp_ble_mesh_server_recv_sensor_get_t} \text{ sensor_data}\]

Sensor Get

\[\text{esp_ble_mesh_server_recv_sensor_column_get_t} \text{ sensor_column}\]

Sensor Column Get

\[\text{esp_ble_mesh_server_recv_sensor_series_get_t} \text{ sensor_series}\]

Sensor Series Get

union \[\text{esp_ble_mesh_sensor_server_recv_set_msg_t}\]

\#include <esp_ble_mesh_sensor_model_api.h> Sensor Server Model received set message union.

**Public Members**
Chapter 2.  API Reference


esp_ble_mesh_server_recv_sensor_cadence_set_t sensor_cadence

Sensor Cadence Set

esp_ble_mesh_server_recv_sensor_setting_set_t sensor_setting

Sensor Setting Set

union esp_ble_mesh_sensor_server_cb_value_t

#include <esp_ble_mesh_sensor_model_api.h> Sensor Server Model callback value union.

Public Members

esp_ble_mesh_sensor_server_state_change_t state_change

ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT

esp_ble_mesh_sensor_server_recv_get_msg_t get

ESP_BLE_MESH_SENSOR_SERVER_RECV_GET_MSG_EVT

esp_ble_mesh_sensor_server_recv_set_msg_t set

ESP_BLE_MESH_SENSOR_SERVER_RECV_SET_MSG_EVT

Structures

struct esp_ble_mesh_sensor_descriptor_get_t

Bluetooth Mesh Sensor Client Model Get and Set parameters structure.

Parameters of Sensor Descriptor Get

Public Members

bool op_en

Indicate if optional parameters are included

uint16_t property_id

Property ID of a sensor (optional)

struct esp_ble_mesh_sensor_cadence_get_t

Parameter of Sensor Cadence Get

Public Members

uint16_t property_id

Property ID of a sensor

struct esp_ble_mesh_sensor_cadence_set_t

Parameters of Sensor Cadence Set
Public Members

uint16_t `property_id`
Property ID for the sensor

uint8_t `fast_cadence_period_divisor`
Divisor for the publish period

uint8_t `status_trigger_type`
The unit and format of the Status Trigger Delta fields

struct net_buf_simple * `status_trigger_delta_down`
Delta down value that triggers a status message

struct net_buf_simple * `status_trigger_delta_up`
Delta up value that triggers a status message

uint8_t `status_min_interval`
Minimum interval between two consecutive Status messages

struct net_buf_simple * `fast_cadence_low`
Low value for the fast cadence range

struct net_buf_simple * `fast_cadence_high`
Fast value for the fast cadence range

struct `esp_ble_mesh_sensor_settings_get_t`
Parameter of Sensor Settings Get

Public Members

uint16_t `sensor_property_id`
Property ID of a sensor

struct `esp_ble_mesh_sensor_setting_get_t`
Parameters of Sensor Setting Get

Public Members

uint16_t `sensor_property_id`
Property ID of a sensor

uint16_t `sensor_setting_property_id`
Setting ID identifying a setting within a sensor

struct `esp_ble_mesh_sensor_setting_set_t`
Parameters of Sensor Setting Set
Chapter 2. API Reference

**Public Members**

`uint16_t sensor_property_id`
Property ID identifying a sensor

`uint16_t sensor_setting_property_id`
Setting ID identifying a setting within a sensor

`struct net_buf_simple *sensor_setting_raw`
Raw value for the setting

`struct esp_ble_mesh_sensor_get_t`
Parameters of Sensor Get

**Public Members**

`bool op_en`
Indicate if optional parameters are included

`uint16_t property_id`
Property ID for the sensor (optional)

**Public Members**

`struct esp_ble_mesh_sensor_column_get_t`
Parameters of Sensor Column Get

**Public Members**

`uint16_t property_id`
Property identifying a sensor

`struct net_buf_simple *raw_value_x`
Raw value identifying a column

**Public Members**

`struct esp_ble_mesh_sensor_series_get_t`
Parameters of Sensor Series Get

**Public Members**

`bool op_en`
Indicate if optional parameters are included

`uint16_t property_id`
Property identifying a sensor

`struct net_buf_simple *raw_value_x1`
Raw value identifying a starting column (optional)
struct net_buf_simple *raw_value_x2
   Raw value identifying an ending column (C.1)

struct esp_ble_mesh_sensor_descriptor_status_cb_t
   Bluetooth Mesh Sensor Client Model Get and Set callback parameters structure.
   Parameter of Sensor Descriptor Status

   Public Members

   struct net_buf_simple *descriptor
      Sequence of 8-octet sensor descriptors (optional)

struct esp_ble_mesh_sensor_cadence_status_cb_t
   Parameters of Sensor Cadence Status

   Public Members

   uint16_t property_id
      Property for the sensor

   struct net_buf_simple *sensor_cadence_value
      Value of sensor cadence state

struct esp_ble_mesh_sensor_settings_status_cb_t
   Parameters of Sensor Settings Status

   Public Members

   uint16_t sensor_property_id
      Property ID identifying a sensor

   struct net_buf_simple *sensor_setting_property_ids
      A sequence of N sensor setting property IDs (optional)

struct esp_ble_mesh_sensor_setting_status_cb_t
   Parameters of Sensor Setting Status

   Public Members

   bool op_en
      Indicate id optional parameters are included

   uint16_t sensor_property_id
      Property ID identifying a sensor
uint16_t sensor_setting_property_id
    Setting ID identifying a setting within a sensor

uint8_t sensor_setting_access
    Read/Write access rights for the setting (optional)

struct net_buf_simple *sensor_setting_raw
    Raw value for the setting

struct esp_ble_mesh_sensor_status_cb_t
    Parameter of Sensor Status

**Public Members**

struct net_buf_simple *marshalled_sensor_data
    Value of sensor data state (optional)

struct esp_ble_mesh_sensor_column_status_cb_t
    Parameters of Sensor Column Status

**Public Members**

uint16_t property_id
    Property identifying a sensor and the Y axis

struct net_buf_simple *sensor_column_value
    Left values of sensor column status

struct esp_ble_mesh_sensor_series_status_cb_t
    Parameters of Sensor Series Status

**Public Members**

uint16_t property_id
    Property identifying a sensor and the Y axis

struct net_buf_simple *sensor_series_value
    Left values of sensor series status

struct esp_ble_mesh_sensor_client_cb_param_t
    Sensor Client Model callback parameters

**Public Members**
### Chapter 2. API Reference

```c
int error_code
0: success, otherwise failure. For the error code values please refer to errno.h file. A negative sign is added to the standard error codes in errno.h.
```

```c
typedef esp_ble_mesh_client_common_param_t *params
The client common parameters.
```

```c
typedef esp_ble_mesh_sensor_client_status_cb_t status_cb
The sensor status message callback values
```

```c
struct esp_ble_mesh_sensor_descriptor_t
Parameters of Sensor Descriptor state
```

#### Public Members

```c
typedef uint32_t positive_tolerance
The value of Sensor Positive Tolerance field
```

```c
typedef uint32_t negative_tolerance
The value of Sensor Negative Tolerance field
```

```c
typedef uint32_t sampling_function
The value of Sensor Sampling Function field
```

```c
typedef uint8_t measure_period
The value of Sensor Measurement Period field
```

```c
typedef uint8_t update_interval
The value of Sensor Update Interval field
```

```c
struct esp_ble_mesh_sensor_setting_t
Parameters of Sensor Setting state
```

#### Public Members

```c
typedef uint16_t property_id
The value of Sensor Setting Property ID field
```

```c
typedef uint8_t access
The value of Sensor Setting Access field
```

```c
typedef net_buf_simple *raw
The value of Sensor Setting Raw field
```

```c
struct esp_ble_mesh_sensor_cadence_t
Parameters of Sensor Cadence state
```
Public Members

```c
uint8_t period_divisor
    The value of Fast Cadence Period Divisor field
```

```c
uint8_t trigger_type
    The value of Status Trigger Type field
```

```c
struct net_buf_simple *trigger_delta_down
    Note: The parameter “size” in trigger_delta_down, trigger_delta_up, fast_cadence_low & fast_cadence_high indicates the exact length of these four parameters, and they are associated with the Sensor Property ID. Users need to initialize the “size” precisely. The value of Status Trigger Delta Down field
```

```c
struct net_buf_simple *trigger_delta_up
    The value of Status Trigger Delta Up field
```

```c
uint8_t min_interval
    The value of Status Min Interval field
```

```c
struct net_buf_simple *fast_cadence_low
    The value of Fast Cadence Low field
```

```c
struct net_buf_simple *fast_cadence_high
    The value of Fast Cadence High field
```

```c
struct esp_ble_mesh_sensor_data_t
    Parameters of Sensor Data state
```

Public Members

```c
uint8_t format
    Format A: The Length field is a 1-based uint4 value (valid range 0x0–0xF, representing range of 1–16). Format B: The Length field is a 1-based uint7 value (valid range 0x0–0x7F, representing range of 1–127). The value 0x7F represents a length of zero. The value of the Sensor Data format
```

```c
uint8_t length
    The value of the Sensor Data length
```

```c
struct net_buf_simple *raw_value
    The value of Sensor Data raw value
```

```c
struct esp_ble_mesh_sensor_series_column_t
    Parameters of Sensor Series Column state
```

Public Members
struct net_buf_simple *raw_value_x
  The value of Sensor Raw Value X field

struct net_buf_simple *column_width
  The value of Sensor Column Width field

struct net_buf_simple *raw_value_y
  The value of Sensor Raw Value Y field

struct esp_ble_mesh_sensor_state_t
  Parameters of Sensor states

Public Members

uint16_t sensor_property_id
  The value of Sensor Property ID field

esp_ble_mesh_sensor_descriptor_t *descriptor
  Parameters of the Sensor Descriptor state

const uint8_t *setting_count
  Multiple Sensor Setting states may be present for each sensor. The Sensor Setting Property ID values shall be unique for each Sensor Property ID that identifies a sensor within an element.

esp_ble_mesh_sensor_setting_t *settings
  Parameters of the Sensor Setting state

esp_ble_mesh_sensor_cadence_t *cadence
  The Sensor Cadence state may be not supported by sensors based on device properties referencing “non-scalar characteristics” such as “histograms” or “composite characteristics”. Parameters of the Sensor Cadence state

esp_ble_mesh_sensor_data_t *sensor_data
  Parameters of the Sensor Data state

esp_ble_mesh_sensor_series_column_t *series_column
  Parameters of the Sensor Series Column state

struct esp_ble_mesh_sensor_srv_t
  User data of Sensor Server Model

Public Members

esp_ble_mesh_model_t *model
  Pointer to the Sensor Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
  Response control of the server model received messages
const uint8_t state_count
    Sensor state count

*esp_ble_mesh_sensor_state_t* states
    Parameters of the Sensor states

struct esp_ble_mesh_sensor_setup_srv_t
    User data of Sensor Setup Server Model

**Public Members**

*esp_ble_mesh_model_t* model
    Pointer to the Sensor Setup Server Model. Initialized internally.

*esp_ble_mesh_server_rsp_ctrl_t* rsp_ctrl
    Response control of the server model received messages

const uint8_t state_count
    Sensor state count

*esp_ble_mesh_sensor_state_t* states
    Parameters of the Sensor states

struct esp_ble_mesh_state_change_sensor_cadence_set_t
    Parameters of Sensor Cadence Set state change event

**Public Members**

uint16_t property_id
    The value of Sensor Property ID state

uint8_t period_divisor
    The value of Fast Cadence Period Divisor state

uint8_t trigger_type
    The value of Status Trigger Type state

struct net_buf_simple *trigger_delta_down
    The value of Status Trigger Delta Down state

struct net_buf_simple *trigger_delta_up
    The value of Status Trigger Delta Up state

uint8_t min_interval
    The value of Status Min Interval state
struct net_buf_simple *fast_cadence_low
The value of Fast Cadence Low state

struct net_buf_simple *fast_cadence_high
The value of Fast Cadence High state

struct esp_ble_mesh_state_change_sensor_setting_set_t
Parameters of Sensor Setting Set state change event

Public Members

uint16_t property_id
The value of Sensor Property ID state

uint16_t setting_property_id
The value of Sensor Setting Property ID state

struct net_buf_simple *setting_value
The value of Sensor Property Value state

struct esp_ble_mesh_server_recv_sensor_descriptor_get_t
Context of the received Sensor Descriptor Get message

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t property_id
Property ID of a sensor (optional)

struct esp_ble_mesh_server_recv_sensor_cadence_get_t
Context of the received Sensor Cadence Get message

Public Members

uint16_t property_id
Property ID of a sensor

struct esp_ble_mesh_server_recv_sensor_settings_get_t
Context of the received Sensor Settings Get message

Public Members

uint16_t property_id
Property ID of a sensor
struct `esp_ble_mesh_server_recv_sensor_setting_get_t`
Context of the received Sensor Setting Get message

**Public Members**

```c
uint16_t property_id
```
Property ID of a sensor

```c
uint16_t setting_property_id
```
Setting ID identifying a setting within a sensor

struct `esp_ble_mesh_server_recv_sensor_get_t`
Context of the received Sensor Get message

**Public Members**

```c
bool op_en
```
Indicate if optional parameters are included

```c
uint16_t property_id
```
Property ID for the sensor (optional)

struct `esp_ble_mesh_server_recv_sensor_column_get_t`
Context of the received Sensor Column Get message

**Public Members**

```c
uint16_t property_id
```
Property identifying a sensor

```c
struct net_buf_simple *raw_value_x
```
Raw value identifying a column

struct `esp_ble_mesh_server_recv_sensor_series_get_t`
Context of the received Sensor Series Get message

**Public Members**

```c
bool op_en
```
Indicate if optional parameters are included

```c
uint16_t property_id
```
Property identifying a sensor

```c
struct net_buf_simple *raw_value
```
Raw value containing X1 and X2 (optional)
**struct esp_ble_mesh_server_recv_sensor_cadence_set_t**

Context of the received Sensor Cadence Set message

**Public Members**

- `uint16_t property_id`
  Property ID for the sensor
- `struct net_buf_simple *cadence`
  Value of Sensor Cadence state

**struct esp_ble_mesh_server_recv_sensor_setting_set_t**

Context of the received Sensor Setting Set message

**Public Members**

- `uint16_t property_id`
  Property ID identifying a sensor
- `uint16_t setting_property_id`
  Setting ID identifying a setting within a sensor
- `struct net_buf_simple *setting_raw`
  Raw value for the setting

**struct esp_ble_mesh_sensor_server_cb_param_t**

Sensor Server Model callback parameters

**Public Members**

- `esp_ble_mesh_model_t *model`
  Pointer to Sensor Server Models
- `esp_ble_mesh_msg_ctx_t *ctx`
  Context of the received messages
- `esp_ble_mesh_sensor_server_cb_value_t *value`
  Value of the received Sensor Messages

**Macros**

**ESP_BLE_MESH_MODEL_SENSOR_CLI (cli_pub, cli_data)**

Define a new Sensor Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Sensor Client Model.
Parameters

- **cli_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** - Pointer to the unique struct `esp_ble_mesh_client_t`.

Returns

New Sensor Client Model instance.

ESP_BLE_MESH_MODEL_SENSOR_SRV (srv_pub, srv_data)

Sensor Server Models related context.

Define a new Sensor Server Model.

**Note:** 1. The Sensor Server model is a root model. When this model is present on an element, the corresponding Sensor Setup Server model shall also be present.

   a. This model shall support model publication and model subscription.

Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_sensor_srv_t`.

Returns

New Sensor Server Model instance.

ESP_BLE_MESH_MODEL_SENSOR_SETUP_SRV (srv_pub, srv_data)

Define a new Sensor Setup Server Model.

**Note:** 1. The Sensor Setup Server model extends the Sensor Server model.

   a. This model shall support model publication and model subscription.

Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_sensor_setup_srv_t`.

Returns

New Sensor Setup Server Model instance.

ESP_BLE_MESH_INVALID_SENSOR_PROPERTY_ID

Invalid Sensor Property ID

ESP_BLE_MESH_SENSOR_PROPERTY_ID_LEN

Length of Sensor Property ID

ESP_BLE_MESH_SENSOR_DESCRIPTOR_LEN

Length of Sensor Descriptor state

ESP_BLE_MESH_SENSOR_UNSPECIFIED_POS_TOLERANCE

Unspecified Sensor Positive Tolerance

ESP_BLE_MESH_SENSOR_UNSPECIFIED_NEG_TOLERANCE

Unspecified Sensor Negative Tolerance

ESP_BLE_MESH_SENSOR_NOT_APPL_MEASURE_PERIOD

Not applicable Sensor Measurement Period

ESP_BLE_MESH_SENSOR_NOT_APPL_UPDATE_INTERVAL

Not applicable Sensor Update Interval
**ESP_BLE_MESH_INVALID_SENSOR_SETTING_PROPERTY_ID**
Invalid Sensor Setting Property ID

**ESP_BLE_MESH_SENSOR_SETTING_PROPERTY_ID_LEN**
Length of Sensor Setting Property ID

**ESP_BLE_MESH_SENSOR_SETTING_ACCESS_LEN**
Length of Sensor Setting Access

**ESP_BLE_MESH_SENSOR_SETTING_ACCESS_READ**
Sensor Setting Access - Read

**ESP_BLE_MESH_SENSOR_SETTING_ACCESS_READ_WRITE**
Sensor Setting Access - Read & Write

**ESP_BLE_MESH_SENSOR_DIVISOR_TRIGGER_TYPE_LEN**
Length of Sensor Divisor Trigger Type

**ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERVAL_LEN**
Length of Sensor Status Min Interval

**ESP_BLE_MESH_SENSOR_PERIOD_DIVISOR_MAX_VALUE**
Maximum value of Sensor Period Divisor

**ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERVAL_MAX**
Maximum value of Sensor Status Min Interval

**ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_CHAR**
Sensor Status Trigger Type - Format Type of the characteristic that the Sensor Property ID state references

**ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_UINT16**
Sensor Status Trigger Type - Format Type “uint16”

**ESP_BLE_MESH_SENSOR_DATA_FORMAT_A**
Sensor Data Format A

**ESP_BLE_MESH_SENSOR_DATA_FORMAT_B**
Sensor Data Format B

**ESP_BLE_MESH_SENSOR_DATA_FORMAT_A_MPID_LEN**
MPID length of Sensor Data Format A

**ESP_BLE_MESH_SENSOR_DATA_FORMAT_B_MPID_LEN**
MPID length of Sensor Data Format B

**ESP_BLE_MESH_SENSOR_DATA_ZERO_LEN**
Zero length of Sensor Data.

Note: The Length field is a 1-based uint7 value (valid range 0x0-0x7F, representing range of 1–127). The value 0x7F represents a length of zero.
Chapter 2. API Reference

ESP_BLE_MESH_GET_SENSOR_DATA_FORMAT (_data)
Get format of the sensor data.

Note: Multiple sensor data may be concatenated. Make sure the _data pointer is updated before getting the format of the corresponding sensor data.

Parameters
- _data – Pointer to the start of the sensor data.

Returns Format of the sensor data.

ESP_BLE_MESH_GET_SENSOR_DATA_LENGTH (_data, _fmt)
Get length of the sensor data.

Note: Multiple sensor data may be concatenated. Make sure the _data pointer is updated before getting the length of the corresponding sensor data.

Parameters
- _data – Pointer to the start of the sensor data.
- _fmt – Format of the sensor data.

Returns Length (zero-based) of the sensor data.

ESP_BLE_MESH_GET_SENSOR_DATA_PROPERTY_ID (_data, _fmt)
Get Sensor Property ID of the sensor data.

Note: Multiple sensor data may be concatenated. Make sure the _data pointer is updated before getting Sensor Property ID of the corresponding sensor data.

Parameters
- _data – Pointer to the start of the sensor data.
- _fmt – Format of the sensor data.

Returns Sensor Property ID of the sensor data.

ESP_BLE_MESH_SENSOR_DATA_FORMAT_A_MPID (_len, _id)
Generate a MPID value for sensor data with Format A.

Note: 1. The Format field is 0b0 and indicates that Format A is used.
   a. The Length field is a 1-based uint4 value (valid range 0x0–0xF, representing range of 1–16).
   b. The Property ID is an 11-bit bit field representing 11 LSb of a Property ID.
   c. This format may be used for Property Values that are not longer than 16 octets and for Property IDs less than 0x0800.

Parameters
- _len – Length of Sensor Raw value.
- _id – Sensor Property ID.

Returns 2-octet MPID value for sensor data with Format A.

ESP_BLE_MESH_SENSOR_DATA_FORMAT_B_MPID (_len, _id)
Generate a MPID value for sensor data with Format B.

Note: 1. The Format field is 0b1 and indicates Format B is used.
a. The Length field is a 1-based uint7 value (valid range 0x0–0x7F, representing range of 1–127). The value 0x7F represents a length of zero.
b. The Property ID is a 16-bit bit field representing a Property ID.
c. This format may be used for Property Values not longer than 128 octets and for any Property IDs. Property values longer than 128 octets are not supported by the Sensor Status message.
d. Exclude the generated 1-octet value, the 2-octet Sensor Property ID

**Parameters**
- **_len** – Length of Sensor Raw value.
- **_id** – Sensor Property ID.

**Returns** 3-octet MPID value for sensor data with Format B.

**Type Definitions**
```c
typedef void (*esp_ble_mesh_sensor_client_cb_t)(
    esp_ble_mesh_sensor_client_cb_event_t event,
    esp_ble_mesh_sensor_client_cb_param_t *param)
```
Bluetooth Mesh Sensor Client Model function.
- **Param event** Event type
- **Param param** Pointer to callback parameter

```c
typedef void (*esp_ble_mesh_sensor_server_cb_t)(
    esp_ble_mesh_sensor_server_cb_event_t event,
    esp_ble_mesh_sensor_server_cb_param_t *param)
```
Bluetooth Mesh Sensor Server Model function.
- **Param event** Event type
- **Param param** Pointer to callback parameter

**Enumerations**
```c
enum esp_ble_mesh_sensor_client_cb_event_t
```
This enum value is the event of Sensor Client Model

**Values:**
- enumerator **ESP_BLE_MESH_SENSOR_CLIENT_GET_STATE_EVT**
- enumerator **ESP_BLE_MESH_SENSOR_CLIENT_SET_STATE_EVT**
- enumerator **ESP_BLE_MESH_SENSOR_CLIENT_PUBLISH_EVT**
- enumerator **ESP_BLE_MESH_SENSOR_CLIENT_TIMEOUT_EVT**
- enumerator **ESP_BLE_MESH_SENSOR_CLIENT_EVT_MAX**

```c
enum esp_ble_mesh_sensor_sample_func
```
This enum value is value of Sensor Sampling Function

**Values:**
- enumerator **ESP_BLE_MESH_SAMPLE_FUNC_UNSPECIFIED**
Chapter 2. API Reference

enumerator ESP_BLE_MESH_SAMPLE_FUNC_INSTANTANEOUS
enumerator ESP_BLE_MESH_SAMPLE_FUNC_ARITHMETIC_MEAN
enumerator ESP_BLE_MESH_SAMPLE_FUNC_RMS
enumerator ESP_BLE_MESH_SAMPLE_FUNC_MAXIMUM
enumerator ESP_BLE_MESH_SAMPLE_FUNC_MINIMUM
enumerator ESP_BLE_MESH_SAMPLE_FUNC_ACCUMULATED
enumerator ESP_BLE_MESH_SAMPLE_FUNC_COUNT

enum esp_ble_mesh_sensor_server_cb_event_t

This enum value is the event of Sensor Server Model

Values:

enumerator ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT

i. When get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, no event will be callback
to the application layer when Sensor Get messages are received.

ii. When set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, this event will be callback
to the application layer when Sensor Set/Set Unack messages are received.

counterpart ESP_BLE_MESH_SENSOR_SERVER_RECV_GET_MSG_EVT

When get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to
the application layer when Sensor Get messages are received.

counterpart ESP_BLE_MESH_SENSOR_SERVER_RECV_SET_MSG_EVT

When set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to
the application layer when Sensor Set/Set Unack messages are received.

counterpart ESP_BLE_MESH_SENSOR_SERVER_EVT_MAX

Time and Scenes Client/Server Models

Header File

- components/bt/esp_ble_mesh/api/models/include/esp_ble_mesh_time_scene_model_api.h

Functions

esp_err_t esp_ble_mesh_register_time_scene_client_callback ( esp_ble_mesh_time_scene_client_cb_t callback)

Register BLE Mesh Time Scene Client Model callback.

Parameters callback –[in] Pointer to the callback function.

Returns ESP_OK on success or error code otherwise.
**esp_err_t esp_ble_mesh_time_scene_client_get_state**

```c
esp_ble_mesh_time_scene_client_get_state_t
*get_state)
```

Get the value of Time Scene Server Model states using the Time Scene Client Model get messages.

**Note:** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_time_scene_message_opcode_t in esp_ble_mesh_defs.h

**Parameters**
- **params** - [in] Pointer to BLE Mesh common client parameters.
- **get_state** - [in] Pointer to time scene get message value. Shall not be set to NULL.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_time_scene_client_set_state**

```c
esp_ble_mesh_time_scene_client_set_state_t
*set_state)
```

Set the value of Time Scene Server Model states using the Time Scene Client Model set messages.

**Note:** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to esp_ble_mesh_time_scene_message_opcode_t in esp_ble_mesh_defs.h

**Parameters**
- **params** - [in] Pointer to BLE Mesh common client parameters.
- **set_state** - [in] Pointer to time scene set message value. Shall not be set to NULL.

**Returns** ESP_OK on success or error code otherwise.

**esp_err_t esp_ble_mesh_register_time_scene_server_callback**

```c
esp_ble_mesh_register_time_scene_server_callback_t
*callback)
```

Register BLE Mesh Time and Scenes Server Model callback.

**Parameters**
callback - [in] Pointer to the callback function.

**Returns** ESP_OK on success or error code otherwise.

**Unions**

```c
union esp_ble_mesh_time_scene_client_get_state_t
    #include <esp_ble_mesh_time_scene_model_api.h> Time Scene Client Model get message union.
```

**Public Members**

```c
esp_ble_mesh_scheduler_act_get_t scheduler_act_get
```

For ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_GET

```c
union esp_ble_mesh_time_scene_client_set_state_t
    #include <esp_ble_mesh_time_scene_model_api.h> Time Scene Client Model set message union.
```

**Public Members**
\texttt{esp\_ble\_mesh\_time\_set\_t time\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_TIME\_SET

\texttt{esp\_ble\_mesh\_time\_zone\_set\_t time\_zone\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_TIME\_ZONE\_SET

\texttt{esp\_ble\_mesh\_tai\_utc\_delta\_set\_t tai\_utc\_delta\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_TAI\_UTC\_DELTA\_SET

\texttt{esp\_ble\_mesh\_time\_role\_set\_t time\_role\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_TIME\_ROLE\_SET

\texttt{esp\_ble\_mesh\_scene\_store\_t scene\_store}
For ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_STORE & ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_STORE\_UNACK

\texttt{esp\_ble\_mesh\_scene\_recall\_t scene\_recall}
For ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_RECALL & ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_RECALL\_UNACK

\texttt{esp\_ble\_mesh\_scene\_delete\_t scene\_delete}
For ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_DELETE & ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_DELETE\_UNACK

\texttt{esp\_ble\_mesh\_scheduler\_act\_set\_t scheduler\_act\_set}
For ESP\_BLE\_MESH\_MODEL\_OP\_SCHEDULER\_ACT\_SET & ESP\_BLE\_MESH\_MODEL\_OP\_SCHEDULER\_ACT\_SET\_UNACK

union \texttt{esp\_ble\_mesh\_time\_scene\_client\_status\_cb\_t}
#include <esp\_ble\_mesh\_time\_scene\_model\_api\_h> Time Scene Client Model received message union.

**Public Members**

\texttt{esp\_ble\_mesh\_time\_status\_cb\_t time\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_TIME\_STATUS

\texttt{esp\_ble\_mesh\_time\_zone\_status\_cb\_t time\_zone\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_TIME\_ZONE\_STATUS

\texttt{esp\_ble\_mesh\_tai\_utc\_delta\_status\_cb\_t tai\_utc\_delta\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_TAI\_UTC\_DELTA\_STATUS

\texttt{esp\_ble\_mesh\_time\_role\_status\_cb\_t time\_role\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_TIME\_ROLE\_STATUS

\texttt{esp\_ble\_mesh\_scene\_status\_cb\_t scene\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_STATUS

\texttt{esp\_ble\_mesh\_scene\_register\_status\_cb\_t scene\_register\_status}
For ESP\_BLE\_MESH\_MODEL\_OP\_SCENE\_REGISTER\_STATUS
```c
esp_ble_mesh_scheduler_status_cb_t scheduler_status
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS

esp_ble_mesh_scheduler_act_status_cb_t scheduler_act_status
For ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_STATUS
```

```
union esp_ble_mesh_time_scene_server_state_change_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model state change value union.

Public Members

```c
esp_ble_mesh_state_change_time_set_t time_set
The recv_op in ctx can be used to decide which state is changed. Time Set

esp_ble_mesh_state_change_time_status_t time_status
Time Status

esp_ble_mesh_state_change_time_zone_set_t time_zone_set
Time Zone Set

esp_ble_mesh_state_change_tai_utc_delta_set_t tai_utc_delta_set
TAI UTC Delta Set

esp_ble_mesh_state_change_time_role_set_t time_role_set
Time Role Set

esp_ble_mesh_state_change_scene_store_t scene_store
Scene Store

esp_ble_mesh_state_change_scene_recall_t scene_recall
Scene Recall

esp_ble_mesh_state_change_scene_delete_t scene_delete
Scene Delete

esp_ble_mesh_state_change_scheduler_act_set_t scheduler_act_set
Scheduler Action Set
```

```
union esp_ble_mesh_time_scene_server_recv_get_msg_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received get message union.

Public Members

```c
esp_ble_mesh_server_recv_scheduler_act_get_t scheduler_act
Scheduler Action Get

union esp_ble_mesh_time_scene_server_recv_set_msg_t
#include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received set message union.
```
Public Members

```c
esp_ble_mesh_server_recv_time_set_t time
   Time Set
```

```c
esp_ble_mesh_server_recv_time_zone_set_t time_zone
   Time Zone Set
```

```c
esp_ble_mesh_server_recv_tai_utc_delta_set_t tai_utc_delta
   TAI-UTC Delta Set
```

```c
esp_ble_mesh_server_recv_time_role_set_t time_role
   Time Role Set
```

```c
esp_ble_mesh_server_recv_scene_store_t scene_store
   Scene Store/Scene Store Unack
```

```c
esp_ble_mesh_server_recv_scene_recall_t scene_recall
   Scene Recall/Scene Recall Unack
```

```c
esp_ble_mesh_server_recv_scene_delete_t scene_delete
   Scene Delete/Scene Delete Unack
```

```c
esp_ble_mesh_server_recv_scheduler_act_set_t scheduler_act
   Scheduler Action Set/Scheduler Action Set Unack
```

union esp_ble_mesh_time_scene_server_recv_status_msg_t
   #include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model received status message union.

Public Members

```c
esp_ble_mesh_server_recv_time_status_t time_status
   Time Status
```

union esp_ble_mesh_time_scene_server_cb_value_t
   #include <esp_ble_mesh_time_scene_model_api.h> Time Scene Server Model callback value union.

Public Members

```c
esp_ble_mesh_time_scene_server_state_change_t state_change
   ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT
```

```c
esp_ble_mesh_time_scene_server_recv_get_msg_t get
   ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT
```

```c
esp_ble_mesh_time_scene_server_recv_set_msg_t set
   ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT
```
structures

```
struct esp_ble_mesh_time_set_t
        Bluetooth Mesh Time Scene Client Model Get and Set parameters structure.
        Parameters of Time Set

        Public Members

        uint8_t tai_seconds[5]
                The current TAI time in seconds

        uint8_t sub_second
                The sub-second time in units of 1/256 second

        uint8_t uncertainty
                The estimated uncertainty in 10-millisecond steps

        uint16_t time_authority
                0 = No Time Authority, 1 = Time Authority

        uint16_t tai_utc_delta
                Current difference between TAI and UTC in seconds

        uint8_t time_zone_offset
                The local time zone offset in 15-minute increments

struct esp_ble_mesh_time_zone_set_t
        Parameters of Time Zone Set

        Public Members

        uint8_t time_zone_offset_new
                Upcoming local time zone offset

        uint8_t tai_zone_change[5]
                TAI Second time of the upcoming Time Zone Offset change

struct esp_ble_mesh_tai_utc_delta_set_t
        Parameters of TAI-UTC Delta Set

        Public Members

        uint16_t tai_utc_delta_new
                Upcoming difference between TAI and UTC in seconds
```
**uint16_t padding**
Always 0b0. Other values are Prohibited.

**uint8_t tai_delta_change[5]**
TAI Seconds time of the upcoming TAI-UTC Delta change

```plaintext
struct esp_ble_mesh_time_role_set_t
Parameter of Time Role Set

Public Members

**uint8_t time_role**
The Time Role for the element

struct esp_ble_mesh_scene_store_t
Parameter of Scene Store

Public Members

**uint16_t scene_number**
The number of scenes to be stored

struct esp_ble_mesh_scene_recall_t
Parameters of Scene Recall

Public Members

**bool op_en**
Indicate if optional parameters are included

**uint16_t scene_number**
The number of scenes to be recalled

**uint8_t tid**
Transaction ID

**uint8_t trans_time**
Time to complete state transition (optional)

**uint8_t delay**
Indicate message execution delay (C.1)

struct esp_ble_mesh_scene_delete_t
Parameter of Scene Delete
Public Members

uint16_t **scene_number**
   The number of scenes to be deleted

struct **esp_ble_mesh_scheduler_act_get_t**
   Parameter of Scheduler Action Get

Public Members

uint8_t **index**
   Index of the Schedule Register entry to get

struct **esp_ble_mesh_scheduler_act_set_t**
   Parameters of Scheduler Action Set

Public Members

uint64_t **index**
   Index of the Schedule Register entry to set

uint64_t **year**
   Scheduled year for the action

uint64_t **month**
   Scheduled month for the action

uint64_t **day**
   Scheduled day of the month for the action

uint64_t **hour**
   Scheduled hour for the action

uint64_t **minute**
   Scheduled minute for the action

uint64_t **second**
   Scheduled second for the action

uint64_t **day_of_week**
   Schedule days of the week for the action

uint64_t **action**
   Action to be performed at the scheduled time

uint64_t **trans_time**
   Transition time for this action
uint16_t scene_number
    Transition time for this action

struct esp_ble_mesh_time_status_cb_t
    Bluetooth Mesh Time Scene Client Model Get and Set callback parameters structure.
    Parameters of Time Status

Public Members

uint8_t tai_seconds[5]
    The current TAI time in seconds

uint8_t sub_second
    The sub-second time in units of 1/256 second

uint8_t uncertainty
    The estimated uncertainty in 10-millisecond steps

uint16_t time_authority
    0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta
    Current difference between TAI and UTC in seconds

uint8_t time_zone_offset
    The local time zone offset in 15-minute increments

struct esp_ble_mesh_time_zone_status_cb_t
    Parameters of Time Zone Status

Public Members

uint8_t time_zone_offset_curr
    Current local time zone offset

uint8_t time_zone_offset_new
    Upcoming local time zone offset

uint8_t tai_zone_change[5]
    TAI Second time of the upcoming Time Zone Offset change

struct esp_ble_mesh_tai_utc_delta_status_cb_t
    Parameters of TAI-UTC Delta Status
Public Members

uint16_t tai_utc_delta_curr
Current difference between TAI and UTC in seconds

uint16_t padding_1
Always 0b0. Other values are Prohibited.

uint16_t tai_utc_delta_new
Upcoming difference between TAI and UTC in seconds

uint16_t padding_2
Always 0b0. Other values are Prohibited.

uint8_t tai_delta_change[5]
TAI Seconds time of the upcoming TAI-UTC Delta change

struct esp_ble_mesh_time_role_status_cb_t
Parameter of Time Role Status

Public Members

uint8_t time_role
The Time Role for the element

struct esp_ble_mesh_scene_status_cb_t
Parameters of Scene Status

Public Members

bool op_en
Indicate if optional parameters are included

uint8_t status_code
Status code of the last operation

uint16_t current_scene
Scene Number of the current scene

uint16_t target_scene
Scene Number of the target scene (optional)

uint8_t remain_time
Time to complete state transition (C.1)

struct esp_ble_mesh_scene_register_status_cb_t
Parameters of Scene Register Status
Public Members

uint8_t status_code
   Status code for the previous operation

uint16_t current_scene
   Scene Number of the current scene

struct net_buf_simple *scenes
   A list of scenes stored within an element

struct esp_ble_mesh_scheduler_status_cb_t
   Parameter of Scheduler Status

Public Members

uint16_t schedules
   Bit field indicating defined Actions in the Schedule Register

struct esp_ble_mesh_scheduler_act_status_cb_t
   Parameters of Scheduler Action Status

Public Members

uint64_t index
   Enumerates (selects) a Schedule Register entry

uint64_t year
   Scheduled year for the action

uint64_t month
   Scheduled month for the action

uint64_t day
   Scheduled day of the month for the action

uint64_t hour
   Scheduled hour for the action

uint64_t minute
   Scheduled minute for the action

uint64_t second
   Scheduled second for the action

uint64_t day_of_week
   Schedule days of the week for the action
Chapter 2. API Reference

```c
uint64_t action
    Action to be performed at the scheduled time
```

```c
uint64_t trans_time
    Transition time for this action
```

```c
uint16_t scene_number
    Transition time for this action
```

```c
struct esp_ble_mesh_time_scene_client_cb_param_t
    Time Scene Client Model callback parameters
```

**Public Members**

```c
int error_code
    Appropriate error code
```

```c
esp_ble_mesh_client_common_param_t *params
    The client common parameters.
```

```c
esp_ble_mesh_time_scene_client_status_cb_t status_cb
    The scene status message callback values
```

```c
struct esp_ble_mesh_time_state_t
    Parameters of Time state
```

**Public Members**

```c
uint8_t tai_seconds[5]
    The value of the TAI Seconds state
```

```c
uint8_t subsecond
    The value of the Subsecond field
```

```c
uint8_t uncertainty
    The value of the Uncertainty field
```

```c
uint8_t time_zone_offset_curr
    The value of the Time Zone Offset Current field
```

```c
uint8_t time_zone_offset_new
    The value of the Time Zone Offset New state
```

```c
uint8_t tai_zone_change[5]
    The value of the TAI of Zone Change field
```
uint16_t **time_authority
   The value of the Time Authority bit

uint16_t **tai_utc_delta_curr
   The value of the TAI-UTC Delta Current state

uint16_t **tai_utc_delta_new
   The value of the TAI-UTC Delta New state

uint8_t **tai_delta_change[5]
   The value of the TAI of Delta Change field

struct esp_ble_mesh_time_state_t::[anonymous] **time
   Parameters of the Time state

uint8_t **time_role
   The value of the Time Role state

struct esp_ble_mesh_time_srv_t
   User data of Time Server Model

Public Members

esp_ble_mesh_model_t *model
   Pointer to the Time Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
   Response control of the server model received messages

struct esp_ble_mesh_time_state_t *state
   Parameters of the Time state

Public Members

esp_ble_mesh_model_t *model
   Pointer to the Time Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
   Response control of the server model received messages

struct esp_ble_mesh_time_state_t *state
   Parameters of the Time state
Chapter 2. API Reference

struct esp_ble_mesh_scene_register_t

a. Scene Store is an operation of storing values of a present state of an element.
b. The structure and meaning of the stored state is determined by a model. States to be stored are specified
   by each model.
c. The Scene Store operation shall persistently store all values of all states marked as Stored with Scene for
   all models present on all elements of a node.
d. If a model is extending another model, the extending model shall determine the Stored with Scene be-
   havior of that model. Parameters of Scene Register state

Public Members

uint16_t scene_number
   The value of the Scene Number

uint8_t scene_type
   The value of the Scene Type

struct net_buf_simple *scene_value
   Scene value may use a union to represent later, the union contains structures of all the model states which
   can be stored in a scene. The value of the Scene Value

struct esp_ble_mesh_scenes_state_t

Parameters of Scenes state.

Scenes serve as memory banks for storage of states (e.g., a power level or a light level/color). Values of states
of an element can be stored as a scene and can be recalled later from the scene memory.

A scene is represented by a Scene Number, which is a 16-bit non-zero, mesh-wide value. (There can be a
maximum of 65535 scenes in a mesh network.) The meaning of a scene, as well as the state storage container
associated with it, are determined by a model.

The Scenes state change may start numerous parallel model transitions. In that case, each individual model
handles the transition internally.

The scene transition is defined as a group of individual model transitions started by a Scene Recall operation.
The scene transition is in progress when at least one transition from the group of individual model transitions
is in progress.

Public Members

const uint16_t scene_count
   The Scenes state’s scene count

esp_ble_mesh_scene_register_t *scenes
   Parameters of the Scenes state

uint16_t current_scene
   The Current Scene state is a 16-bit value that contains either the Scene Number of the currently active
   scene or a value of 0x0000 when no scene is active.

When a Scene Store operation or a Scene Recall operation completes with success, the Current Scene
state value shall be to the Scene Number used during that operation.
When the Current Scene Number is deleted from a Scene Register state as a result of Scene Delete operation, the Current Scene state shall be set to 0x0000.

When any of the element’s state that is marked as “Stored with Scene” has changed not as a result of a Scene Recall operation, the value of the Current Scene state shall be set to 0x0000.

When a scene transition is in progress, the value of the Current Scene state shall be set to 0x0000. The value of the Current Scene state

uint16_t target_scene

The Target Scene state is a 16-bit value that contains the target Scene Number when a scene transition is in progress.

When the scene transition is in progress and the target Scene Number is deleted from a Scene Register state as a result of Scene Delete operation, the Target Scene state shall be set to 0x0000.

When the scene transition is in progress and a new Scene Number is stored in the Scene Register as a result of Scene Store operation, the Target Scene state shall be set to the new Scene Number.

When the scene transition is not in progress, the value of the Target Scene state shall be set to 0x0000. The value of the Target Scene state

uint8_t status_code

The status code of the last scene operation

bool in_progress

Indicate if the scene transition is in progress

struct esp_ble_mesh_scene_srv_t

User data of Scene Server Model

Public Members

esp_ble_mesh_model_t *model

Pointer to the Scene Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t rsp_ctrl

Response control of the server model received messages

esp_ble_mesh_scenes_state_t *state

Parameters of the Scenes state

esp_ble_mesh_last_msg_info_t last

Parameters of the last received set message

esp_ble_mesh_state_transition_t transition

Parameters of state transition

struct esp_ble_mesh_scene_setup_srv_t

User data of Scene Setup Server Model
Public Members

`esp_ble_mesh_model_t *model`
Pointer to the Scene Setup Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t * rsp_ctrl`
Response control of the server model received messages

`esp_ble_mesh_scenes_state_t *state`
Parameters of the Scenes state

```
struct esp_ble_mesh_schedule_register_t
Parameters of Scheduler Register state
```

Public Members

`bool in_use`
Indicate if the registered schedule is in use

`uint64_t year`
The value of Scheduled year for the action

`uint64_t month`
The value of Scheduled month for the action

`uint64_t day`
The value of Scheduled day of the month for the action

`uint64_t hour`
The value of Scheduled hour for the action

`uint64_t minute`
The value of Scheduled minute for the action

`uint64_t second`
The value of Scheduled second for the action

`uint64_t day_of_week`
The value of Schedule days of the week for the action

`uint64_t action`
The value of Action to be performed at the scheduled time

`uint64_t trans_time`
The value of Transition time for this action

`uint16_t scene_number`
The value of Scene Number to be used for some actions
Chapter 2. API Reference

```c
struct esp_ble_mesh_scheduler_state_t
Parameters of Scheduler state

Public Members

const uint8_t schedule_count
Scheduler count

esp_ble_mesh_schedule_register_t *schedules
Up to 16 scheduled entries

struct esp_ble_mesh_scheduler_srv_t
User data of Scheduler Server Model

Public Members

estp_ble_mesh_model_t *model
Pointer to the Scheduler Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t rsp_ctrl
Response control of the server model received messages

estp_ble_mesh_scheduler_state_t *state
Parameters of the Scheduler state

struct esp_ble_mesh_scheduler_setup_srv_t
User data of Scheduler Setup Server Model

Public Members

estp_ble_mesh_model_t *model
Pointer to the Scheduler Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t rsp_ctrl
Response control of the server model received messages

estp_ble_mesh_scheduler_state_t *state
Parameters of the Scheduler state

struct esp_ble_mesh_state_change_time_set_t
Parameters of Time Set state change event

Public Members

uint8_t tai_seconds[5]
The current TAI time in seconds
```
uint8_t subsecond
    The sub-second time in units of 1/256 second

uint8_t uncertainty
    The estimated uncertainty in 10-millisecond steps

uint16_t time_authority
    0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta_curr
    Current difference between TAI and UTC in seconds

uint8_t time_zone_offset_curr
    The local time zone offset in 15-minute increments

struct esp_ble_mesh_state_change_time_status_t
    Parameters of Time Status state change event

Public Members

uint8_t [5] tai_seconds
    The current TAI time in seconds

uint8_t subsecond
    The sub-second time in units of 1/256 second

uint8_t uncertainty
    The estimated uncertainty in 10-millisecond steps

uint16_t time_authority
    0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta_curr
    Current difference between TAI and UTC in seconds

uint8_t time_zone_offset_curr
    The local time zone offset in 15-minute increments

struct esp_ble_mesh_state_change_time_zone_set_t
    Parameters of Time Zone Set state change event

Public Members

uint8_t time_zone_offset_new
    Upcoming local time zone offset


```c
uint8_t tai_zone_change[5]
TAI Seconds time of the upcoming Time Zone Offset change
```

**struct esp_ble_mesh_state_change_tai_utc_delta_set_t**
Parameters of TAI UTC Delta Set state change event

**Public Members**

```c
uint16_t tai_utc_delta_new
Upcoming difference between TAI and UTC in seconds
```

```c
uint8_t tai_delta_change[5]
TAI Seconds time of the upcoming TAI-UTC Delta change
```

**struct esp_ble_mesh_state_change_time_role_set_t**
Parameter of Time Role Set state change event

**Public Members**

```c
uint8_t time_role
The Time Role for the element
```

**struct esp_ble_mesh_state_change_scene_store_t**
Parameter of Scene Store state change event

**Public Members**

```c
uint16_t scene_number
The number of scenes to be stored
```

**struct esp_ble_mesh_state_change_scene_recall_t**
Parameter of Scene Recall state change event

**Public Members**

```c
uint16_t scene_number
The number of scenes to be recalled
```

**struct esp_ble_mesh_state_change_scene_delete_t**
Parameter of Scene Delete state change event

**Public Members**

```c
uint16_t scene_number
The number of scenes to be deleted
```
struct `esp_ble_mesh_state_change_scheduler_act_set_t`
Parameter of Scheduler Action Set state change event

**Public Members**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>index</code></td>
<td>Index of the Schedule Register entry to set</td>
</tr>
<tr>
<td><code>year</code></td>
<td>Scheduled year for the action</td>
</tr>
<tr>
<td><code>month</code></td>
<td>Scheduled month for the action</td>
</tr>
<tr>
<td><code>day</code></td>
<td>Scheduled day of the month for the action</td>
</tr>
<tr>
<td><code>hour</code></td>
<td>Scheduled hour for the action</td>
</tr>
<tr>
<td><code>minute</code></td>
<td>Scheduled minute for the action</td>
</tr>
<tr>
<td><code>second</code></td>
<td>Scheduled second for the action</td>
</tr>
<tr>
<td><code>day_of_week</code></td>
<td>Schedule days of the week for the action</td>
</tr>
<tr>
<td><code>action</code></td>
<td>Action to be performed at the scheduled time</td>
</tr>
<tr>
<td><code>trans_time</code></td>
<td>Transition time for this action</td>
</tr>
<tr>
<td><code>scene_number</code></td>
<td>Scene number to be used for some actions</td>
</tr>
</tbody>
</table>

struct `esp_ble_mesh_server_recv_scheduler_act_get_t`
Context of the received Scheduler Action Get message

**Public Members**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>index</code></td>
<td>Index of the Schedule Register entry to get</td>
</tr>
</tbody>
</table>

struct `esp_ble_mesh_server_recv_time_set_t`
Context of the received Time Set message
Public Members

uint8_t tai_seconds[5]
  The current TAI time in seconds

uint8_t subsecond
  The sub-second time in units of 1/256 second

uint8_t uncertainty
  The estimated uncertainty in 10-millisecond steps

uint16_t time_authority
  0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta
  Current difference between TAI and UTC in seconds

uint8_t time_zone_offset
  The local time zone offset in 15-minute increments

struct esp_ble_mesh_server_recv_time_zone_set_t
  Context of the received Time Zone Set message

Public Members

uint8_t time_zone_offset_new
  Upcoming local time zone offset

uint8_t tai_zone_change[5]
  TAI Second time of the upcoming Time Zone Offset change

struct esp_ble_mesh_server_recv_tai_utc_delta_set_t
  Context of the received TAI UTC Delta Set message

Public Members

uint16_t tai_utc_delta_new
  Upcoming difference between TAI and UTC in seconds

uint16_t padding
  Always 0b0. Other values are Prohibited.

uint8_t tai_delta_change[5]
  TAI Seconds time of the upcoming TAI-UTC Delta change

struct esp_ble_mesh_server_recv_tai_utc_delta_change_set_t
  Context of the received Time Role Set message
Public Members

```c
uint8_t time_role
    The Time Role for the element
```

```c
struct esp_ble_mesh_server_recv_scene_store_t
    Context of the received Scene Store message
```

Public Members

```c
uint16_t scene_number
    The number of scenes to be stored
```

```c
struct esp_ble_mesh_server_recv_scene_recall_t
    Context of the received Scene Recall message
```

Public Members

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t scene_number
    The number of scenes to be recalled
```

```c
uint8_t tid
    Transaction ID
```

```c
uint8_t trans_time
    Time to complete state transition (optional)
```

```c
uint8_t delay
    Indicate message execution delay (C.1)
```

```c
struct esp_ble_mesh_server_recv_scene_delete_t
    Context of the received Scene Delete message
```

Public Members

```c
uint16_t scene_number
    The number of scenes to be deleted
```

```c
struct esp_ble_mesh_server_recv_scheduler_act_set_t
    Context of the received Scheduler Action Set message
```
Chapter 2. API Reference

Public Members

`uint64_t index`
Index of the Schedule Register entry to set

`uint64_t year`
Scheduled year for the action

`uint64_t month`
Scheduled month for the action

`uint64_t day`
Scheduled day of the month for the action

`uint64_t hour`
Scheduled hour for the action

`uint64_t minute`
Scheduled minute for the action

`uint64_t second`
Scheduled second for the action

`uint64_t day_of_week`
Scheduled day of the week for the action

`uint64_t action`
Action to be performed at the scheduled time

`uint64_t trans_time`
Transition time for this action

`uint16_t scene_number`
Scene number to be used for some actions

`struct esp_ble_mesh_server_recv_time_status_t`
Context of the received Time Status message

Public Members

`uint8_t tai_seconds[5]`
The current TAI time in seconds

`uint8_t subsecond`
The sub-second time in units of 1/256 second

`uint8_t uncertainty`
The estimated uncertainty in 10-millisecond steps
**Chapter 2. API Reference**

`uint16_t time_authority`
0 = No Time Authority, 1 = Time Authority

`uint16_t tai_utc_delta`
Current difference between TAI and UTC in seconds

`uint8_t time_zone_offset`
The local time zone offset in 15-minute increments

**struct esp_ble_mesh_time_scene_server_cb_param_t**
Time Scene Server Model callback parameters

**Public Members**

`esp_ble_mesh_model_t *model`
Pointer to Time and Scenes Server Models

`esp_ble_mesh_msg_ctx_t ctx`
Context of the received messages

`esp_ble_mesh_time_scene_server_cb_value_t value`
Value of the received Time and Scenes Messages

**Macros**

`ESP_BLE_MESH_MODEL_TIME_CLI(cli_pub, cli_data)`
Define a new Time Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Time Client Model.

**Parameters**

- `cli_pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `cli_data` – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Time Client Model instance.

`ESP_BLE_MESH_MODEL_SCENE_CLI(cli_pub, cli_data)`
Define a new Scene Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Scene Client Model.

**Parameters**

- `cli_pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `cli_data` – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Scene Client Model instance.
ESP_BLE_MESH_MODEL_SCHEDULER_CLI (cli_pub, cli_data)

Define a new Scheduler Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Scheduler Client Model.

**Parameters**
- cli_pub – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- cli_data – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Scheduler Client Model instance.

ESP_BLE_MESH_MODEL_TIME_SRV (srv_pub, srv_data)

Time Scene Server Models related context.

Define a new Time Server Model.

**Note:** 1. The Time Server model is a root model. When this model is present on an Element, the corresponding Time Setup Server model shall also be present.

   a. This model shall support model publication and model subscription.

**Parameters**
- srv_pub – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- srv_data – Pointer to the unique struct `esp_ble_mesh_time_srv_t`.

**Returns** New Time Server Model instance.

ESP_BLE_MESH_MODEL_TIME_SETUP_SRV (srv_data)

Define a new Time Setup Server Model.

**Note:** 1. The Time Setup Server model extends the Time Server model. Time is sensitive information that is propagated across a mesh network.

   a. Only an authorized Time Client should be allowed to change the Time and Time Role states. A dedicated application key Bluetooth SIG Proprietary should be used on the Time Setup Server to restrict access to the server to only authorized Time Clients.
   b. This model does not support subscribing nor publishing.

**Parameters**
- srv_data – Pointer to the unique struct `esp_ble_mesh_time_setup_srv_t`.

**Returns** New Time Setup Server Model instance.

ESP_BLE_MESH_MODEL_SCENE_SRV (srv_pub, srv_data)

Define a new Scene Server Model.

**Note:** 1. The Scene Server model is a root model. When this model is present on an Element, the corresponding Scene Setup Server model shall also be present.

   a. This model shall support model publication and model subscription.
   b. The model may be present only on the Primary element of a node.

**Parameters**
- srv_pub – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- srv_data – Pointer to the unique struct `esp_ble_mesh_scene_srv_t`. 
Chapter 2. API Reference

Returns  New Scene Server Model instance.

**ESP_BLE_MESH_MODEL_SCENE_SETUP_SRV** (srv_pub, srv_data)
Define a new Scene Setup Server Model.

**Note:** 1. The Scene Setup Server model extends the Scene Server model and the Generic Default Transition Time Server model.

   a. This model shall support model subscription.
   b. The model may be present only on the Primary element of a node.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_scene_setup_srv_t`.

**Returns**  New Scene Setup Server Model instance.

**ESP_BLE_MESH_MODEL_SCHEDULER_SRV** (srv_pub, srv_data)
Define a new Scheduler Server Model.

**Note:** 1. The Scheduler Server model extends the Scene Server model. When this model is present on an Element, the corresponding Scheduler Setup Server model shall also be present.

   a. This model shall support model publication and model subscription.
   b. The model may be present only on the Primary element of a node.
   c. The model requires the Time Server model shall be present on the element.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_scheduler_srv_t`.

**Returns**  New Scheduler Server Model instance.

**ESP_BLE_MESH_MODEL_SCHEDULER_SETUP_SRV** (srv_pub, srv_data)
Define a new Scheduler Setup Server Model.

**Note:** 1. The Scheduler Setup Server model extends the Scheduler Server and the Scene Setup Server models.

   a. This model shall support model subscription.
   b. The model may be present only on the Primary element of a node.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_scheduler_setup_srv_t`.

**Returns**  New Scheduler Setup Server Model instance.

**ESP_BLE_MESH_UNKNOWN_TAI_SECONDS**
Unknown TAI Seconds

**ESP_BLE_MESH_UNKNOWN_TAI_ZONE_CHANGE**
Unknown TAI of Zone Change

**ESP_BLE_MESH_UNKNOWN_TAI_DELTA_CHANGE**
Unknown TAI of Delta Change
Chapter 2. API Reference

ESP_BLE_MESH_TAI_UTC_DELTA_MAX_VALUE
Maximum TAI-UTC Delta value

ESP_BLE_MESH_TAI_SECONDS_LEN
Length of TAI Seconds

ESP_BLE_MESH_TAI_OF_ZONE_CHANGE_LEN
Length of TAI of Zone Change

ESP_BLE_MESH_TAI_OF_DELTA_CHANGE_LEN
Length of TAI of Delta Change

ESP_BLE_MESH_INVALID_SCENE_NUMBER
Invalid Scene Number

ESP_BLE_MESH_SCENE_NUMBER_LEN
Length of the Scene Number

ESP_BLE_MESH_SCHEDULE_YEAR_ANY_YEAR
Any year of the Scheduled year

ESP_BLE_MESH_SCHEDULE_DAY_ANY_DAY
Any day of the Scheduled day

ESP_BLE_MESH_SCHEDULE_HOUR_ANY_HOUR
Any hour of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_HOUR_ONCE_A_DAY
Any hour of the Scheduled Day

ESP_BLE_MESH_SCHEDULE_SEC_ANY_OF_HOUR
Any minute of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_MIN
Every 15 minutes of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_MIN
Every 20 minutes of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_ONCE_AN_HOUR
Once of the Scheduled hour

ESP_BLE_MESH_SCHEDULE_SEC_ANY_OF_MIN
Any second of the Scheduled minute

ESP_BLE_MESH_SCHEDULE_SEC_EVERY_15_SEC
Every 15 seconds of the Scheduled minute
**ESP_BLE_MESH_SCHEDULE_SEC_EVERY_20_SEC**
Every 20 seconds of the Scheduled minute

**ESP_BLE_MESH_SCHEDULE_SEC_ONCE_AN_MIN**
Once of the Scheduled minute

**ESP_BLE_MESH_SCHEDULE_ACT_TURN_OFF**
Scheduled Action - Turn Off

**ESP_BLE_MESH_SCHEDULE_ACT_TURN_ON**
Scheduled Action - Turn On

**ESP_BLE_MESH_SCHEDULE_ACT_SCENE_RECALL**
Scheduled Action - Scene Recall

**ESP_BLE_MESH_SCHEDULE_ACT_NO_ACTION**
Scheduled Action - No Action

**ESP_BLE_MESH_SCHEDULE_SCENE_NO_SCENE**
Scheduled Scene - No Scene

**ESP_BLE_MESH_SCHEDULE_ENTRY_MAX_INDEX**
Maximum number of Scheduled entries

**ESP_BLE_MESH_TIME_NONE**
Time Role - None

**ESP_BLE_MESH_TIME_AUTHORITY**
Time Role - Mesh Time Authority

**ESP_BLE_MESH_TIME_RELAY**
Time Role - Mesh Time Relay

**ESP_BLE_MESH_TIME_CLINET**
Time Role - Mesh Time Client

**ESP_BLE_MESH_SCENE_SUCCESS**
Scene operation - Success

**ESP_BLE_MESH_SCENE_REG_FULL**
Scene operation - Scene Register Full

**ESP_BLE_MESH_SCENE_NOT_FOUND**
Scene operation - Scene Not Found

**Type Definitions**
typedef void (*esp_ble_mesh_time_scene_client_cb_t)(esp_ble_mesh_time_scene_client_cb_event_t event, esp_ble_mesh_time_scene_client_cb_param_t *param)

Bluetooth Mesh Time Scene Client Model function.

Time Scene Client Model callback function type

Param event  Event type
Param param  Pointer to callback parameter

typedef void (*esp_ble_mesh_time_scene_server_cb_t)(esp_ble_mesh_time_scene_server_cb_event_t event, esp_ble_mesh_time_scene_server_cb_param_t *param)

Bluetooth Mesh Time and Scenes Server Model function.

Time Scene Server Model callback function type

Param event  Event type
Param param  Pointer to callback parameter

Enumerations

enum esp_ble_mesh_time_scene_client_cb_event_t

This enum value is the event of Time Scene Client Model

Values:

enumerator ESP_BLE_MESH_TIME_SCENE_CLIENT_GET_STATE_EVT

enumerator ESP_BLE_MESH_TIME_SCENE_CLIENT_SET_STATE_EVT

enumerator ESP_BLE_MESH_TIME_SCENE_CLIENT_PUBLISH_EVT

enumerator ESP_BLE_MESH_TIME_SCENE_CLIENT_TIMEOUT_EVT

enumerator ESP_BLE_MESH_TIME_SCENE_CLIENT_EVT_MAX

enum esp_ble_mesh_time_scene_server_cb_event_t

This enum value is the event of Time Scene Server Model

Values:

enumerator ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT

i. When get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, no event will be callback to the application layer when Time Scene Get messages are received.

ii. When set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, this event will be callback to the application layer when Time Scene Set/Set Unack messages are received.

enumerator ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT

When get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to the application layer when Time Scene Get messages are received.

enumerator ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT

When set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to the application layer when Time Scene Set/Set Unack messages are received.
Chapter 2. API Reference

enumerator `ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT`
When `status_auto_rsp` is set to `ESP_BLE_MESH_SERVER_RSP_BY_APP`, this event will be callback to the application layer when Time Status message is received.

enumerator `ESP_BLE_MESH_TIME_SCENE_SERVER_EVT_MAX`

Lighting Client/Server Models

Header File

- `components/bt/esp_ble_mesh/api/models/include/esp_ble_mesh_lighting_model_api.h`

Functions

`esp_err_t esp_ble_mesh_register_light_client_callback (esp_ble_mesh_light_client_cb_t callback)`
Register BLE Mesh Light Client Model callback.

- **Parameters**
  - `callback` — [in] pointer to the callback function.
- **Returns**
  - ESP_OK on success or error code otherwise.

`esp_err_t esp_ble_mesh_light_client_get_state (esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_light_client_get_state_t *get_state)`
Get the value of Light Server Model states using the Light Client Model get messages.

- **Note:** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to `esp_ble_mesh_light_message_opcode_t` in `esp_ble_mesh_defs.h`

- **Parameters**
  - `get_state` — [in] Pointer of light get message value. Shall not be set to NULL.
- **Returns**
  - ESP_OK on success or error code otherwise.

`esp_err_t esp_ble_mesh_light_client_set_state (esp_ble_mesh_client_common_param_t *params, esp_ble_mesh_light_client_set_state_t *set_state)`
Set the value of Light Server Model states using the Light Client Model set messages.

- **Note:** If you want to know the opcodes and corresponding meanings accepted by this API, please refer to `esp_ble_mesh_light_message_opcode_t` in `esp_ble_mesh_defs.h`

- **Parameters**
  - `set_state` — [in] Pointer of light set message value. Shall not be set to NULL.
- **Returns**
  - ESP_OK on success or error code otherwise.

`esp_err_t esp_ble_mesh_register_lighting_server_callback (esp_ble_mesh_lighting_server_cb_t callback)`
Register BLE Mesh Lighting Server Model callback.

- **Parameters**
  - `callback` — [in] Pointer to the callback function.
- **Returns**
  - ESP_OK on success or error code otherwise.
Unions

union **esp_ble_mesh_light_client_get_state_t**
#include <esp_ble_mesh_lighting_model_api.h> Lighting Client Model get message union.

Public Members

*esp_ble_mesh_light_lc_property_get_t* lc_property_get
For ESP BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_GET

union **esp_ble_mesh_light_client_set_state_t**
#include <esp_ble_mesh_lighting_model_api.h> Lighting Client Model set message union.

Public Members

*esp_ble_mesh_light_lightness_set_t* lightness_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_SET_UNACK

*esp_ble_mesh_light_lightness_linear_set_t* lightness_linear_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_SET_UNACK

*esp_ble_mesh_light_lightness_default_set_t* lightness_default_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_SET_UNACK

*esp_ble_mesh_light_lightness_range_set_t* lightness_range_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET_UNACK

*esp_ble_mesh_light_ctl_set_t* ctl_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET_UNACK

*esp_ble_mesh_light_ctl_temperature_set_t* ctl_temperature_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET_UNACK

*esp_ble_mesh_light_ctl_temperature_range_set_t* ctl_temperature_range_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET_UNACK

*esp_ble_mesh_light_ctl_default_set_t* ctl_default_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK

*esp_ble_mesh_light_hsl_set_t* hsl_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SET_UNACK
Chapter 2. API Reference

esp_ble_mesh_light_hsl_hue_set_t hsl_hue_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_SET_UNACK

esp_ble_mesh_light_hsl_saturation_set_t hsl_saturation_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_SET_UNACK

esp_ble_mesh_light_hsl_default_set_t hsl_default_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET_UNACK

esp_ble_mesh_light_hsl_range_set_t hsl_range_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_SET_UNACK

esp_ble_mesh_light_xyl_set_t xyl_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET_UNACK

esp_ble_mesh_light_xyl_default_set_t xyl_default_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK

esp_ble_mesh_light_xyl_range_set_t xyl_range_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET_UNACK

esp_ble_mesh_light_lc_mode_set_t lc_mode_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET_UNACK

esp_ble_mesh_light_lc_om_set_t lc_om_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET_UNACK

esp_ble_mesh_light_lc_light_onoff_set_t lc_light_onoff_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET_UNACK

esp_ble_mesh_light_lc_property_set_t lc_property_set
For ESP_BLE_MESH_MODEL_OP_LIGHT_LCPROPERTY_SET &
 ESP_BLE_MESH_MODEL_OP_LIGHT_LCPROPERTY_SET_UNACK

union esp_ble_mesh_light_client_status_cb_t
#include <esp_ble_mesh_lighting_model_api.h> Lighting Client Model received message union.

Public Members

esp_ble_mesh_light_lightness_status_cb_t lightness_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_STATUS

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esp_ble_mesh_light_lightness_linear_status_cb_t lightness_linear_status
For ESP_BLE_MESH_MODELOPLEIGHT_LIGHTNESS_LINEAR_STATUS

esp_ble_mesh_light_lightness_last_status_cb_t lightness_last_status
For ESP_BLE_MESH_MODELOPLEIGHT_LIGHTNESS_LAST_STATUS

esp_ble_mesh_light_lightness_default_status_cb_t lightness_default_status
For ESP_BLE_MESH_MODELOPLEIGHT_LIGHTNESS_DEFAULT_STATUS

esp_ble_mesh_light_lightness_range_status_cb_t lightness_range_status
For ESP_BLE_MESH_MODELOPLEIGHT_LIGHTNESS_RANGE_STATUS

esp_ble_mesh_light_ctl_status_cb_t ctl_status
For ESP_BLE_MESH_MODELOPLEIGHT_CTL_STATUS

esp_ble_mesh_light_ctl_temperature_status_cb_t ctl_temperature_status
For ESP_BLE_MESH_MODELOPLEIGHT_CTL_TEMPERATURE_STATUS

esp_ble_mesh_light_ctl_temperature_range_status_cb_t ctl_temperature_range_status
For ESP_BLE_MESH_MODELOPLEIGHT_CTL_RANGE_STATUS

esp_ble_mesh_light_ctl_default_status_cb_t ctl_default_status
For ESP_BLE_MESH_MODELOPLEIGHT_CTL_DEFAULT_STATUS

esp_ble_mesh_light_hsl_status_cb_t hsl_status
For ESP_BLE_MESH_MODELOPLEIGHT_HSL_STATUS

esp_ble_mesh_light_hsl_target_status_cb_t hsl_target_status
For ESP_BLE_MESH_MODELOPLEIGHT_HSL_TARGET_STATUS

esp_ble_mesh_light_hsl_hue_status_cb_t hsl_hue_status
For ESP_BLE_MESH_MODELOPLEIGHT_HSL_HUE_STATUS

esp_ble_mesh_light_hsl_saturation_status_cb_t hsl_saturation_status
For ESP_BLE_MESH_MODELOPLEIGHT_HSL_SATURATION_STATUS

esp_ble_mesh_light_hsl_default_status_cb_t hsl_default_status
For ESP_BLE_MESH_MODELOPLEIGHT_HSL_DEFAULT_STATUS

esp_ble_mesh_light_hsl_range_status_cb_t hsl_range_status
For ESP_BLE_MESH_MODELOPLEIGHT_HSL_RANGE_STATUS

esp_ble_mesh_light_xyl_status_cb_t xyl_status
For ESP_BLE_MESH_MODELOPLEIGHT_XYL_STATUS

esp_ble_mesh_light_xyl_target_status_cb_t xyl_target_status
For ESP_BLE_MESH_MODELOPLEIGHT_XYL_TARGET_STATUS
Chapter 2  API Reference

```

esp_ble_mesh_light_xyl_default_status_cb_t xyl_default_status
  For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_STATUS

esp_ble_mesh_light_xyl_range_status_cb_t xyl_range_status
  For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_STATUS

esp_ble_mesh_light_lc_mode_status_cb_t lc_mode_status
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_STATUS

esp_ble_mesh_light_lc_om_status_cb_t lc_om_status
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_STATUS

esp_ble_mesh_light_lc_light_onoff_status_cb_t lc_light_onoff_status
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_STATUS

esp_ble_mesh_light_lc_property_status_cb_t lc_property_status
  For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_STATUS

union esp_ble_mesh_lighting_server_state_change_t
  #include <esp_ble_mesh_lighting_model_api.h> Lighting Server Model state change value union.

Public Members

esp_ble_mesh_state_change_light_lightness_set_t lightness_set
  The recv_op in ctx can be used to decide which state is changed. Light Lightness Set

esp_ble_mesh_state_change_light_lightness_linear_set_t lightness_linear_set
  Light Lightness Linear Set

esp_ble_mesh_state_change_light_lightness_default_set_t lightness_default_set
  Light Lightness Default Set

esp_ble_mesh_state_change_light_lightness_range_set_t lightness_range_set
  Light Lightness Range Set

esp_ble_mesh_state_change_light_ctl_set_t ctl_set
  Light CTL Set

esp_ble_mesh_state_change_light_ctl_temperature_set_t ctl_temp_set
  Light CTL Temperature Set

esp_ble_mesh_state_change_light_ctl_temperature_range_set_t ctl_temp_range_set
  Light CTL Temperature Range Set

esp_ble_mesh_state_change_light_ctl_default_set_t ctl_default_set
  Light CTL Default Set
```
`esp_ble_mesh_state_change_light_hsl_set_t` **hsl_set**
Light HSL Set

`esp_ble_mesh_state_change_light_hsl_hue_set_t` **hsl_hue_set**
Light HSL Hue Set

`esp_ble_mesh_state_change_light_hsl_saturation_set_t` **hsl_saturation_set**
Light HSL Saturation Set

`esp_ble_mesh_state_change_light_hsl_default_set_t` **hsl_default_set**
Light HSL Default Set

`esp_ble_mesh_state_change_light_hsl_range_set_t` **hsl_range_set**
Light HSL Range Set

`esp_ble_mesh_state_change_light_xyl_set_t` **xyl_set**
Light xyl Set

`esp_ble_mesh_state_change_light_xyl_default_set_t` **xyl_default_set**
Light xyl Default Set

`esp_ble_mesh_state_change_light_xyl_range_set_t` **xyl_range_set**
Light xyl Range Set

`esp_ble_mesh_state_change_light_lc_mode_set_t` **lc_mode_set**
Light LC Mode Set

`esp_ble_mesh_state_change_light_lc_om_set_t` **lc_om_set**
Light LC Occupancy Mode Set

`esp_ble_mesh_state_change_light_lc_light_onoff_set_t` **lc_light_onoff_set**
Light LC Light OnOff Set

`esp_ble_mesh_state_change_light_lc_property_set_t` **lc_property_set**
Light LC Property Set

`esp_ble_mesh_state_change_sensor_status_t` **sensor_status**
Sensor Status

union `esp_ble_mesh_lighting_server_recv_get_msg_t`
#include `<esp_ble_mesh_lighting_model_api.h>` Lighting Server Model received get message union.

**Public Members**

`esp_ble_mesh_server_recv_light_lc_property_get_t` **lc_property**
Light LC Property Get

union `esp_ble_mesh_lighting_server_recv_set_msg_t`
#include `<esp_ble_mesh_lighting_model_api.h>` Lighting Server Model received set message union.
Public Members

`esp_ble_mesh_server_recv_light_lightness_set_t lightness`
Light Lightness Set/Light Lightness Set Unack

`esp_ble_mesh_server_recv_light_lightness_linear_set_t lightness_linear`
Light Lightness Linear Set/Light Lightness Linear Set Unack

`esp_ble_mesh_server_recv_light_lightness_default_set_t lightness_default`
Light Lightness Default Set/Light Lightness Default Set Unack

`esp_ble_mesh_server_recv_light_lightness_range_set_t lightness_range`
Light Lightness Range Set/Light Lightness Range Set Unack

`esp_ble_mesh_server_recv_light_ctl_set_t ctl`
Light CTL Set/Light CTL Set Unack

`esp_ble_mesh_server_recv_light_ctl_temperature_set_t ctl_temp`
Light CTL Temperature Set/Light CTL Temperature Set Unack

`esp_ble_mesh_server_recv_light_ctl_temperature_range_set_t ctl_temp_range`
Light CTL Temperature Range Set/Light CTL Temperature Range Set Unack

`esp_ble_mesh_server_recv_light CTL_default_set_t ctl_default`
Light CTL Default Set/Light CTL Default Set Unack

`esp_ble_mesh_server_recv_light_hsl_set_t hsl`
Light HSL Set/Light HSL Set Unack

`esp_ble_mesh_server_recv_light_hsl_hue_set_t hsl_hue`
Light HSL Hue Set/Light HSL Hue Set Unack

`esp_ble_mesh_server_recv_light_hsl_saturation_set_t hsl_saturation`
Light HSL Saturation Set/Light HSL Saturation Set Unack

`esp_ble_mesh_server_recv_light hsl_default_set_t hsl_default`
Light HSL Default Set/Light HSL Default Set Unack

`esp_ble_mesh_server_recv_light hsl_range_set_t hsl_range`
Light HSL Range Set/Light HSL Range Set Unack

`esp_ble_mesh_server_recv_light xyl_set_t xyl`
Light xyL Set/Light xyL Set Unack

`esp_ble_mesh_server_recv_light xyl default_set_t xyl_default`
Light xyL Default Set/Light xyL Default Set Unack

`esp_ble_mesh_server_recv_light xyl range_set_t xyl_range`
Light xyL Range Set/Light xyL Range Set Unack
Chapter 2. API Reference

```c
#include <esp_ble_mesh_lighting_model_api.h>
```

### Public Members

**`esp_ble_mesh_server_recv_light_lc_mode_set_t lc_mode`**
Light LC Mode Set/Light LC Mode Set Unack

**`esp_ble_mesh_server_recv_light_lc_om_set_t lc_om`**
Light LC OM Set/Light LC OM Set Unack

**`esp_ble_mesh_server_recv_light_lc_light_onoff_set_t lc_light_onoff`**
Light LC Light OnOff Set/Light LC Light Off Set Unack

**`esp_ble_mesh_server_recv_light_lc_property_set_t lc_property`**
Light LC Property Set/Light LC Property Set Unack

### Structures

**`struct esp_ble_mesh_light_lightness_set_t`**
Bluetooth Mesh Light Lightness Client Model Get and Set parameters structure.

Parameters of Light Lightness Set

**Public Members**
bool op_en
   Indicate if optional parameters are included

uint16_t lightness
   Target value of light lightness actual state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lightness_linear_set_t
   Parameters of Light Lightness Linear Set

**Public Members**

bool op_en
   Indicate if optional parameters are included

uint16_t lightness
   Target value of light lightness linear state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lightness_default_set_t
   Parameter of Light Lightness Default Set

**Public Members**

uint16_t lightness
   The value of the Light Lightness Default state

struct esp_ble_mesh_light_lightness_range_set_t
   Parameters of Light Lightness Range Set
Public Members

**uint16_t range_min**
Value of range min field of light lightness range state

**uint16_t range_max**
Value of range max field of light lightness range state

struct *esp_ble_mesh_light_ctl_set_t*
Parameters of Light CTL Set

**Public Members**

bool **op_en**
Indicate if optional parameters are included

**uint16_t ctl_lightness**
Target value of light ctl lightness state

**uint16_t ctl_temperature**
Target value of light ctl temperature state

**int16_t ctl_delta_uv**
Target value of light ctl delta UV state

**uint8_t tid**
Transaction ID

**uint8_t trans_time**
Time to complete state transition (optional)

**uint8_t delay**
Indicate message execution delay (C.1)

struct *esp_ble_mesh_light_ctl_temperature_set_t*
Parameters of Light CTL Temperature Set

**Public Members**

bool **op_en**
Indicate if optional parameters are included

**uint16_t ctl_temperature**
Target value of light ctl temperature state

**int16_t ctl_delta_uv**
Target value of light ctl delta UV state
Chapter 2. API Reference

```c
uint8_t tid
    Transaction ID

uint8_t trans_time
    Time to complete state transition (optional)

uint8_t delay
    Indicate message execution delay (C.1)
```

```c
struct esp_ble_mesh_light_ctl_temperature_range_set_t
    Parameters of Light CTL Temperature Range Set

Public Members

```c
uint16_t range_min
    Value of temperature range min field of light ctl temperature range state

uint16_t range_max
    Value of temperature range max field of light ctl temperature range state
```

```c
struct esp_ble_mesh_light_ctl_default_set_t
    Parameters of Light CTL Default Set

Public Members

```c
uint16_t lightness
    Value of light lightness default state

uint16_t temperature
    Value of light temperature default state

int16_t delta_uv
    Value of light delta UV default state
```

```c
struct esp_ble_mesh_light_hsl_set_t
    Parameters of Light HSL Set

Public Members

```c
bool op_en
    Indicate if optional parameters are included

uint16_t hsl_lightness
    Target value of light hsl lightness state
```
uint16_t hsl_hue
   Target value of light hsl hue state

uint16_t hsl_saturation
   Target value of light hsl saturation state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_light_hsl_hue_set_t
   Parameters of Light HSL Hue Set

   Public Members

   bool op_en
      Indicate if optional parameters are included

   uint16_t hue
      Target value of light hsl hue state

   uint8_t tid
      Transaction ID

   uint8_t trans_time
      Time to complete state transition (optional)

   uint8_t delay
      Indicate message execution delay (C.1)

struct esp_ble_mesh_light_hsl_saturation_set_t
   Parameters of Light HSL Saturation Set

   Public Members

   bool op_en
      Indicate if optional parameters are included

   uint16_t saturation
      Target value of light hsl hue state
uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_light_hsl_default_set_t
Parameters of Light HSL Default Set

Public Members

uint16_t lightness
Value of light lightness default state

uint16_t hue
Value of light hue default state

uint16_t saturation
Value of light saturation default state

struct esp_ble_mesh_light_hsl_range_set_t
Parameters of Light HSL Range Set

Public Members

uint16_t hue_range_min
Value of hue range min field of light hsl hue range state

uint16_t hue_range_max
Value of hue range max field of light hsl hue range state

uint16_t saturation_range_min
Value of saturation range min field of light hsl saturation range state

uint16_t saturation_range_max
Value of saturation range max field of light hsl saturation range state

struct esp_ble_mesh_light_xyl_set_t
Parameters of Light xyL Set

Public Members
bool op_en
   Indicate whether optional parameters included

uint16_t xyl_lightness
   The target value of the Light xyl Lightness state

uint16_t xyl_x
   The target value of the Light xyl X state

uint16_t xyl_y
   The target value of the Light xyl Y state

uint8_t tid
   Transaction Identifier

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_light_xyl_default_set_t
   Parameters of Light xyl Default Set

   Public Members

uint16_t lightness
   The value of the Light Lightness Default state

uint16_t xyl_x
   The value of the Light xyl X Default state

uint16_t xyl_y
   The value of the Light xyl Y Default state

struct esp_ble_mesh_light_xyl_range_set_t
   Parameters of Light xyl Range Set

   Public Members

uint16_t xyl_x_range_min
   The value of the xyl X Range Min field of the Light xyl X Range state

uint16_t xyl_x_range_max
   The value of the xyl X Range Max field of the Light xyl X Range state
uint16_t *xyl_y_range_min
   The value of the xyL y Range Min field of the Light xyL y Range state

uint16_t *xyl_y_range_max
   The value of the xyL y Range Max field of the Light xyL y Range state

struct esp_ble_mesh_light_lc_mode_set_t
   Parameter of Light LC Mode Set

   **Public Members**

   uint8_t *mode
      The target value of the Light LC Mode state

struct esp_ble_mesh_light_lc_om_set_t
   Parameter of Light LC OM Set

   **Public Members**

   uint8_t *mode
      The target value of the Light LC Occupancy Mode state

struct esp_ble_mesh_light_lc_light_onoff_set_t
   Parameters of Light LC Light OnOff Set

   **Public Members**

   bool *op_en
      Indicate whether optional parameters included

   uint8_t *light_onoff
      The target value of the Light LC Light OnOff state

   uint8_t *tid
      Transaction Identifier

   uint8_t *trans_time
      Time to complete state transition (optional)

   uint8_t *delay
      Indicate message execution delay (C.1)

struct esp_ble_mesh_light_lc_property_get_t
   Parameter of Light LC Property Get
Public Members

```c
uint16_t property_id
    Property ID identifying a Light LC Property
```

```c
struct esp_ble_mesh_light_lc_property_set_t
    Parameters of Light LC Property Set
```

Public Members

```c
uint16_t property_id
    Property ID identifying a Light LC Property
```

```c
struct net_buf_simple *property_value
    Raw value for the Light LC Property
```

```c
struct esp_ble_mesh_light_lightness_status_cb_t
    Bluetooth Mesh Light Lightness Client Model Get and Set callback parameters structure.
    Parameters of Light Lightness Status
```

Public Members

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t present_lightness
    Current value of light lightness actual state
```

```c
uint16_t target_lightness
    Target value of light lightness actual state (optional)
```

```c
uint8_t remain_time
    Time to complete state transition (C.1)
```

```c
struct esp_ble_mesh_light_lightness_linear_status_cb_t
    Parameters of Light Lightness Linear Status
```

Public Members

```c
bool op_en
    Indicate if optional parameters are included
```

```c
uint16_t present_lightness
    Current value of light lightness linear state
```
### Public Members

**uint16_t target_lightness**
Target value of light lightness linear state (optional)

**uint8_t remain_time**
Time to complete state transition (C.1)

**struct esp_ble_mesh_light_lightness_last_status_cb_t**
Parameter of Light Lightness Last Status

**Public Members**

**uint16_t lightness**
The value of the Light Lightness Last state

**struct esp_ble_mesh_light_lightness_default_status_cb_t**
Parameter of Light Lightness Default Status

**Public Members**

**uint16_t lightness**
The value of the Light Lightness default State

**struct esp_ble_mesh_light_lightness_range_status_cb_t**
Parameters of Light Lightness Range Status

**Public Members**

**uint8_t status_code**
Status Code for the request message

**uint16_t range_min**
Value of range min field of light lightness range state

**uint16_t range_max**
Value of range max field of light lightness range state

**struct esp_ble_mesh_light_ctl_status_cb_t**
Parameters of Light CTL Status

**Public Members**

**bool op_en**
Indicate if optional parameters are included

**uint16_t present_ctl_lightness**
Current value of light ctl lightness state
### Chapter 2. API Reference

- **uint16_t present_ctl_temperature**
  - Current value of light control temperature state

- **uint16_t target_ctl_lightness**
  - Target value of light control lightness state (optional)

- **uint16_t target_ctl_temperature**
  - Target value of light control temperature state (C.1)

- **uint8_t remain_time**
  - Time to complete state transition (C.1)

**struct esp_ble_mesh_light_ctl_temperature_status_cb_t**

Parameters of Light CTL Temperature Status

#### Public Members

- **bool op_en**
  - Indicate if optional parameters are included

- **uint16_t present_ctl_temperature**
  - Current value of light control temperature state

- **uint16_t present_ctl_delta_uv**
  - Current value of light control delta UV state

- **uint16_t target_ctl_temperature**
  - Target value of light control temperature state (optional)

- **uint16_t target_ctl_delta_uv**
  - Target value of light control delta UV state (C.1)

- **uint8_t remain_time**
  - Time to complete state transition (C.1)

**struct esp_ble_mesh_light_ctl_temperature_range_status_cb_t**

Parameters of Light CTL Temperature Range Status

#### Public Members

- **uint8_t status_code**
  - Status code for the request message

- **uint16_t range_min**
  - Value of temperature range min field of light control temperature range state


```c
uint16_t range_max
   Value of temperature range max field of light ctl temperature range state
```

```c
struct esp_ble_mesh_light_ctl_default_status_cb_t
   Parameters of Light CTL Default Status
```

**Public Members**

```c
uint16_t lightness
   Value of light lightness default state
```

```c
uint16_t temperature
   Value of light temperature default state
```

```c
int16_t delta_uv
   Value of light delta UV default state
```

```c
struct esp_ble_mesh_light_hsl_status_cb_t
   Parameters of Light HSL Status
```

**Public Members**

```c
bool op_en
   Indicate if optional parameters are included
```

```c
uint16_t hsl_lightness
   Current value of light hsl lightness state
```

```c
uint16_t hsl_hue
   Current value of light hsl hue state
```

```c
uint16_t hsl_saturation
   Current value of light hsl saturation state
```

```c
uint8_t remain_time
   Time to complete state transition (optional)
```

```c
struct esp_ble_mesh_light_hsl_target_status_cb_t
   Parameters of Light HSL Target Status
```

**Public Members**

```c
bool op_en
   Indicate if optional parameters are included
```
uint16_t \textit{hsl\_lightness\_target}  
Target value of light hsl lightness state

uint16_t \textit{hsl\_hue\_target}  
Target value of light hsl hue state

uint16_t \textit{hsl\_saturation\_target}  
Target value of light hsl saturation state

uint8_t \textit{remain\_time}  
Time to complete state transition (optional)

\begin{verbatim}
struct esp\_ble\_mesh\_light\_hsl\_hue\_status\_cb\_t 
Parameters of Light HSL Hue Status

    Public Members
    
    bool \textit{op\_en} 
    Indicate if optional parameters are included

    uint16_t \textit{present\_hue}  
    Current value of light hsl hue state

    uint16_t \textit{target\_hue}  
    Target value of light hsl hue state (optional)

    uint8_t \textit{remain\_time}  
    Time to complete state transition (C.1)
\end{verbatim}

\begin{verbatim}
struct esp\_ble\_mesh\_light\_hsl\_saturation\_status\_cb\_t 
Parameters of Light HSL Saturation Status

    Public Members
    
    bool \textit{op\_en} 
    Indicate if optional parameters are included

    uint16_t \textit{present\_saturation}  
    Current value of light hsl saturation state

    uint16_t \textit{target\_saturation}  
    Target value of light hsl saturation state (optional)

    uint8_t \textit{remain\_time}  
    Time to complete state transition (C.1)
\end{verbatim}

\begin{verbatim}
struct esp\_ble\_mesh\_light\_hsl\_default\_status\_cb\_t 
Parameters of Light HSL Default Status
\end{verbatim}
Chapter 2. API Reference

Public Members

```cpp
uint16_t lightness
    Value of light lightness default state
```

```cpp
uint16_t hue
    Value of light hue default state
```

```cpp
uint16_t saturation
    Value of light saturation default state
```

```cpp
struct esp_ble_mesh_light_hsl_range_status_cb_t
    Parameters of Light HSL Range Status
```

```cpp
uint8_t status_code
    Status code for the request message
```

```cpp
uint16_t hue_range_min
    Value of hue range min field of light hsl hue range state
```

```cpp
uint16_t hue_range_max
    Value of hue range max field of light hsl hue range state
```

```cpp
uint16_t saturation_range_min
    Value of saturation range min field of light hsl saturation range state
```

```cpp
uint16_t saturation_range_max
    Value of saturation range max field of light hsl saturation range state
```

```cpp
struct esp_ble_mesh_light_xyl_status_cb_t
    Parameters of Light xyL Status
```

```cpp
bool op_en
    Indicate whether optional parameters included
```

```cpp
uint16_t xyl_lightness
    The present value of the Light xyL Lightness state
```

```cpp
uint16_t xyl_x
    The present value of the Light xyL x state
```

```cpp
uint16_t xyl_y
    The present value of the Light xyL y state
```
uint8_t remain_time
    Time to complete state transition (optional)

struct esp_ble_mesh_light_xyl_target_status_cb_t
    Parameters of Light xyL Target Status

Public Members

bool op_en
    Indicate whether optional parameters included

uint16_t target_xyl_lightness
    The target value of the Light xyL Lightness state

uint16_t target_xyl_x
    The target value of the Light xyL x state

uint16_t target_xyl_y
    The target value of the Light xyL y state

uint8_t remain_time
    Time to complete state transition (optional)

struct esp_ble_mesh_light_xyl_default_status_cb_t
    Parameters of Light xyL Default Status

Public Members

uint16_t lightness
    The value of the Light Lightness Default state

uint16_t xyl_x
    The value of the Light xyL x Default state

uint16_t xyl_y
    The value of the Light xyL y Default state

struct esp_ble_mesh_light_xyl_range_status_cb_t
    Parameters of Light xyL Range Status

Public Members

uint8_t status_code
    Status Code for the requesting message
uint16_t `xyl_x_range_min`
The value of the xyl x Range Min field of the Light xyl x Range state

uint16_t `xyl_x_range_max`
The value of the xyl x Range Max field of the Light xyl x Range state

uint16_t `xyl_y_range_min`
The value of the xyl y Range Min field of the Light xyl y Range state

uint16_t `xyl_y_range_max`
The value of the xyl y Range Max field of the Light xyl y Range state

struct `esp_ble_mesh_light_lc_mode_status_cb_t`
Parameter of Light LC Mode Status

**Public Members**

uint8_t `mode`
The present value of the Light LC Mode state

struct `esp_ble_mesh_light_lc_cm_status_cb_t`
Parameter of Light LC CM Status

**Public Members**

uint8_t `mode`
The present value of the Light LC CM Mode state

struct `esp_ble_mesh_light_lc_light_onoff_status_cb_t`
Parameters of Light LC Light OnOff Status

**Public Members**

bool `op_en`
Indicate whether optional parameters included

uint8_t `present_light_onoff`
The present value of the Light LC Light OnOff state

uint8_t `target_light_onoff`
The target value of the Light LC Light OnOff state (Optional)

uint8_t `remain_time`
Time to complete state transition (C.1)

struct `esp_ble_mesh_light_lc_property_status_cb_t`
Parameters of Light LC Property Status
Public Members

`uint16_t property_id`
Property ID identifying a Light LC Property

`struct net_buf_simple *property_value`
Raw value for the Light LC Property

`struct esp_ble_mesh_light_client_cb_param_t`
Lighting Client Model callback parameters

Public Members

`int error_code`
Appropriate error code

`esp_ble_mesh_client_common_param_t *params`
The client common parameters.

`esp_ble_mesh_light_client_status_cb_t status_cb`
The light status message callback values

`struct esp_ble_mesh_light_lightness_state_t`
Parameters of Light Lightness state

Public Members

`uint16_t lightness_linear`
The present value of Light Lightness Linear state

`uint16_t target_lightness_linear`
The target value of Light Lightness Linear state

`uint16_t lightness_actual`
The present value of Light Lightness Actual state

`uint16_t target_lightness_actual`
The target value of Light Lightness Actual state

`uint16_t lightness_last`
The value of Light Lightness Last state

`uint16_t lightness_default`
The value of Light Lightness Default state

`uint8_t status_code`
The status code of setting Light Lightness Range state
uint16_t lightness_range_min
    The minimum value of Light Lightness Range state

uint16_t lightness_range_max
    The maximum value of Light Lightness Range state

struct esp_ble_mesh_light_lightness_srv_t
    User data of Light Lightness Server Model

Public Members

esp_ble_mesh_model_t *model
    Pointer to the Lighting Lightness Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages

esp_ble_mesh_light_lightness_state_t *state
    Parameters of the Light Lightness state

esp_ble_mesh_last_msg_info_t *last
    Parameters of the last received set message

esp_ble_mesh_state_transition_t actual_transition
    Parameters of state transition

esp_ble_mesh_state_transition_t linear_transition
    Parameters of state transition

int32_t tt_delta_lightness_actual
    Delta change value of lightness actual state transition

int32_t tt_delta_lightness_linear
    Delta change value of lightness linear state transition

struct esp_ble_mesh_light_lightness_setup_srv_t
    User data of Light Lightness Setup Server Model

Public Members

esp_ble_mesh_model_t *model
    Pointer to the Lighting Lightness Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages
esp_ble_mesh_light_lightness_state_t *state
Parameters of the Light Lightness state

struct esp_ble_mesh_light_ctl_state_t
Parameters of Light CTL state

**Public Members**

uint16_t lightness
The present value of Light CTL Lightness state

uint16_t target_lightness
The target value of Light CTL Lightness state

uint16_t temperature
The present value of Light CTL Temperature state

uint16_t target_temperature
The target value of Light CTL Temperature state

int16_t delta_uv
The present value of Light CTL Delta UV state

int16_t target_delta_uv
The target value of Light CTL Delta UV state

uint8_t status_code
The statue code of setting Light CTL Temperature Range state

uint16_t temperature_range_min
The minimum value of Light CTL Temperature Range state

uint16_t temperature_range_max
The maximum value of Light CTL Temperature Range state

uint16_t lightness_default
The value of Light Lightness Default state

uint16_t temperature_default
The value of Light CTL Temperature Default state

int16_t delta_uv_default
The value of Light CTL Delta UV Default state

struct esp_ble_mesh_light_ctl_srv_t
User data of Light CTL Server Model
Public Members

`esp_ble_mesh_model_t *model`
Pointer to the Lighting CTL Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages

`esp_ble_mesh_light_ctl_state_t *state`
Parameters of the Light CTL state

`esp_ble_mesh_last_msg_info_t last`
Parameters of the last received set message

`esp_ble_mesh_state_transition_t transition`
Parameters of state transition

`int32_t tt_delta_lightness`
Delta change value of lightness state transition

`int32_t tt_delta_temperature`
Delta change value of temperature state transition

`int32_t tt_delta_delta_uv`
Delta change value of delta uv state transition

`struct esp_ble_mesh_light_ctl_setup_srv_t`
User data of Light CTL Setup Server Model

Public Members

`esp_ble_mesh_model_t *model`
Pointer to the Lighting CTL Setup Server Model. Initialized internally.

`esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl`
Response control of the server model received messages

`esp_ble_mesh_light_ctl_state_t *state`
Parameters of the Light CTL state

`struct esp_ble_mesh_light_ctl_temp_srv_t`
User data of Light CTL Temperature Server Model

Public Members

`esp_ble_mesh_model_t *model`
Pointer to the Lighting CTL Temperature Server Model. Initialized internally.
esp_ble_mesh_server_rsp_ctrl_t \textit{rsp\_ctrl}
Response control of the server model received messages

\textit{esp\_ble\_mesh\_light\_ctl\_state\_t *state}
Parameters of the Light CTL state

\textit{esp\_ble\_mesh\_last\_msg\_info\_t last}
Parameters of the last received set message

\textit{esp\_ble\_mesh\_state\_transition\_t transition}
Parameters of state transition

\text{int32\_t tt\_delta\_temperature}
Delta change value of temperature state transition

\text{int32\_t tt\_delta\_delta\_uv}
Delta change value of delta uv state transition

\texttt{struct esp\_ble\_mesh\_light\_hsl\_state\_t}
Parameters of Light HSL state

**Public Members**

\texttt{uint16\_t lightness}
The present value of Light HSL Lightness state

\texttt{uint16\_t target\_lightness}
The target value of Light HSL Lightness state

\texttt{uint16\_t hue}
The present value of Light HSL Hue state

\texttt{uint16\_t target\_hue}
The target value of Light HSL Hue state

\texttt{uint16\_t saturation}
The present value of Light HSL Saturation state

\texttt{uint16\_t target\_saturation}
The target value of Light HSL Saturation state

\texttt{uint16\_t lightness\_default}
The value of Light Lightness Default state

\texttt{uint16\_t hue\_default}
The value of Light HSL Hue Default state
uint16_t saturation_default
   The value of Light HSL Saturation Default state

uint8_t status_code
   The status code of setting Light HSL Hue & Saturation Range state

uint16_t hue_range_min
   The minimum value of Light HSL Hue Range state

uint16_t hue_range_max
   The maximum value of Light HSL Hue Range state

uint16_t saturation_range_min
   The minimum value of Light HSL Saturation state

uint16_t saturation_range_max
   The maximum value of Light HSL Saturation state

struct esp_ble_mesh_light_hsl_srv_t
   User data of Light HSL Server Model

Public Members

esp_ble_mesh_model_t *model
   Pointer to the Lighting HSL Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
   Response control of the server model received messages

esp_ble_mesh_light_hsl_state_t *state
   Parameters of the Light HSL state

esp_ble_mesh_last_msg_info_t last
   Parameters of the last received set message

esp_ble_mesh_state_transition_t *transition
   Parameters of state transition

int32_t tt_delta_lightness
   Delta change value of lightness state transition

int32_t tt_delta_hue
   Delta change value of hue state transition

int32_t tt_delta_saturation
   Delta change value of saturation state transition

struct esp_ble_mesh_light_hsl_setup_srv_t
   User data of Light HSL Setup Server Model
Public Members

```c
esp_ble_mesh_model_t *model
```

Pointer to the Lighting HSL Setup Server Model. Initialized internally.

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
```

Response control of the server model received messages

```c
esp_ble_mesh_light_hsl_state_t *state
```

Parameters of the Light HSL state

```c
struct esp_ble_mesh_light_hsl_hue_srv_t
```

User data of Light HSL Hue Server Model

Public Members

```c
esp_ble_mesh_model_t *model
```

Pointer to the Lighting HSL Hue Server Model. Initialized internally.

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
```

Response control of the server model received messages

```c
esp_ble_mesh_light_hsl_state_t *state
```

Parameters of the Light HSL state

```c
esp_ble_mesh_last_msg_info_t last
```

Parameters of the last received set message

```c
esp_ble_mesh_state_transition_t transition
```

Parameters of state transition

```c
int32_t tt_delta_hue
```

Delta change value of hue state transition

```c
struct esp_ble_mesh_light_hsl_sat_srv_t
```

User data of Light HSL Saturation Server Model

Public Members

```c
esp_ble_mesh_model_t *model
```

Pointer to the Lighting HSL Saturation Server Model. Initialized internally.

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
```

Response control of the server model received messages

```c
esp_ble_mesh_light_hsl_state_t *state
```

Parameters of the Light HSL state
Chapter 2. API Reference

\texttt{esp\_ble\_mesh\_last\_msg\_info\_t last}
Parameters of the last received set message

\texttt{esp\_ble\_mesh\_state\_transition\_t transition}
Parameters of state transition

\texttt{int32\_t tt\_delta\_saturation}
Delta change value of saturation state transition

\texttt{struct esp\_ble\_mesh\_light\_xyl\_state\_t}
Parameters of Light xyL state

**Public Members**

\texttt{uint16\_t lightness}
The present value of Light xyL Lightness state

\texttt{uint16\_t target\_lightness}
The target value of Light xyL Lightness state

\texttt{uint16\_t x}
The present value of Light xyL x state

\texttt{uint16\_t target\_x}
The target value of Light xyL x state

\texttt{uint16\_t y}
The present value of Light xyL y state

\texttt{uint16\_t target\_y}
The target value of Light xyL y state

\texttt{uint16\_t lightness\_default}
The value of Light Lightness Default state

\texttt{uint16\_t x\_default}
The value of Light xyL x Default state

\texttt{uint16\_t y\_default}
The value of Light xyL y Default state

\texttt{uint8\_t status\_code}
The status code of setting Light xyL x & y Range state

\texttt{uint16\_t x\_range\_min}
The minimum value of Light xyL x Range state
uint16_t x_range_max
    The maximum value of Light xyL x Range state

uint16_t y_range_min
    The minimum value of Light xyL y Range state

uint16_t y_range_max
    The maximum value of Light xyL y Range state

struct esp_ble_mesh_light_xyl_srv_t
User data of Light xyL Server Model

Public Members

esp_ble_mesh_model_t *model
    Pointer to the Lighting xyL Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages

esp_ble_mesh_light_xyl_state_t *state
    Parameters of the Light xyL state

esp_ble_mesh_last_msg_info_t last
    Parameters of the last received set message

esp_ble_mesh_state_transition_t transition
    Parameters of state transition

int32_t tt_delta_lightness
    Delta change value of lightness state transition

int32_t tt_delta_x
    Delta change value of x state transition

int32_t tt_delta_y
    Delta change value of y state transition

struct esp_ble_mesh_light_xyl_setup_srv_t
User data of Light xyL Setup Server Model

Public Members

esp_ble_mesh_model_t *model
    Pointer to the Lighting xyL Setup Server Model. Initialized internally.
Chapter 2. API Reference

`esp_ble_mesh_server_rsp_ctrl_t` **rsp_ctrl**  
Response control of the server model received messages

`esp_ble_mesh_light_xyl_state_t` *state*  
Parameters of the Light xYL state

`struct esp_ble_mesh_light_lc_state_t`  
Parameters of Light LC states

**Public Members**

`uint32_t mode`  
0b0 The controller is turned off.  
• The binding with the Light Lightness state is disabled. 0b1 The controller is turned on.  
• The binding with the Light Lightness state is enabled. The value of Light LC Mode state

`uint32_t occupancy_mode`  
The value of Light LC Occupancy Mode state

`uint32_t light_onoff`  
The present value of Light LC Light OnOff state

`uint32_t target_light_onoff`  
The target value of Light LC Light OnOff state

`uint32_t occupancy`  
The value of Light LC Occupancy state

`uint32_t ambient_luxlevel`  
The value of Light LC Ambient LuxLevel state

`uint16_t linear_output`  
i. Light LC Linear Output = max((Lightness Out)^2/65535, Regulator Output)  
ii. If the Light LC Mode state is set to 0b1, the binding is enabled and upon a change of the Light LC Linear Output state, the following operation shall be performed: Light Lightness Linear = Light LC Linear Output  
iii. If the Light LC Mode state is set to 0b0, the binding is disabled (i.e., upon a change of the Light LC Linear Output state, no operation on the Light Lightness Linear state is performed). The value of Light LC Linear Output state

`struct esp_ble_mesh_light_lc_property_state_t`  
Parameters of Light Property states. The Light LC Property states are read / write states that determine the configuration of a Light Lightness Controller. Each state is represented by a device property and is controlled by Light LC Property messages.

**Public Members**
Chapter 2. API Reference

uint32_t `time_occupancy_delay`
A timing state that determines the delay for changing the Light LC Occupancy state upon receiving a Sensor Status message from an occupancy sensor. The value of Light LC Time Occupancy Delay state

uint32_t `time_fade_on`
A timing state that determines the time the controlled lights fade to the level determined by the Light LC Lightness On state. The value of Light LC Time Fade On state

uint32_t `time_run_on`
A timing state that determines the time the controlled lights stay at the level determined by the Light LC Lightness On state. The value of Light LC Time Run On state

uint32_t `time_fade`
A timing state that determines the time the controlled lights fade from the level determined by the Light LC Lightness On state to the level determined by the Light Lightness Prolong state. The value of Light LC Time Fade state

uint32_t `time_prolong`
A timing state that determines the time the controlled lights stay at the level determined by the Light LC Lightness Prolong state. The value of Light LC Time Prolong state

uint32_t `time_fade_standby_auto`
A timing state that determines the time the controlled lights fade from the level determined by the Light LC Lightness Prolong state to the level determined by the Light LC Lightness Standby state when the transition is automatic. The value of Light LC Time Fade Standby Auto state

uint32_t `time_fade_standby_manual`
A timing state that determines the time the controlled lights fade from the level determined by the Light LC Lightness Prolong state to the level determined by the Light LC Lightness Standby state when the transition is triggered by a change in the Light LC Light OnOff state. The value of Light LC Time Fade Standby Manual state

uint16_t `lightness_on`
A lightness state that determines the perceptive light lightness at the Occupancy and Run internal controller states. The value of Light LC Lightness On state

uint16_t `lightness_prolong`
A lightness state that determines the light lightness at the Prolong internal controller state. The value of Light LC Lightness Prolong state

uint16_t `lightness_standby`
A lightness state that determines the light lightness at the Standby internal controller state. The value of Light LC Lightness Standby state

uint16_t `ambient_luxlevel_on`
A uint16 state representing the Ambient LuxLevel level that determines if the controller transitions from the Light Control Standby state. The value of Light LC Ambient LuxLevel On state

uint16_t `ambient_luxlevel_prolong`
A uint16 state representing the required Ambient LuxLevel level in the Prolong state. The value of Light LC Ambient LuxLevel Prolong state
uint16_t ambient_luxlevel_standby
A uint16 state representing the required Ambient LuxLevel level in the Standby state. The value of Light LC Ambient LuxLevel Standby state

float regulator_kiu
A float32 state representing the integral coefficient that determines the integral part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is less than LuxLevel Out. Valid range: 0.0 ~ 1000.0. The default value is 250.0. The value of Light LC Regulator Kiu state

float regulator_kid
A float32 state representing the integral coefficient that determines the integral part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is greater than or equal to the value of the LuxLevel Out state. Valid range: 0.0 ~ 1000.0. The default value is 25.0. The value of Light LC Regulator Kid state

float regulator_kpu
A float32 state representing the proportional coefficient that determines the proportional part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is less than the value of the LuxLevel Out state. Valid range: 0.0 ~ 1000.0. The default value is 80.0. The value of Light LC Regulator Kpu state

float regulator_kpd
A float32 state representing the proportional coefficient that determines the proportional part of the equation defining the output of the Light LC PI Feedback Regulator, when Light LC Ambient LuxLevel is greater than or equal to the value of the LuxLevel Out state. Valid range: 0.0 ~ 1000.0. The default value is 80.0. The value of Light LC Regulator Kpd state

int8_t regulator_accuracy
A int8 state representing the percentage accuracy of the Light LC PI Feedback Regulator. Valid range: 0.0 ~ 100.0. The default value is 2.0. The value of Light LC Regulator Accuracy state

uint32_t set_occupancy_to_1_delay
If the message Raw field contains a Raw Value for the Time Since Motion Sensed device property, which represents a value less than or equal to the value of the Light LC Occupancy Delay state, it shall delay setting the Light LC Occupancy state to 0b1 by the difference between the value of the Light LC OccupancyDelay state and the received Time Since Motion value. The value of the difference between the value of the Light LC Occupancy Delay state and the received Time Since Motion value

struct esp_ble_mesh_light_lc_state_machine_t
Parameters of Light LC state machine

Public Members

uint8_t fade_on
The value of transition time of Light LC Time Fade On

uint8_t fade
The value of transition time of Light LC Time Fade
Chapter 2. API Reference

uint8_t fade_standby_auto

The value of transition time of Light LC Time Fade Standby Auto

uint8_t fade_standby_manual

The value of transition time of Light LC Time Fade Standby Manual

struct esp_ble_mesh_light_lc_state_machine_t::[anonymous] trans_time

The Fade On, Fade, Fade Standby Auto, and Fade Standby Manual states are transition states that define the transition of the Lightness Out and LuxLevel Out states. This transition can be started as a result of the Light LC State Machine change or as a result of receiving the Light LC Light OnOff Set or Light LC Light Set Unacknowledged message. The value of transition time

esp_ble_mesh_lc_state_t state

The value of Light LC state machine state

struct k_delayed_work timer

Timer of Light LC state machine

struct esp_ble_mesh_light_control_t

Parameters of Light Lightness controller

Public Members

esp_ble_mesh_light_lc_state_t state
Parameters of Light LC state

esp_ble_mesh_light_lc_property_state_t prop_state
Parameters of Light LC Property state

esp_ble_mesh_light_lc_state_machine_t state_machine
Parameters of Light LC state machine

struct esp_ble_mesh_light_lc_srv_t

User data of Light LC Server Model

Public Members

esp_ble_mesh_model_t *model

Pointer to the Lighting LC Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t rsp_ctrl

Response control of the server model received messages

esp_ble_mesh_light_control_t *lc

Parameters of the Light controller

esp_ble_mesh_last_msg_info_t last
Parameters of the last received set message
\textit{esp\_ble\_mesh\_state\_transition\_t} \texttt{transition}
Parameters of state transition

\begin{verbatim}
struct esp_ble_mesh_light_lc_setup_srv_t
User data of Light LC Setup Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Lighting LC Setup Server Model. Initialized internally.

esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
Response control of the server model received messages

esp_ble_mesh_light_control_t *lc
Parameters of the Light controller
\end{verbatim}

\begin{verbatim}
struct esp_ble_mesh_state_change_light_lightness_set_t
Parameter of Light Lightness Actual state change event

Public Members

uint16_t lightness
The value of Light Lightness Actual state
\end{verbatim}

\begin{verbatim}
struct esp_ble_mesh_state_change_light_lightness_linear_set_t
Parameter of Light Lightness Linear state change event

Public Members

uint16_t lightness
The value of Light Lightness Linear state
\end{verbatim}

\begin{verbatim}
struct esp_ble_mesh_state_change_light_lightness_default_set_t
Parameter of Light Lightness Default state change event

Public Members

uint16_t lightness
The value of Light Lightness Default state
\end{verbatim}

\begin{verbatim}
struct esp_ble_mesh_state_change_light_lightness_range_set_t
Parameters of Light Lightness Range state change event
\end{verbatim}
Public Members

`uint16_t range_min`
The minimum value of Light Lightness Range state

`uint16_t range_max`
The maximum value of Light Lightness Range state

`struct esp_ble_mesh_state_change_light_ctl_set_t`
Parameters of Light CTL state change event

Public Members

`uint16_t lightness`
The value of Light CTL Lightness state

`uint16_t temperature`
The value of Light CTL Temperature state

`int16_t delta_uv`
The value of Light CTL Delta UV state

`struct esp_ble_mesh_state_change_light_ctl_temperature_set_t`
Parameters of Light CTL Temperature state change event

Public Members

`uint16_t temperature`
The value of Light CTL Temperature state

`int16_t delta_uv`
The value of Light CTL Delta UV state

`struct esp_ble_mesh_state_change_light_ctl_temperature_range_set_t`
Parameters of Light CTL Temperature Range state change event

Public Members

`uint16_t range_min`
The minimum value of Light CTL Temperature Range state

`uint16_t range_max`
The maximum value of Light CTL Temperature Range state

`struct esp_ble_mesh_state_change_light_ctl_default_set_t`
Parameters of Light CTL Default state change event
Public Members

uint16_t lightness
The value of Light Lightness Default state

uint16_t temperature
The value of Light CTL Temperature Default state

int16_t delta_uv
The value of Light CTL Delta UV Default state

struct esp_ble_mesh_state_change_light_hsl_set_t
Parameters of Light HSL state change event

Public Members

uint16_t lightness
The value of Light HSL Lightness state

uint16_t hue
The value of Light HSL Hue state

uint16_t saturation
The value of Light HSL Saturation state

struct esp_ble_mesh_state_change_light_hsl_hue_set_t
Parameter of Light HSL Hue state change event

Public Members

uint16_t hue
The value of Light HSL Hue state

struct esp_ble_mesh_state_change_light_hsl_saturation_set_t
Parameter of Light HSL Saturation state change event

Public Members

uint16_t saturation
The value of Light HSL Saturation state

struct esp_ble_mesh_state_change_light_hsl_default_set_t
Parameters of Light HSL Default state change event
## Public Members

```c
uint16_t lightness
```

The value of Light HSL Lightness Default state

```c
uint16_t hue
```

The value of Light HSL Hue Default state

```c
uint16_t saturation
```

The value of Light HSL Saturation Default state

```c
struct esp_ble_mesh_state_change_light_hsl_range_set_t
```

Parameters of Light HSL Range state change event

## Public Members

```c
uint16_t hue_range_min
```

The minimum hue value of Light HSL Range state

```c
uint16_t hue_range_max
```

The maximum hue value of Light HSL Range state

```c
uint16_t saturation_range_min
```

The minimum saturation value of Light HSL Range state

```c
uint16_t saturation_range_max
```

The maximum saturation value of Light HSL Range state

```c
struct esp_ble_mesh_state_change_light_xy_l_set_t
```

Parameters of Light xyL state change event

## Public Members

```c
uint16_t lightness
```

The value of Light xyL Lightness state

```c
uint16_t x
```

The value of Light xyL x state

```c
uint16_t y
```

The value of Light xyL y state

```c
struct esp_ble_mesh_state_change_light_xy_l_default_set_t
```

Parameters of Light xyL Default state change event
Public Members

```c
uint16_t lightness
    The value of Light Lightness Default state
```

```c
uint16_t x
    The value of Light xyL x Default state
```

```c
uint16_t y
    The value of Light xyL y Default state
```

```c
struct esp_ble_mesh_state_change_light_xyl_range_set_t
    Parameters of Light xyl Range state change event
```

Public Members

```c
uint16_t x_range_min
    The minimum value of Light xyL x Range state
```

```c
uint16_t x_range_max
    The maximum value of Light xyL x Range state
```

```c
uint16_t y_range_min
    The minimum value of Light xyL y Range state
```

```c
uint16_t y_range_max
    The maximum value of Light xyL y Range state
```

```c
struct esp_ble_mesh_state_change_light_lc_mode_set_t
    Parameter of Light LC Mode state change event
```

Public Members

```c
uint8_t mode
    The value of Light LC Mode state
```

```c
struct esp_ble_mesh_state_change_light_lc_om_set_t
    Parameter of Light LC Occupancy Mode state change event
```

Public Members

```c
uint8_t mode
    The value of Light LC Occupancy Mode state
```

```c
struct esp_ble_mesh_state_change_light_lc_light_onoff_set_t
    Parameter of Light LC Light OnOff state change event
```
Public Members

uint8_t onoff
   The value of Light LC Light OnOff state

struct esp_ble_mesh_state_change_light_lc_property_set_t
   Parameters of Light LC Property state change event

Public Members

uint16_t property_id
   The property id of Light LC Property state

struct net_buf_simple *property_value
   The property value of Light LC Property state

struct esp_ble_mesh_state_change_sensor_status_t
   Parameters of Sensor Status state change event

Public Members

uint16_t property_id
   The value of Sensor Property ID

uint8_t occupancy
   The value of Light LC Occupancy state

uint32_t set_occupancy_to_1_delay
   The value of Light LC Set Occupancy to 1 Delay state

uint32_t ambient_luxlevel
   The value of Light LC Ambient Luxlevel state

union esp_ble_mesh_state_change_sensor_status_t::[anonymous] state
   Parameters of Sensor Status related state

struct esp_ble_mesh_server_recv_light_lc_property_get_t
   Context of the received Light LC Property Get message

Public Members

uint16_t property_id
   Property ID identifying a Light LC Property

struct esp_ble_mesh_server_recv_light_lightness_set_t
   Context of the received Light Lightness Set message
Public Members

bool op_en
Indicate if optional parameters are included

uint16_t lightness
Target value of light lightness actual state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_light_lightness_linear_set_t
Context of the received Light Lightness Linear Set message

Public Members

bool op_en
Indicate if optional parameters are included

uint16_t lightness
Target value of light lightness linear state

uint8_t tid
Transaction ID

uint8_t trans_time
Time to complete state transition (optional)

uint8_t delay
Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_light_lightness_default_set_t
Context of the received Light Lightness Default Set message

Public Members

uint16_t lightness
The value of the Light Lightness Default state

struct esp_ble_mesh_server_recv_light_lightness_range_set_t
Context of the received Light Lightness Range Set message
**Public Members**

```c
uint16_t range_min
   Value of range min field of light lightness range state

uint16_t range_max
   Value of range max field of light lightness range state
```

```
struct esp_ble_mesh_server_recv_light_ctl_set_t
   Context of the received Light CTL Set message
```

**Public Members**

```c
bool op_en
   Indicate if optional parameters are included

uint16_t lightness
   Target value of light ctl lightness state

uint16_t temperature
   Target value of light ctl temperature state

int16_t delta_uv
   Target value of light ctl delta UV state

uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)
```

```
struct esp_ble_mesh_server_recv_light_ctl_temperature_set_t
   Context of the received Light CTL Temperature Set message
```

**Public Members**

```c
bool op_en
   Indicate if optional parameters are included

uint16_t temperature
   Target value of light ctl temperature state

int16_t delta_uv
   Target value of light ctl delta UV state
```
uint8_t tid
   Transaction ID

uint8_t trans_time
   Time to complete state transition (optional)

uint8_t delay
   Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_light_ctl_temperature_range_set_t
   Context of the received Light CTL Temperature Range Set message

**Public Members**

uint16_t range_min
   Value of temperature range min field of light ctl temperature range state

uint16_t range_max
   Value of temperature range max field of light ctl temperature range state

struct esp_ble_mesh_server_recv_light_ctl_default_set_t
   Context of the received Light_CTL Default Set message

**Public Members**

uint16_t lightness
   Value of light lightness default state

uint16_t temperature
   Value of light temperature default state

int16_t delta_uv
   Value of light delta UV default state

struct esp_ble_mesh_server_recv_light_hsl_set_t
   Context of the received Light HSL Set message

**Public Members**

bool op_en
   Indicate if optional parameters are included

uint16_t lightness
   Target value of light hsl lightness state
### Chapter 2. API Reference

**uint16_t hue**
Target value of light hsl hue state

**uint16_t saturation**
Target value of light hsl saturation state

**uint8_t tid**
Transaction ID

**uint8_t trans_time**
Time to complete state transition (optional)

**uint8_t delay**
Indicate message execution delay (C.1)

**struct esp_ble_mesh_server_recv_light_hsl_hue_set_t**
Context of the received Light HSL Hue Set message

**Public Members**

- **bool op_en**
  Indicate if optional parameters are included

- **uint16_t hue**
  Target value of light hsl hue state

- **uint8_t tid**
  Transaction ID

- **uint8_t trans_time**
  Time to complete state transition (optional)

- **uint8_t delay**
  Indicate message execution delay (C.1)

**struct esp_ble_mesh_server_recv_light_hsl_saturation_set_t**
Context of the received Light HSL Saturation Set message

**Public Members**

- **bool op_en**
  Indicate if optional parameters are included

- **uint16_t saturation**
  Target value of light hsl hue state
Chapter 2. API Reference

`uint8_t tid`
Transaction ID

`uint8_t trans_time`
Time to complete state transition (optional)

`uint8_t delay`
Indicate message execution delay (C.1)

```c
struct esp_ble_mesh_server_recv_light_hsl_default_set_t
```
Context of the received Light HSL Default Set message

**Public Members**

`uint16_t lightness`
Value of light lightness default state

`uint16_t hue`
Value of light hue default state

`uint16_t saturation`
Value of light saturation default state

```c
struct esp_ble_mesh_server_recv_light_hsl_range_set_t
```
Context of the received Light HSL Range Set message

**Public Members**

`uint16_t hue_range_min`
Value of hue range min field of light hsl hue range state

`uint16_t hue_range_max`
Value of hue range max field of light hsl hue range state

`uint16_t saturation_range_min`
Value of saturation range min field of light hsl saturation range state

`uint16_t saturation_range_max`
Value of saturation range max field of light hsl saturation range state

```c
struct esp_ble_mesh_server_recv_light_xyl_set_t
```
Context of the received Light xyl Set message

**Public Members**
bool **op_en**
Indicate whether optional parameters included

uint16_t **lightness**
The target value of the Light xyL Lightness state

uint16_t **x**
The target value of the Light xyL x state

uint16_t **y**
The target value of the Light xyL y state

uint8_t **tid**
Transaction Identifier

uint8_t **trans_time**
Time to complete state transition (optional)

uint8_t **delay**
Indicate message execution delay (C.1)

**struct esp_ble_mesh_server_recv_light_xyl_default_set_t**
Context of the received Light xyL Default Set message

**Public Members**

uint16_t **lightness**
The value of the Light Lightness Default state

uint16_t **x**
The value of the Light xyL x Default state

uint16_t **y**
The value of the Light xyL y Default state

**struct esp_ble_mesh_server_recv_light_xyl_range_set_t**
Context of the received Light xyL Range Set message

**Public Members**

uint16_t **x_range_min**
The value of the xyL x Range Min field of the Light xyL x Range state

uint16_t **x_range_max**
The value of the xyL x Range Max field of the Light xyL x Range state
uint16_t y_range_min
    The value of the xyL y Range Min field of the Light xyL y Range state

uint16_t y_range_max
    The value of the xyL y Range Max field of the Light xyL y Range state

struct esp_ble_mesh_server_recv_light_lc_mode_set_t
    Context of the received Light LC Mode Set message

    Public Members

    uint8_t mode
        The target value of the Light LC Mode state

struct esp_ble_mesh_server_recv_light_lc_om_set_t
    Context of the received Light OM Set message

    Public Members

    uint8_t mode
        The target value of the Light LC Occupancy Mode state

struct esp_ble_mesh_server_recv_light_lc_light_onoff_set_t
    Context of the received Light LC Light OnOff Set message

    Public Members

    bool op_en
        Indicate whether optional parameters included

    uint8_t light_onoff
        The target value of the Light LC Light OnOff state

    uint8_t tid
        Transaction Identifier

    uint8_t trans_time
        Time to complete state transition (optional)

    uint8_t delay
        Indicate message execution delay (C.1)

struct esp_ble_mesh_server_recv_light_lc_property_set_t
    Context of the received Light LC Property Set message
Chapter 2. API Reference

Public Members

uint16_t **property_id
Property ID identifying a Light LC Property

struct net_buf_simple *property_value
Raw value for the Light LC Property

struct esp_ble_mesh_server_recv_sensor_status_t
Context of the received Sensor Status message

Public Members

struct net_buf_simple *data
Value of sensor data state (optional)

struct esp_ble_mesh_lighting_server_cb_param_t
Lighting Server Model callback parameters

Public Members

esp_ble_mesh_model_t *model
Pointer to Lighting Server Models

esp_ble_mesh_msg_ctx_t ctx
Context of the received messages

esp_ble_mesh_lighting_server_cb_value_t value
Value of the received Lighting Messages

Macros

ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_CLI(cli_pub, cli_data)
Define a new Light Lightness Client Model.

Note: This API needs to be called for each element on which the application needs to have a Light Lightness Client Model.

Parameters
  • cli_pub – Pointer to the unique struct esp_ble_mesh_model_pub_t.
  • cli_data – Pointer to the unique struct esp_ble_mesh_client_t.

Returns
New Light Lightness Client Model instance.

ESP_BLE_MESH_MODEL_LIGHT_CTL_CLI(cli_pub, cli_data)
Define a new Light CTL Client Model.

Note: This API needs to be called for each element on which the application needs to have a Light CTL Client Model.
Chapter 2. API Reference

**Parameters**
- **cli_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Light CTL Client Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_HSL_CLI** (cli_pub, cli_data)
Define a new Light HSL Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Light HSL Client Model.

**Parameters**
- **cli_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Light HSL Client Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_XYL_CLI** (cli_pub, cli_data)
Define a new Light xyL Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Light xyL Client Model.

**Parameters**
- **cli_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Light xyL Client Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_LC_CLI** (cli_pub, cli_data)
Define a new Light LC Client Model.

**Note:** This API needs to be called for each element on which the application needs to have a Light LC Client Model.

**Parameters**
- **cli_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **cli_data** – Pointer to the unique struct `esp_ble_mesh_client_t`.

**Returns** New Light LC Client Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_SRV** (srv_pub, srv_data)
Lighting Server Models related context.
Define a new Light Lightness Server Model.

**Note:** 1. The Light Lightness Server model extends the Generic Power OnOff Server model and the Generic Level Server model. When this model is present on an Element, the corresponding Light Lightness Setup Server model shall also be present.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_light_lightness_srv_t`. 
**Chapter 2. API Reference**

**Returns** New Light Lightness Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_SETUP_SRV** *(srv_pub, srv_data)*

Define a new Light Lightness Setup Server Model.

**Note:** 1. The Light Lightness Setup Server model extends the Light Lightness Server model and the Generic Power OnOff Setup Server model.

   a. This model shall support model subscription.

**Parameters**

- `srv_pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data` – Pointer to the unique struct `esp_ble_mesh_light_lightness_setup_srv_t`.

**Returns** New Light Lightness Setup Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_CTL_SRV** *(srv_pub, srv_data)*

Define a new Light CTL Server Model.

**Note:** 1. The Light CTL Server model extends the Light Lightness Server model. When this model is present on an Element, the corresponding Light CTL Temperature Server model and the corresponding Light CTL Setup Server model shall also be present.

   a. This model shall support model publication and model subscription.

   b. The model requires two elements: the main element and the Temperature element. The Temperature element contains the corresponding Light CTL Temperature Server model and an instance of a Generic Level state bound to the Light CTL Temperature state on the Temperature element. The Light CTL Temperature state on the Temperature element is bound to the Light CTL state on the main element.

**Parameters**

- `srv_pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data` – Pointer to the unique struct `esp_ble_mesh_light_ctl_srv_t`.

**Returns** New Light CTL Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_CTL_SETUP_SRV** *(srv_pub, srv_data)*

Define a new Light CTL Setup Server Model.

**Note:** 1. The Light CTL Setup Server model extends the Light CTL Server and the Light Lightness Setup Server.

   a. This model shall support model subscription.

**Parameters**

- `srv_pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data` – Pointer to the unique struct `esp_ble_mesh_light_ctl_setup_srv_t`.

**Returns** New Light CTL Setup Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_CTL_TEMP_SRV** *(srv_pub, srv_data)*

Define a new Light CTL Temperature Server Model.

**Note:** 1. The Light CTL Temperature Server model extends the Generic Level Server model.

   a. This model shall support model publication and model subscription.
Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_light_ctl_temp_srv_t`.

Returns

New Light CTL Temperature Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_HSL_SRV** (srv_pub, srv_data)

Define a new Light HSL Server Model.

**Note:** 1. The Light HSL Server model extends the Light Lightness Server model. When this model is present on an Element, the corresponding Light HSL Hue Server model and the corresponding Light HSL Saturation Server model and the corresponding Light HSL Setup Server model shall also be present.

   a. This model shall support model publication and model subscription.

   b. The model requires three elements: the main element and the Hue element and the Saturation element. The Hue element contains the corresponding Light HSL Hue Server model and an instance of a Generic Level state bound to the Light HSL Hue state on the Hue element. The Saturation element contains the corresponding Light HSL Saturation Server model and an instance of a Generic Level state bound to the Light HSL Saturation state on the Saturation element. The Light HSL Hue state on the Hue element is bound to the Light HSL state on the main element and the Light HSL Saturation state on the Saturation element is bound to the Light HSL state on the main element.

Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_light_hsl_srv_t`.

Returns

New Light HSL Setup Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_HSL_SETUP_SRV** (srv_pub, srv_data)

Define a new Light HSL Setup Server Model.

**Note:** 1. The Light HSL Setup Server model extends the Light HSL Server and the Light Lightness Setup Server.

   a. This model shall support model subscription.

Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_light_hsl_setup_srv_t`.

Returns

New Light HSL Setup Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_HSL_HUE_SRV** (srv_pub, srv_data)

Define a new Light HSL Hue Server Model.

**Note:** 1. The Light HSL Hue Server model extends the Generic Level Server model. This model is associated with the Light HSL Server model.

   a. This model shall support model publication and model subscription.

Parameters

- **srv_pub** - Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** - Pointer to the unique struct `esp_ble_mesh_light_hsl_hue_srv_t`.

Returns

New Light HSL Hue Server Model instance.
Chapter 2. API Reference

**ESP_BLE_MESH_MODEL_LIGHT_HSL_SAT_SRV** (srv_pub, srv_data)
Define a new Light HSL Saturation Server Model.

**Note:** 1. The Light HSL Saturation Server model extends the Generic Level Server model. This model is associated with the Light HSL Server model.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_light_hsl_sat_srv_t`.

**Returns** New Light HSL Saturation Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_XYL_SRV** (srv_pub, srv_data)
Define a new Light xyL Server Model.

**Note:** 1. The Light xyL Server model extends the Light Lightness Server model. When this model is present on an Element, the corresponding Light xyL Setup Server model shall also be present.
   a. This model shall support model publication and model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_light_xyl_srv_t`.

**Returns** New Light xyL Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_XYL_SETUP_SRV** (srv_pub, srv_data)
Define a new Light xyL Setup Server Model.

**Note:** 1. The Light xyL Setup Server model extends the Light xyL Server and the Light Lightness Setup Server.
   a. This model shall support model subscription.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_light_xyl_setup_srv_t`.

**Returns** New Light xyL Setup Server Model instance.

**ESP_BLE_MESH_MODEL_LIGHT_LC_SRV** (srv_pub, srv_data)
Define a new Light LC Server Model.

**Note:** 1. The Light LC (Lightness Control) Server model extends the Light Lightness Server model and the Generic OnOff Server model. When this model is present on an Element, the corresponding Light LC Setup Server model shall also be present.
   a. This model shall support model publication and model subscription.
   b. This model may be used to represent an element that is a client to a Sensor Server model and controls the Light Lightness Actual state via defined state bindings.

**Parameters**
- **srv_pub** – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- **srv_data** – Pointer to the unique struct `esp_ble_mesh_light_lc_srv_t`. 
Returns New Light LC Server Model instance.

ESP_BLE_MESH_MODEL_LIGHT_LC_SETUP_SRV (srv_pub, srv_data)
Define a new Light LC Setup Server Model.

Note: 1. The Light LC (Lightness Control) Setup model extends the Light LC Server model.
   a. This model shall support model publication and model subscription.
   b. This model may be used to configure setup parameters for the Light LC Server model.

Parameters
- `srv_pub` – Pointer to the unique struct `esp_ble_mesh_model_pub_t`.
- `srv_data` – Pointer to the unique struct `esp_ble_mesh_light_lc_setup_srv_t`.

Returns New Light LC Setup Server Model instance.

Type Definitions

typedef void (*esp_ble_mesh_light_client_cb_t)(esp_ble_mesh_light_client_cb_event_t event,
                                          esp_ble_mesh_light_client_cb_param_t *param)
  Bluetooth Mesh Light Client Model function.
  Lighting Client Model callback function type
  
  **Param event** Event type
  **Param param** Pointer to callback parameter

typedef void (*esp_ble_mesh_lighting_server_cb_t)(esp_ble_mesh_lighting_server_cb_event_t event,
                                                esp_ble_mesh_lighting_server_cb_param_t *param)
  Bluetooth Mesh Lighting Server Model function.
  Lighting Server Model callback function type
  
  **Param event** Event type
  **Param param** Pointer to callback parameter

Enumerations

enum esp_ble_mesh_light_client_cb_event_t
  This enum value is the event of Lighting Client Model
  
  Values:

  enumerator ESP_BLE_MESH_LIGHT_CLIENT_GET_STATE_EVT
  enumerator ESP_BLE_MESH_LIGHT_CLIENT_SET_STATE_EVT
  enumerator ESP_BLE_MESH_LIGHT_CLIENT_PUBLISH_EVT
  enumerator ESP_BLE_MESH_LIGHT_CLIENT_TIMEOUT_EVT
  enumerator ESP_BLE_MESH_LIGHT_CLIENT_EVT_MAX

enum esp_ble_mesh_lc_state_t
  This enum value is the Light LC State Machine states
  
  Values:
Chapter 2. API Reference

enumerator ESP_BLE_MESH_LC_OFF
enumerator ESP_BLE_MESH_LC_STANDBY
enumerator ESP_BLE_MESH_LC_FADE_ON
enumerator ESP_BLE_MESH_LC_RUN
enumerator ESP_BLE_MESH_LC_FADE
enumerator ESP_BLE_MESH_LC_PROLONG
enumerator ESP_BLE_MESH_LC_FADE_STANDBY_AUTO
enumerator ESP_BLE_MESH_LC_FADE_STANDBY_MANUAL

enum esp_ble_mesh_lighting_server_cb_event_t
This enum value is the event of Lighting Server Model

Values:

enumerator ESP_BLE_MESH_LIGHTING_SERVER_STATE_CHANGE_EVT
  i. When get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, no event will be callback
     to the application layer when Lighting Get messages are received.
  ii. When set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, this event will be callback
     to the application layer when Lighting Set/Set Unack messages are received.

enumerator ESP_BLE_MESH_LIGHTING_SERVER_RECV_GET_MSG_EVT
  When get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to
  the application layer when Lighting Get messages are received.

enumerator ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_MSG_EVT
  When set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback to
  the application layer when Lighting Set/Set Unack messages are received.

enumerator ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT
  When status_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, this event will be callback
  to the application layer when Sensor Status message is received.

enumerator ESP_BLE_MESH_LIGHTING_SERVER_EVT_MAX

2.3.6 NimBLE-based host APIs

Overview

Apache MyNewt NimBLE is a highly configurable and BT SIG qualifiable BLE stack providing both host and
controller functionalities. ESP-IDF supports NimBLE host stack which is specifically ported for ESP32 platform and
FreeRTOS. The underlying controller is still the same (as in case of Bluedroid) providing VHCI interface. Refer to
NimBLE user guide for a complete list of features and additional information on NimBLE stack. Most features
Chapter 2. API Reference

of NimBLE including BLE Mesh are supported by ESP-IDF. The porting layer is kept cleaner by maintaining all
the existing APIs of NimBLE along with a single ESP-NimBLE API for initialization, making it simpler for the
application developers.

Architecture

Currently, NimBLE host and controller support different transports such as UART and RAM between them. How-
ever, RAM transport cannot be used as is in case of ESP as ESP controller supports VHCI interface and buffering
schemes used by NimBLE host is incompatible with that used by ESP controller. Therefore, a new transport between
NimBLE host and ESP controller has been added. This is depicted in the figure below. This layer is responsible for
maintaining pool of transport buffers and formatting buffers exchanges between host and controller as per the re-
quirements.

![Fig. 1: ESP NimBLE Stack](image)

Threading Model

The NimBLE host can run inside the application thread or can have its own independent thread. This flexibil-
ity is inherently provided by NimBLE design. By default, a thread is spawned by the porting function nim-
ble_port_freertos_init. This behavior can be changed by overriding the same function. For BLE Mesh,
additional thread (advertising thread) is used which keeps on feeding advertisement events to the main thread.

Programming Sequence

To begin with, make sure that the NimBLE stack is enabled from menuconfig choose NimBLE for the Bluetooth host.

Typical programming sequence with NimBLE stack consists of the following steps:

- Initialize NVS flash using nvs_flash_init() API. This is because ESP controller uses NVS during
  initialization.
- Initialize the host and controller stack using nimble_port_init.
- Initialize the required NimBLE host configuration parameters and callbacks
- Perform application specific tasks/initiation
- Run the thread for host stack using nimble_port_freertos_init

This documentation does not cover NimBLE APIs. Refer to NimBLE tutorial for more details on the programming
sequence/NimBLE APIs for different scenarios.

API Reference

Header File

- components/bt/host/nimble/esp-hci/include/esp_nimble_hci.h

Functions
Chapter 2. API Reference

`esp_err_t esp_nimble_hci_init(void)`

Initialize VHCI transport layer between NimBLE Host and ESP Bluetooth controller.

This function initializes the transport buffers to be exchanged between NimBLE host and ESP controller. It also registers required host callbacks with the controller.

**Returns**
- ESP_OK if the initialization is successful
- Appropriate error code from esp_err_t in case of an error

`esp_err_t esp_nimble_hci_deinit(void)`

Deinitialize VHCI transport layer between NimBLE Host and ESP Bluetooth controller.

**Note:** This function should be called after the NimBLE host is deinitialized.

**Returns**
- ESP_OK if the deinitialization is successful
- Appropriate error codes from esp_err_t in case of an error

**Macros**

`BLE_HCI_UART_H4_NONE`

`BLE_HCI_UART_H4_CMD`

`BLE_HCI_UART_H4_ACL`

`BLE_HCI_UART_H4_SCO`

`BLE_HCI_UART_H4_EVT`

ESP-IDF currently supports two host stacks. The Bluedroid based stack (default) supports classic Bluetooth as well as BLE. On the other hand, Apache NimBLE based stack is BLE only. For users to make a choice:

- For usecases involving classic Bluetooth as well as BLE, Bluedroid should be used.
- For BLE-only usecases, using NimBLE is recommended. It is less demanding in terms of code footprint and runtime memory, making it suitable for such scenarios.

For the overview of the ESP32 Bluetooth stack architecture, follow the links below:

- ESP32 Bluetooth Architecture (PDF)

Code examples for this API section are provided in the `bluetooth/bluedroid` directory of ESP-IDF examples.

The following examples contain detailed walkthroughs:

- GATT Client Example Walkthrough
- GATT Server Service Table Example Walkthrough
- GATT Server Example Walkthrough
- GATT Security Client Example Walkthrough
- GATT Security Server Example Walkthrough
- GATT Client Multi-connection Example Walkthrough

### 2.4 Error Codes Reference

This section lists various error code constants defined in ESP-IDF.

For general information about error codes in ESP-IDF, see *Error Handling.*
**ESP_FAIL** (-1): Generic esp_err_t code indicating failure

**ESP_OK** (0): esp_err_t value indicating success (no error)

**ESP_ERR_NO_MEM** (0x101): Out of memory

**ESP_ERR_INVALID_ARG** (0x102): Invalid argument

**ESP_ERR_INVALID_STATE** (0x103): Invalid state

**ESP_ERR_INVALID_SIZE** (0x104): Invalid size

**ESP_ERR_NOT_FOUND** (0x105): Requested resource not found

**ESP_ERR_NOT_SUPPORTED** (0x106): Operation or feature not supported

**ESP_ERR_TIMEOUT** (0x107): Operation timed out

**ESP_ERR_INVALID_RESPONSE** (0x108): Received response was invalid

**ESP_ERR_INVALID_CRC** (0x109): CRC or checksum was invalid

**ESP_ERR_INVALID_VERSION** (0x10a): Version was invalid

**ESP_ERR_INVALID_MAC** (0x10b): MAC address was invalid

**ESP_ERR_NOT_FINISHED** (0x10c): There are items remained to retrieve

**ESP_ERR_NVS_BASE** (0x1100): Starting number of error codes

**ESP_ERR_NVS_NOT_INITIALIZED** (0x1101): The storage driver is not initialized

**ESP_ERR_NVS_NOT_FOUND** (0x1102): A requested entry couldn’t be found or namespace doesn’t exist yet and mode is NVS_READONLY

**ESP_ERR_NVS_TYPE_MISMATCH** (0x1103): The type of set or get operation doesn’t match the type of value stored in NVS

**ESP_ERR_NVS_READ_ONLY** (0x1104): Storage handle was opened as read only

**ESP_ERR_NVS_NOT_ENOUGH_SPACE** (0x1105): There is not enough space in the underlying storage to save the value

**ESP_ERR_NVS_INVALID_NAME** (0x1106): Namespace name doesn’t satisfy constraints

**ESP_ERR_NVS_INVALID_HANDLE** (0x1107): Handle has been closed or is NULL

**ESP_ERR_NVS_REMOVE_FAILED** (0x1108): The value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.

**ESP_ERR_NVS_KEY_TOO_LONG** (0x1109): Key name is too long

**ESP_ERR_NVS_PAGE_FULL** (0x110a): Internal error; never returned by nvs API functions

**ESP_ERR_NVS_INVALID_STATE** (0x110b): NVS is in an inconsistent state due to a previous error. Call nvs_flash_init and nvs_open again, then retry.

**ESP_ERR_NVS_INVALID_LENGTH** (0x110c): String or blob length is not sufficient to store data

**ESP_ERR_NVS_NO_FREE_PAGES** (0x110d): NVS partition doesn’t contain any empty pages. This may happen if NVS partition was truncated. Erase the whole partition and call nvs_flash_init again.

**ESP_ERR_NVS_VALUE_TOO_LONG** (0x110e): Value doesn’t fit into the entry or string or blob length is longer than supported by the implementation

**ESP_ERR_NVS_PART_NOT_FOUND** (0x110f): Partition with specified name is not found in the partition table

**ESP_ERR_NVS_NEW_VERSION_FOUND** (0x1110): NVS partition contains data in new format and cannot be recognized by this version of code

**ESP_ERR_NVS_XTS_ENCR_FAILED** (0x1111): XTS encryption failed while writing NVS entry

**ESP_ERR_NVS_XTS_DECR_FAILED** (0x1112): XTS decryption failed while reading NVS entry
**ESP_ERR_NVS_XTS_CFG_FAILED** (0x1113): XTS configuration setting failed

**ESP_ERR_NVS_XTS_CFG_NOT_FOUND** (0x1114): XTS configuration not found

**ESP_ERR_NVS_ENCR_NOT_SUPPORTED** (0x1115): NVS encryption is not supported in this version

**ESP_ERR_NVS_KEYS_NOT_INITIALIZED** (0x1116): NVS key partition is uninitialized

**ESP_ERR_NVS_CORRUPT_KEY_PART** (0x1117): NVS key partition is corrupt

**ESP_ERR_NVSCONTENTDIFFERS** (0x1118): Internal error; never returned by nvs API functions. NVS key is different in comparison

**ESP_ERR_NVS_WRONG_ENCRYPTION** (0x1119): NVS partition is marked as encrypted with generic flash encryption. This is forbidden since the NVS encryption works differently.

**ESP_ERR_ULP_BASE** (0x1200): Offset for ULP-related error codes

**ESP_ERR_ULP_SIZE_TOO_BIG** (0x1201): Program doesn’t fit into RTC memory reserved for the ULP

**ESP_ERR_ULP_INVALID_LOAD_ADDR** (0x1202): Load address is outside of RTC memory reserved for the ULP

**ESP_ERR_ULP_DUPLICATE_LABEL** (0x1203): More than one label with the same number was defined

**ESP_ERR_ULP_UNDEFINITE_LABEL** (0x1204): Branch instructions references an undefined label

**ESP_ERR_ULP_BRANCH_OUT_OF_RANGE** (0x1205): Branch target is out of range of B instruction (try replacing with BX)

**ESP_ERR_OTA_BASE** (0x1500): Base error code for ota_ops api

**ESP_ERR_OTA_PARTITION_CONFLICT** (0x1501): Error if request was to write or erase the current running partition

**ESP_ERR_OTA_SELECT_INFO_INVALID** (0x1502): Error if OTA data partition contains invalid content

**ESP_ERR_OTA_VALIDATE_FAILED** (0x1503): Error if OTA app image is invalid

**ESP_ERR_OTA_SMALL_SEC_VER** (0x1504): Error if the firmware has a secure version less than the running firmware.

**ESP_ERR_OTA_ROLLBACK_FAILED** (0x1505): Error if flash does not have valid firmware in passive partition and hence rollback is not possible

**ESP_ERR_OTA_ROLLBACK_INVALID_STATE** (0x1506): Error if current active firmware is still marked in pending validation state (ESP_OTA_IMG_PENDING_VERIFY), essentially first boot of firmware image post upgrade and hence firmware upgrade is not possible

**ESP_ERR_EFUSE** (0x1600): Base error code for efuse api

**ESP_OK_EFUSE_CNT** (0x1601): OK the required number of bits is set.

**ESP_ERR_EFUSE_CNT_IS_FULL** (0x1602): Error field is full.

**ESP_ERR_EFUSE_REPEATED_PROG** (0x1603): Error repeated programming of programmed bits is strictly forbidden.

**ESP_ERR_CODING** (0x1604): Error while a encoding operation.

**ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS** (0x1605): Error not enough unused key blocks available

**ESP_ERR_DAMAGED_READING** (0x1606): Error. Burn or reset was done during a reading operation leads to damage read data. This error is internal to the efuse component and not returned by any public API.

**ESP_ERR_IMAGE_BASE** (0x2000)

**ESP_ERR_IMAGE_FLASH_FAIL** (0x2001)

**ESP_ERR_IMAGE_INVALID** (0x2002)

**ESP_ERR_WIFI_BASE** (0x3000): Starting number of WiFi error codes

**ESP_ERR_WIFI_NOT_INIT** (0x3001): WiFi driver was not installed by esp_wifi_init
ESP_ERR_WIFI_NOT_STARTED (0x3002): WiFi driver was not started by esp_wifi_start
ESP_ERR_WIFI_NOT_STOPPED (0x3003): WiFi driver was not stopped by esp_wifi_stop
ESP_ERR_WIFI_IF (0x3004): WiFi interface error
ESP_ERR_WIFI_MODE (0x3005): WiFi mode error
ESP_ERR_WIFI_STATE (0x3006): WiFi internal state error
ESP_ERR_WIFI_CONN (0x3007): WiFi internal control block of station or soft-AP error
ESP_ERR_WIFI_NVS (0x3008): WiFi internal NVS module error
ESP_ERR_WIFI_MAC (0x3009): MAC address is invalid
ESP_ERR_WIFI_SSID (0x300a): SSID is invalid
ESP_ERR_WIFI_PASSWORD (0x300b): Password is invalid
ESP_ERR_WIFI_TIMEOUT (0x300c): Timeout error
ESP_ERR_WIFI_WAKE_FAIL (0x300d): WiFi is in sleep state(RF closed) and wakeup fail
ESP_ERR_WIFI_WOULD_BLOCK (0x300e): The caller would block
ESP_ERR_WIFI_NOT_CONNECT (0x300f): Station still in disconnect status
ESP_ERR_WIFI_POST (0x3012): Failed to post the event to WiFi task
ESP_ERR_WIFI_INIT_STATE (0x3013): Invalid WiFi state when init/deinit is called
ESP_ERR_WIFI_STOP_STATE (0x3014): Returned when WiFi is stopping
ESP_ERR_WIFI_NOT_ASSOC (0x3015): The WiFi connection is not associated
ESP_ERR_WIFI_TX_DISALLOW (0x3016): The WiFi TX is disallowed
ESP_ERR_WIFI_TWT_FULL (0x3017): no available flow id
ESP_ERR_WIFI_TWT_SETUP_TIMEOUT (0x3018): Timeout of receiving twt setup response frame, timeout times can be set during twt setup
ESP_ERR_WIFI_TWT_SETUP_TXFAIL (0x3019): TWT setup frame tx failed
ESP_ERR_WIFI_TWT_SETUP_REJECT (0x301a): The twt setup request was rejected by the AP
ESP_ERR_WIFI_DISCARD (0x301b): Discard frame
ESP_ERR_WIFI_REGISTRAR (0x3033): WPS registrar is not supported
ESP_ERR_WIFI_WPS_TYPE (0x3034): WPS type error
ESP_ERR_WIFI_WPS_SM (0x3035): WPS state machine is not initialized
ESP_ERR_ESPNOW_BASE (0x3064): ESPNOW error number base.
ESP_ERR_ESPNOW_NOT_INIT (0x3065): ESPNOW is not initialized.
ESP_ERR_ESPNOW_ARG (0x3066): Invalid argument
ESP_ERR_ESPNOW_NO_MEM (0x3067): Out of memory
ESP_ERR_ESPNOW_FULL (0x3068): ESPNOW peer list is full
ESP_ERR_ESPNOW_NOT_FOUND (0x3069): ESPNOW peer is not found
ESP_ERR_ESPNOW_INTERNAL (0x306a): Internal error
ESP_ERR_ESPNOW_EXIST (0x306b): ESPNOW peer has existed
ESP_ERR_ESPNOW_IF (0x306c): Interface error
ESP_ERR_DPP_FAILURE (0x3097): Generic failure during DPP Operation
ESP_ERR_DPP_TX_FAILURE (0x3098): DPP Frame Tx failed OR not Acked
Chapter 2. API Reference

ESP_ERR_DPP_INVALID_ATTR (0x3099): Encountered invalid DPP Attribute
ESP_ERR_MESH_BASE (0x4000): Starting number of MESH error codes
ESP_ERR_MESH_WIFI_NOT_START (0x4001)
ESP_ERR_MESH_NOT_INIT (0x4002)
ESP_ERR_MESH_NOT_CONFIG (0x4003)
ESP_ERR_MESH_NOT_START (0x4004)
ESP_ERR_MESH_NOT_SUPPORT (0x4005)
ESP_ERR_MESH_NOT_ALLOWED (0x4006)
ESP_ERR_MESH_NO_MEMORY (0x4007)
ESP_ERR_MESH_ARGUMENT (0x4008)
ESP_ERR_MESH_EXCEED_MTU (0x4009)
ESP_ERR_MESH_TIMEOUT (0x400a)
ESP_ERR_MESH_DISCONNECTED (0x400b)
ESP_ERR_MESH_QUEUE_FAIL (0x400c)
ESP_ERR_MESH_QUEUE_FULL (0x400d)
ESP_ERR_MESH_NO_PARENT_FOUND (0x400e)
ESP_ERR_MESH_NO_ROUTE_FOUND (0x400f)
ESP_ERR_MESH_OPTION_NULL (0x4010)
ESP_ERR_MESH_OPTION_UNKNOWN (0x4011)
ESP_ERR_MESH_XON_NO_WINDOW (0x4012)
ESP_ERR_MESH_INTERFACE (0x4013)
ESP_ERR_MESH_DISCARD_DUPLICATE (0x4014)
ESP_ERR_MESH_DISCARD (0x4015)
ESP_ERR_MESH_VOTING (0x4016)
ESP_ERR_MESH_XMIT (0x4017)
ESP_ERR_MESH_QUEUE_READ (0x4018)
ESP_ERR_MESH_PS (0x4019)
ESP_ERR_MESH_RECV_RELEASE (0x401a)
ESP_ERR_ESP_NETIF_BASE (0x5000)
ESP_ERR_ESP_NETIF_INVALID_PARAMS (0x5001)
ESP_ERR_ESP_NETIF_IF_NOT_READY (0x5002)
ESP_ERR_ESP_NETIF_DHCPPC_START_FAILED (0x5003)
ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED (0x5004)
ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED (0x5005)
ESP_ERR_ESP_NETIF_NO_MEM (0x5006)
ESP_ERR_ESP_NETIF_DHCP_NOT_STOPPED (0x5007)
ESP_ERR_ESP_NETIF_DRIVER_ATTACH_FAILED (0x5008)
ESP_ERR_ESP_NETIF_INIT_FAILED (0x5009)
ESP_ERR_ESP_NETIF_DNS_NOT_CONFIGURED (0x500a)
Chapter 2. API Reference

ESP_ERR_ESP_NETIF_MLD6_FAILED (0x500b)
ESP_ERR_ESP_NETIF_IP6_ADDR_FAILED (0x500c)
ESP_ERR_ESP_NETIF_DHCPS_START_FAILED (0x500d)
ESP_ERR_FLASH_BASE (0x6000): Starting number of flash error codes
ESP_ERR_FLASH_OP_FAIL (0x6001)
ESP_ERR_FLASH_OP_TIMEOUT (0x6002)
ESP_ERR_FLASH_NOTInicialised (0x6003)
ESP_ERR_FLASH_UNSUPPORTED_HOST (0x6004)
ESP_ERR_FLASH_UNSUPPORTED_CHIP (0x6005)
ESP_ERR_FLASH_PROTECTED (0x6006)
ESP_ERR_HTTP_BASE (0x7000): Starting number of HTTP error codes
ESP_ERR_HTTP_MAX_REDIRECT (0x7001): The error exceeds the number of HTTP redirects
ESP_ERR_HTTP_CONNECT (0x7002): Error open the HTTP connection
ESP_ERR_HTTP_WRITE_DATA (0x7003): Error write HTTP data
ESP_ERR_HTTP_FETCH_HEADER (0x7004): Error read HTTP header from server
ESP_ERR_HTTP_INVALID_TRANSPORT (0x7005): There are no transport support for the input scheme
ESP_ERR_HTTP_CONNECTING (0x7006): HTTP connection hasn’t been established yet
ESP_ERR_HTTP_EAGAIN (0x7007): Mapping of errno EAGAIN to esp_err_t
ESP_ERR_HTTP_CONNECTION_CLOSED (0x7008): Read FIN from peer and the connection closed
ESP_ERR_ESP_TLS_BASE (0x8000): Starting number of ESP-TLS error codes
ESP_ERR_ESP_TLS_CANNOT_RESOLVE_HOSTNAME (0x8001): Error if hostname couldn’t be resolved upon tls connection
ESP_ERR_ESP_TLS_CANNOT_CREATE_SOCKET (0x8002): Failed to create socket
ESP_ERR_ESP_TLS_UNSUPPORTED_PROTOCOL_FAMILY (0x8003): Unsupported protocol family
ESP_ERR_ESP_TLS_FAILED_CONNECT_TO_HOST (0x8004): Failed to connect to host
ESP_ERR_ESP_TLS_SOCKET_SETOPT_FAILED (0x8005): failed to set/get socket option
ESP_ERR_ESP_TLS_CONNECTION_TIMEOUT (0x8006): new connection in esp_tls_low_level_conn connection timeouted
ESP_ERR_ESP_TLS_SE_FAILED (0x8007)
ESP_ERR_ESP_TLS_TCP_CLOSED_FIN (0x8008)
ESP_ERR_MBEDTLS_CERT_PARTLY_OK (0x8010): mbedtls parse certificates was partly successful
ESP_ERR_MBEDTLS_CTR_DRBG_SEED_FAILED (0x8011): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_SET_HOSTNAME_FAILED (0x8012): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_CONFIG_DEFAULTS_FAILED (0x8013): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_CONF_ALPN_PROTOCOLS_FAILED (0x8014): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_X509_CRT_PARSE_FAILED (0x8015): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_CONF_OWN_CERT_FAILED (0x8016): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_SETUP_FAILED (0x8017): mbedtls api returned error
ESP_ERR_MBEDTLS_SSL_WRITE_FAILED (0x8018): mbedtls api returned error
ESP_ERR_MBEDTLS_PK_PARSE_KEY_FAILED (0x8019): mbedtls api returned failed
**Chapter 2. API Reference**

`ESP_ERR_MBEDTLS_SSL_HANDSHAKE_FAILED` (0x801a): mbedtls api returned failed

`ESP_ERR_MBEDTLS_SSL_CONF_PSK_FAILED` (0x801b): mbedtls api returned failed

`ESP_ERR_MBEDTLS_SSL_TICKET_SETUP_FAILED` (0x801c): mbedtls api returned failed

`ESP_ERR_WOLFSSL_SSL_SET_HOSTNAME_FAILED` (0x8031): wolfSSL api returned error

`ESP_ERR_WOLFSSL_SSL_CONF_ALPN_PROTOCOLS_FAILED` (0x8032): wolfSSL api returned error

`ESP_ERR_WOLFSSL_CERT_VERIFY_SETUP_FAILED` (0x8033): wolfSSL api returned error

`ESP_ERR_WOLFSSL_KEY_VERIFY_SETUP_FAILED` (0x8034): wolfSSL api returned error

`ESP_ERR_WOLFSSL_SSL_HANDSHAKE_FAILED` (0x8035): wolfSSL api returned failed

`ESP_ERR_WOLFSSL_CTX_SETUP_FAILED` (0x8036): wolfSSL api returned failed

`ESP_ERR_WOLFSSL_SSL_SETUP_FAILED` (0x8037): wolfSSL api returned failed

`ESP_ERR_WOLFSSL_SSL_WRITE_FAILED` (0x8038): wolfSSL api returned failed

`ESP_ERR_HTTPS_OTA_BASE` (0x9000)

`ESP_ERR_HTTPS_OTA_IN_PROGRESS` (0x9001)

`ESP_ERR_PING_BASE` (0xa000)

`ESP_ERR_PING_INVALID_PARAMS` (0xa001)

`ESP_ERR_PING_NO_MEM` (0xa002)

`ESP_ERR_HTTPD_BASE` (0xb000): Starting number of HTTPD error codes

`ESP_ERR_HTTPD_HANDLERS_FULL` (0xb001): All slots for registering URI handlers have been consumed

`ESP_ERR_HTTPD_HANDLER_EXISTS` (0xb002): URI handler with same method and target URI already registered

`ESP_ERR_HTTPD_INVALID_REQ` (0xb003): Invalid request pointer

`ESP_ERR_HTTPD_RESULT_TRUNC` (0xb004): Result string truncated

`ESP_ERR_HTTPD_RESP_HDR` (0xb005): Response header field larger than supported

`ESP_ERR_HTTPD_RESP_SEND` (0xb006): Error occurred while sending response packet

`ESP_ERR_HTTPD_ALLOC_MEM` (0xb007): Failed to dynamically allocate memory for resource

`ESP_ERR_HTTPD_TASK` (0xb008): Failed to launch server task/thread

`ESP_ERR_HW_CRYPTO_BASE` (0xc000): Starting number of HW cryptography module error codes

`ESP_ERR_HW_CRYPTO_DS_HMAC_FAIL` (0xc001): HMAC peripheral problem

`ESP_ERR_HW_CRYPTO_DS_INVALID_KEY` (0xc002)

`ESP_ERR_HW_CRYPTO_DS_INVALID_DIGEST` (0xc004)

`ESP_ERR_HW_CRYPTO_DS_INVALID_PADDING` (0xc005)

`ESP_ERR_MEMPROT_BASE` (0xd000): Starting number of Memory Protection API error codes

`ESP_ERR_MEMPROT_MEMORY_TYPE_INVALID` (0xd001)

`ESP_ERR_MEMPROT_SPLIT_ADDR_INVALID` (0xd002)

`ESP_ERR_MEMPROT_SPLIT_ADDR_OUT_OF_RANGE` (0xd003)

`ESP_ERR_MEMPROT_SPLIT_ADDR_UNALIGNED` (0xd004)

`ESP_ERR_MEMPROT_UNIMGMT_BLOCK_INVALID` (0xd005)

`ESP_ERR_MEMPROT_WORLD_INVALID` (0xd006)

`ESP_ERR_MEMPROT_AREA_INVALID` (0xd007)
Chapter 2. API Reference

ESP_ERR_MEMPROT_CPUID_INVALID (0xd008)
ESP_ERR_TCP_TRANSPORT_BASE (0xe000): Starting number of TCP Transport error codes
ESP_ERR_TCP_TRANSPORT_CONNECTION_TIMEOUT (0xe001): Connection has timed out
ESP_ERR_TCP_TRANSPORT_CONNECTION_CLOSED_BY_FIN (0xe002): Read FIN from peer and the connection has closed (in a clean way)
ESP_ERR_TCP_TRANSPORT_CONNECTION_FAILED (0xe003): Failed to connect to the peer
ESP_ERR_TCP_TRANSPORT_NO_MEM (0xe004): Memory allocation failed

2.5 Networking APIs

2.5.1 Wi-Fi

ESP-NOW

Overview ESP-NOW is a kind of connectionless Wi-Fi communication protocol that is defined by Espressif. In ESP-NOW, application data is encapsulated in a vendor-specific action frame and then transmitted from one Wi-Fi device to another without connection. CTR with CBC-MAC Protocol (CCMP) is used to protect the action frame for security. ESP-NOW is widely used in smart light, remote controlling, sensor, etc.

Frame Format ESP-NOW uses a vendor-specific action frame to transmit ESP-NOW data. The default ESP-NOW bitrate is 1 Mbps. The format of the vendor-specific action frame is as follows:

<table>
<thead>
<tr>
<th>MAC Header</th>
<th>Category Code</th>
<th>Organization Identifier</th>
<th>Random Values</th>
<th>Vendor Specific Content</th>
<th>FCS</th>
</tr>
</thead>
</table>

24 bytes 1 byte 3 bytes 4 bytes 7-

- Category Code: The Category Code field is set to the value (127) indicating the vendor-specific category.
- Organization Identifier: The Organization Identifier contains a unique identifier (0x18fe34), which is the first three bytes of MAC address applied by Espressif.
- Random Value: The Random Value field is used to prevents relay attacks.
- Vendor Specific Content: The Vendor Specific Content contains vendor-specific fields as follows:

<table>
<thead>
<tr>
<th>Element ID</th>
<th>Length</th>
<th>Organization Identifier</th>
<th>Type</th>
<th>Version</th>
<th>Body</th>
</tr>
</thead>
</table>

1 byte 1 byte 3 bytes 1 byte 1 byte 0~250 bytes

- Element ID: The Element ID field is set to the value (221), indicating the vendor-specific element.
- Length: The length is the total length of Organization Identifier, Type, Version and Body.
- Organization Identifier: The Organization Identifier contains a unique identifier (0x18fe34), which is the first three bytes of MAC address applied by Espressif.
- Type: The Type field is set to the value (4) indicating ESP-NOW.
- Version: The Version field is set to the version of ESP-NOW.
- Body: The Body contains the ESP-NOW data.
Chapter 2. API Reference

As ESP-NOW is connectionless, the MAC header is a little different from that of standard frames. The FromDS and ToDS bits of FrameControl field are both 0. The first address field is set to the destination address. The second address field is set to the source address. The third address field is set to broadcast address (0xff:0xff:0xff:0xff:0xff:0xff).

Security

ESP-NOW uses the CCMP method, which is described in IEEE Std. 802.11-2012, to protect the vendor-specific action frame. ESP-NOW uses the CCMP method, which is described in IEEE Std. 802.11-2012, to protect the vendor-specific action frame.

- PMK is used to encrypt LMK with the AES-128 algorithm. Call `esp_now_set_pmk()` to set PMK.
  - If PMK is not set, a default PMK will be used.
- LMK of the paired device is used to encrypt the vendor-specific action frame with the CCMP method.
  - The maximum number of different LMKs is six. If the LMK of the paired device is not set, the vendor-specific action frame will not be encrypted.

Encrypting multicast vendor-specific action frame is not supported.

Initialization and De-initialization Call `esp_now_init()` to initialize ESP-NOW and `esp_now_deinit()` to de-initialize ESP-NOW. ESP-NOW data must be transmitted after Wi-Fi is started, so it is recommended to start Wi-Fi before initializing ESP-NOW and stop Wi-Fi after de-initializing ESP-NOW. When `esp_now_deinit()` is called, all of the information of paired devices will be deleted.

Add Paired Device Call `esp_now_add_peer()` to add the device to the paired device list before you send data to this device. If security is enabled, the LMK must be set. You can send ESP-NOW data via both the Station and the SoftAP interface. Make sure that the interface is enabled before sending ESP-NOW data.

The maximum number of paired devices is 20, and the paired encryption devices are no more than 17, the default is 7. If you want to change the number of paired encryption devices, set `CONFIG_ESP_WIFI_ESPNOW_MAX_ENCRYPT_NUM` in the Wi-Fi component configuration menu.

A device with a broadcast MAC address must be added before sending broadcast data. The range of the channel of paired devices is from 0 to 14. If the channel is set to 0, data will be sent on the current channel. Otherwise, the channel must be set as the channel that the local device is on.

Send ESP-NOW Data Call `esp_now_send()` to send ESP-NOW data and `esp_now_register_send_cb()` to register sending callback function. It will return `ESP_NOW_SEND_SUCCESS` in sending callback function if the data is received successfully on the MAC layer. Otherwise, it will return `ESP_NOW_SEND_FAIL`. Several reasons can lead to ESP-NOW fails to send data. For example, the destination device doesn’t exist; the channels of the devices are not the same; the action frame is lost when transmitting on the air, etc. It is not guaranteed that application layer can receive the data. If necessary, send back ack data when receiving ESP-NOW data. If receiving ack data timeouts, retransmit the ESP-NOW data. A sequence number can also be assigned to ESP-NOW data to drop the duplicate data.

If there is a lot of ESP-NOW data to send, call `esp_now_send()` to send less than or equal to 250 bytes of data once a time. Note that too short interval between sending two ESP-NOW data may lead to disorder of sending callback function. So, it is recommended that sending the next ESP-NOW data after the sending callback function of the previous sending has returned. The sending callback function runs from a high-priority Wi-Fi task. So, do not do lengthy operations in the callback function. Instead, post the necessary data to a queue and handle it from a lower priority task.

Receiving ESP-NOW Data Call `esp_now_register_recv_cb()` to register receiving callback function. Call the receiving callback function when receiving ESP-NOW. The receiving callback function also runs from the Wi-Fi task. So, do not do lengthy operations in the callback function. Instead, post the necessary data to a queue and handle it from a lower priority task.

Config ESP-NOW Rate Call `esp_wifi_config_espnow_rate()` to config ESPNOW rate of specified interface. Make sure that the interface is enabled before config rate. This API should be called after `esp_wifi_start()`.
**Config ESP-NOW Power-saving Parameter**  
Sleep is supported only when ESP32 is configured as station.

Call `esp_now_set_wake_window()` to configure Window for ESP-NOW RX at sleep. The default value is the maximum, which allowing RX all the time.

If Power-saving is needed for ESP-NOW, call `esp_wifi_connectionless_module_set_wake_interval()` to configure Interval as well.

Please refer to connectionless module power save to get more detail.

**Application Examples**

- Example of sending and receiving ESP-NOW data between two devices: `wifi/espnnow`.
- For more application examples of how to use ESP-NOW, please visit ESP-NOW repository.

**API Reference**

**Header File**

- `components/esp_wifi/include/esp_now.h`

**Functions**

```c
esp_err_t esp_now_init (void)
Initialize ESPNOW function.

Returns
• ESP_OK : succeed
• ESP_ERR_ESPNOW_INTERNAL : Internal error
```

```c
esp_err_t esp_now_deinit (void)
De-initialize ESPNOW function.

Returns
• ESP_OK : succeed
```

```c
esp_err_t esp_now_get_version (uint32_t *version)
Get the version of ESPNOW.

Parameters
version - ESPNOW version

Returns
• ESP_OK : succeed
• ESP_ERR_ESPNOW_ARG : invalid argument
```

```c
esp_err_t esp_now_register_recv_cb (esp_now_recv_cb_t cb)
Register callback function of receiving ESPNOW data.

Parameters
cb - callback function of receiving ESPNOW data

Returns
• ESP_OK : succeed
• ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
• ESP_ERR_ESPNOW_INTERNAL : internal error
```

```c
esp_err_t esp_now_unregister_recv_cb (void)
Unregister callback function of receiving ESPNOW data.

Returns
• ESP_OK : succeed
• ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
```
**esp_err_t esp_now_register_send_cb (esp_now_send_cb_t cb)**

Register callback function of sending ESPNOW data.

**Parameters**
- `cb` - callback function of sending ESPNOW data

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_INTERNAL : internal error

**esp_err_t esp_now_unregister_send_cb (void)**

Unregister callback function of sending ESPNOW data.

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized

**esp_err_t esp_now_send (const uint8_t *peer_addr, const uint8_t *data, size_t len)**

Send ESPNOW data.

**Attention**
1. If `peer_addr` is not NULL, send data to the peer whose MAC address matches `peer_addr`
2. If `peer_addr` is NULL, send data to all of the peers that are added to the peer list
3. The maximum length of data must be less than ESP_NOW_MAX_DATA_LEN
4. The buffer pointed to by data argument does not need to be valid after esp_now_send returns

**Parameters**
- `peer_addr` - peer MAC address
- `data` - data to send
- `len` - length of data

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG : invalid argument
- ESP_ERR_ESPNOW_INTERNAL : internal error
- ESP_ERR_ESPNOW_NO_MEM : out of memory, when this happens, you can delay a while before sending the next data
- ESP_ERR_ESPNOW_NOT_FOUND : peer is not found
- ESP_ERR_ESPNOW_IF : current WiFi interface doesn’t match that of peer

**esp_err_t esp_now_add_peer (const esp_now_peer_info_t *peer)**

Add a peer to peer list.

**Parameters**
- `peer` - peer information

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG : invalid argument
- ESP_ERR_ESPNOW_FULL : peer list is full
- ESP_ERR_ESPNOW_NO_MEM : out of memory
- ESP_ERR_ESPNOW_EXIST : peer has existed

**esp_err_t esp_now_del_peer (const uint8_t *peer_addr)**

Delete a peer from peer list.

**Parameters**
- `peer_addr` - peer MAC address

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG : invalid argument
- ESP_ERR_ESPNOW_NOT_FOUND : peer is not found
**esp_err_t esp_now_mod_peer** (const esp_now_peer_info_t *peer)

Modify a peer.

**Parameters** peer – peer information

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG : invalid argument
- ESP_ERR_ESPNOW_FULL : peer list is full

**esp_err_t esp_wifi_config_espnow_rate** (wifi_interface_t ifx, wifi_phy_rate_t rate)

Config ESPNOW rate of specified interface.

*Deprecated:*  
please use *esp_now_set_peer_rate_config()* instead.

**Attention** 1. This API should be called after esp_wifi_start().
**Attention** 2. This API only work when not use Wi-Fi 6 and *esp_now_set_peer_rate_config()* not called.

**Parameters**
- *ifx* – Interface to be configured.
- *rate* – Phy rate to be configured.

**Returns**
- ESP_OK: succeed
- others: failed

**esp_err_t esp_now_set_peer_rate_config** (const uint8_t* peer_addr, esp_now_rate_config_t *config)

Set ESPNOW rate config for each peer.

**Attention** 1. This API should be called after esp_wifi_start() and *esp_now_init()*.

**Parameters**
- *peer_addr* – peer MAC address
- *config* – rate config to be configured.

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG : invalid argument
- ESP_ERR_ESPNOW_INTERNAL : internal error

**esp_err_t esp_now_get_peer** (const uint8_t* peer_addr, esp_now_peer_info_t *peer)

Get a peer whose MAC address matches peer_addr from peer list.

**Parameters**
- *peer_addr* – peer MAC address
- *peer* – peer information

**Returns**
- ESP_OK : succeed
- ESP_ERR_ESPNOW_NOT_INIT : ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG : invalid argument
- ESP_ERR_ESPNOW_NOT_FOUND : peer is not found

**esp_err_t esp_now_fetch_peer** (bool from_head, esp_now_peer_info_t *peer)

Fetch a peer from peer list. Only return the peer which address is unicast, for the multicast/broadcast address, the function will ignore and try to find the next in the peer list.
### Parameters

- **from_head** - fetch from head of list or not
- **peer** - peer information

### Returns

- **ESP_OK** : succeed
- **ESP_ERR_ESPNOW_NOT_INIT** : ESPNOW is not initialized
- **ESP_ERR_ESPNOW_ARG** : invalid argument
- **ESP_ERR_ESPNOW_NOT_FOUND** : peer is not found

```c
bool esp_now_is_peer_exist (const uint8_t *peer_addr)
```

Peer exists or not.

**Parameters**

- **peer_addr** - peer MAC address

**Returns**

- **true** : peer exists
- **false** : peer not exists

```c
esp_err_t esp_now_get_peer_num (esp_now_peer_num_t *num)
```

Get the number of peers.

**Parameters**

- **num** - number of peers

**Returns**

- **ESP_OK** : succeed
- **ESP_ERR_ESPNOW_NOT_INIT** : ESPNOW is not initialized
- **ESP_ERR_ESPNOW_ARG** : invalid argument

```c
esp_err_t esp_now_set_pmk (const uint8_t *pmk)
```

Set the primary master key.

**Attention** 1. primary master key is used to encrypt local master key

**Parameters**

- **pmk** - primary master key

**Returns**

- **ESP_OK** : succeed
- **ESP_ERR_ESPNOW_NOT_INIT** : ESPNOW is not initialized
- **ESP_ERR_ESPNOW_ARG** : invalid argument

```c
esp_err_t esp_now_set_wake_window (uint16_t window)
```

Set wake window for esp_now to wake up in interval unit.

**Attention** 1. This configuration could work at connected status. When ESP_WIFI_STA_DISCONNECTED_PM_ENABLE is enabled, this configuration could work at disconnected status.

**Attention** 2. Default value is the maximum.

**Parameters**

- **window** - Milliseconds would the chip keep waked each interval, from 0 to 65535.

**Returns**

- **ESP_OK** : succeed
- **ESP_ERR_ESPNOW_NOT_INIT** : ESPNOW is not initialized

### Structures

```c
struct esp_now_peer_info
```

ESPNOW peer information parameters.
Public Members

uint8_t peer_addr[ESP_NOW_ETH_ALEN]
ESPNOW peer MAC address that is also the MAC address of station or softap

uint8_t lmk[ESP_NOW_KEY_LEN]
ESPNOW peer local master key that is used to encrypt data

uint8_t channel
Wi-Fi channel that peer uses to send/receive ESPNOW data. If the value is 0, use the current channel which station or softap is on. Otherwise, it must be set as the channel that station or softap is on.

wifi_interface_t ifidx
Wi-Fi interface that peer uses to send/receive ESPNOW data

bool encrypt
ESPNOW data that this peer sends/receives is encrypted or not

void *priv
ESPNOW peer private data

struct esp_now_peer_num
Number of ESPNOW peers which exist currently.

Public Members

int total_num
Total number of ESPNOW peers, maximum value is ESP_NOW_MAX_TOTAL_PEER_NUM

int encrypt_num
Number of encrypted ESPNOW peers, maximum value is ESP_NOW_MAX_ENCRYPT_PEER_NUM

struct esp_now_recv_info
ESPNOW packet information.

Public Members

uint8_t *src_addr
Source address of ESPNOW packet

uint8_t *des_addr
Destination address of ESPNOW packet

wifi_pkt_rx_ctrl_t *rx_ctrl
Rx control info of ESPNOW packet

struct esp_now_rate_config
ESPNOW rate config.
Chapter 2. API Reference

Public Members

\texttt{wifi\_phy\_mode\_t phymode}

ESP NOW phymode of specified interface

\texttt{wifi\_phy\_rate\_t rate}

ESP NOW rate of specified interface

\texttt{bool ersu}

ESP NOW using ersu send frame

Macros

\texttt{ESP\_ERR\_ESPNOW\_BASE}

ESP NOW error number base.

\texttt{ESP\_ERR\_ESPNOW\_NOT\_INIT}

ESP NOW is not initialized.

\texttt{ESP\_ERR\_ESPNOW\_ARG}

Invalid argument

\texttt{ESP\_ERR\_ESPNOW\_NO\_MEM}

Out of memory

\texttt{ESP\_ERR\_ESPNOW\_FULL}

ESP NOW peer list is full

\texttt{ESP\_ERR\_ESPNOW\_NOT\_FOUND}

ESP NOW peer is not found

\texttt{ESP\_ERR\_ESPNOW\_INTERNAL}

Internal error

\texttt{ESP\_ERR\_ESPNOW\_EXIST}

ESP NOW peer has existed

\texttt{ESP\_ERR\_ESPNOW\_IF}

Interface error

\texttt{ESP\_NOW\_ETH\_ALEN}

Length of ESP NOW peer MAC address

\texttt{ESP\_NOW\_KEY\_LEN}

Length of ESP NOW peer local master key

\texttt{ESP\_NOW\_MAX\_TOTAL\_PEER\_NUM}

Maximum number of ESP NOW total peers
**ESP_NOW_MAX_ENCRYPT_PEER_NUM**

Maximum number of ESPNOW encrypted peers

**ESP_NOW_MAX_DATA_LEN**

Maximum length of ESPNOW data which is sent very time

**Type Definitions**

typedef struct esp_now_peer_info esp_now_peer_info_t

ESPNOW peer information parameters.

typedef struct esp_now_peer_num esp_now_peer_num_t

Number of ESPNOW peers which exist currently.

typedef struct esp_now_recv_info esp_now_recv_info_t

ESPNOW packet information.

typedef struct esp_now_rate_config esp_now_rate_config_t

ESPNOW rate config.

typedef void (*esp_now_recv_cb_t)(const esp_now_recv_info_t *esp_now_info, const uint8_t *data, int data_len)

Callback function of receiving ESPNOW data.

**Attention** esp_now_info is a local variable, it can only be used in the callback.

**Param esp_now_info** received ESPNOW packet information
**Param data** received data
**Param data_len** length of received data

typedef void (*esp_now_send_cb_t)(const uint8_t *mac_addr, esp_now_send_status_t status)

Callback function of sending ESPNOW data.

**Param mac_addr** peer MAC address
**Param status** status of sending ESPNOW data (succeed or fail)

**Enumerations**

enum esp_now_send_status_t

Status of sending ESPNOW data.

**Values:**

**enumerator ESP_NOW_SEND_SUCCESS**
Send ESPNOW data successfully

**enumerator ESP_NOW_SEND_FAIL**
Send ESPNOW data fail
Chapter 2. API Reference

ESP-WIFI-MESH Programming Guide

This is a programming guide for ESP-WIFI-MESH, including the API reference and coding examples. This guide is split into the following parts:

1. ESP-WIFI-MESH Programming Model
2. Writing an ESP-WIFI-MESH Application
3. Self Organized Networking
4. Application Examples
5. API Reference

For documentation regarding the ESP-WIFI-MESH protocol, please see the ESP-WIFI-MESH API Guide. For more information about ESP-WIFI-MESH Development Framework, please see ESP-WIFI-MESH Development Framework.

ESP-WIFI-MESH Programming Model

Software Stack  The ESP-WIFI-MESH software stack is built atop the Wi-Fi Driver/FreeRTOS and may use the LwIP Stack in some instances (i.e. the root node). The following diagram illustrates the ESP-WIFI-MESH software stack.

![ESP-WIFI-MESH Software Stack](image)

**Fig. 2: ESP-WIFI-MESH Software Stack**

System Events  An application interfaces with ESP-WIFI-MESH via ESP-WIFI-MESH Events. Since ESP-WIFI-MESH is built atop the Wi-Fi stack, it is also possible for the application to interface with the Wi-Fi driver via the Wi-Fi Event Task. The following diagram illustrates the interfaces for the various System Events in an ESP-WIFI-MESH application.

![ESP-WIFI-MESH System Events Delivery](image)

**Fig. 3: ESP-WIFI-MESH System Events Delivery**
Chapter 2. API Reference

The `mesh_event_id_t` defines all possible ESP-WIFI-MESH events and can indicate events such as the connection/disconnection of parent/child. Before ESP-WIFI-MESH events can be used, the application must register a Mesh Events handler via `esp_event_handler_register()` to the default event task. The Mesh Events handler that is registered contain handlers for each ESP-WIFI-MESH event relevant to the application.

Typical use cases of mesh events include using events such as `MESH_EVENT_PARENT_CONNECTED` and `MESH_EVENT_CHILD_CONNECTED` to indicate when a node can begin transmitting data upstream and downstream respectively. Likewise, `IP_EVENT_STA_GOT_IP` and `IP_EVENT_STA_LOST_IP` can be used to indicate when the root node can and cannot transmit data to the external IP network.

**Warning:** When using ESP-WIFI-MESH under self-organized mode, users must ensure that no calls to Wi-Fi API are made. This is due to the fact that the self-organizing mode will internally make Wi-Fi API calls to connect/disconnect/scan etc. Any Wi-Fi calls from the application (including calls from callbacks and handlers of Wi-Fi events) may interfere with ESP-WIFI-MESH’s self-organizing behavior. Therefore, users should not call Wi-Fi APIs after `esp_mesh_start()` is called, and before `esp_mesh_stop()` is called.

### LwIP & ESP-WIFI-MESH

The application can access the ESP-WIFI-MESH stack directly without having to go through the LwIP stack. The LwIP stack is only required by the root node to transmit/receive data to/from an external IP network. However, since every node can potentially become the root node (due to automatic root node selection), each node must still initialize the LwIP stack.

Each node that could become root is required to initialize LwIP by calling `esp_netif_init()`. In order to prevent non-root node access to LwIP, the application should not create or register any network interfaces using `esp_netif` APIs.

ESP-WIFI-MESH requires a root node to be connected with a router. Therefore, in the event that a node becomes the root, the corresponding handler must start the DHCP client service and immediately obtain an IP address. Doing so will allow other nodes to begin transmitting/receiving packets to/from the external IP network. However, this step is unnecessary if static IP settings are used.

#### Writing an ESP-WIFI-MESH Application

The prerequisites for starting ESP-WIFI-MESH is to initialize LwIP and Wi-Fi. The following code snippet demonstrates the necessary prerequisite steps before ESP-WIFI-MESH itself can be initialized.

```c
ESP_ERROR_CHECK(esp_netif_init());
/* event initialization */
ESP_ERROR_CHECK(esp_event_loop_create_default());
/* Wi-Fi initialization */
wifi_init_config_t config = WIFI_INIT_CONFIG_DEFAULT();
ESP_ERROR_CHECK(esp_wifi_init(&config));
/* register IP events handler */
ESP_ERROR_CHECK(esp_event_handler_register(IP_EVENT, IP_EVENT_STA_GOT_IP, &ip_event_handler, NULL));
ESP_ERROR_CHECK(esp_wifi_set_storage(WIFI_STORAGE_FLASH));
ESP_ERROR_CHECK(esp_wifi_start());
```

After initializing LwIP and Wi-Fi, the process of getting an ESP-WIFI-MESH network up and running can be summarized into the following three steps:

1. **Initialize Mesh**
2. **Configuring an ESP-WIFI-MESH Network**
3. **Start Mesh**

**Initialize Mesh** The following code snippet demonstrates how to initialize ESP-WIFI-MESH
Chapter 2. API Reference

```c
/* mesh initialization */
ESP_ERROR_CHECK(esp_mesh_init);

/* register mesh events handler */
ESP_ERROR_CHECK(esp_event_handler_register(MESH_EVENT, ESP_EVENT_ANY_ID, &mesh_,
                                          event_handler, NULL));
```

**Configuring an ESP-WIFI-MESH Network** ESP-WIFI-MESH is configured via `esp_mesh_set_config()` which receives its arguments using the `mesh_cfg_t` structure. The structure contains the following parameters used to configure ESP-WIFI-MESH:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>Range from 1 to 14</td>
</tr>
<tr>
<td>Mesh ID</td>
<td>ID of ESP-WIFI-MESH Network, see <code>mesh_addr_t</code></td>
</tr>
<tr>
<td>Router</td>
<td>Router Configuration, see <code>mesh_router_t</code></td>
</tr>
<tr>
<td>Mesh AP</td>
<td>Mesh AP Configuration, see <code>mesh_ap_cfg_t</code></td>
</tr>
<tr>
<td>Crypto Functions</td>
<td>Crypto Functions for Mesh IE, see <code>mesh_crypto_funcs_t</code></td>
</tr>
</tbody>
</table>

The following code snippet demonstrates how to configure ESP-WIFI-MESH.

```c
/* Enable the Mesh IE encryption by default */
mesh_cfg_t cfg = MESH_INIT_CONFIG_DEFAULT();

/* mesh ID */
memcpy((uint8_t *) &cfg.mesh_id, MESH_ID, 6);

/* channel (must match the router's channel) */
cfg.channel = CONFIG_MESH_CHANNEL;

/* router */
cfg.router.ssid_len = strlen(CONFIG_MESH_ROUTER_SSID);
memcpy((uint8_t *) &cfg.router.ssid, CONFIG_MESH_ROUTER_SSID, cfg.router.ssid_len);
memcpy((uint8_t *) &cfg.router.password, CONFIG_MESH_ROUTER_PASSWD,
      strlen(CONFIG_MESH_ROUTER_PASSWD));

/* mesh softAP */
cfg.mesh_ap.max_connection = CONFIG_MESH_AP_CONNECTIONS;
memcpy((uint8_t *) &cfg.mesh_ap.password, CONFIG_MESH_AP_PASSWD,
      strlen(CONFIG_MESH_AP_PASSWD));

ESP_ERROR_CHECK(esp_mesh_set_config(&cfg));
```

**Start Mesh** The following code snippet demonstrates how to start ESP-WIFI-MESH.

```c
/* mesh start */
ESP_ERROR_CHECK(esp_mesh_start());
```

After starting ESP-WIFI-MESH, the application should check for ESP-WIFI-MESH events to determine when it has connected to the network. After connecting, the application can start transmitting and receiving packets over the ESP-WIFI-MESH network using `esp_mesh_send()` and `esp_mesh_recv()`.

**Self Organized Networking** Self organized networking is a feature of ESP-WIFI-MESH where nodes can autonomously scan/select/connect/reconnect to other nodes and routers. This feature allows an ESP-WIFI-MESH network to operate with high degree of autonomy by making the network robust to dynamic network topologies and conditions. With self organized networking enabled, nodes in an ESP-WIFI-MESH network are able to carry out the following actions without autonomously:

- Selection or election of the root node (see **Automatic Root Node Selection** in **Building a Network**)
- Selection of a preferred parent node (see **Parent Node Selection** in **Building a Network**)
- Automatic reconnection upon detecting a disconnection (see **Intermediate Parent Node Failure** in **Managing a Network**)

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Espressif Systems 833
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Release v5.1.2
When self organized networking is enabled, the ESP-WIFI-MESH stack will internally make calls to Wi-Fi APIs. Therefore, the application layer should not make any calls to Wi-Fi APIs whilst self organized networking is enabled as doing so would risk interfering with ESP-WIFI-MESH.

**Toggling Self Organized Networking** Self organized networking can be enabled or disabled by the application at runtime by calling the `esp_mesh_set_self_organized()` function. The function has the two following parameters:

- `bool enable` specifies whether to enable or disable self organized networking.
- `bool select_parent` specifies whether a new parent node should be selected when enabling self organized networking. Selecting a new parent has different effects depending the node type and the node’s current state. This parameter is unused when disabling self organized networking.

**Disabling Self Organized Networking** The following code snippet demonstrates how to disable self organized networking.

```c
//Disable self organized networking
esp_mesh_set_self_organized(false, false);
```

ESP-WIFI-MESH will attempt to maintain the node’s current Wi-Fi state when disabling self organized networking.

- If the node was previously connected to other nodes, it will remain connected.
- If the node was previously disconnected and was scanning for a parent node or router, it will stop scanning.
- If the node was previously attempting to reconnect to a parent node or router, it will stop reconnecting.

**Enabling Self Organized Networking** ESP-WIFI-MESH will attempt to maintain the node’s current Wi-Fi state when enabling self organized networking. However, depending on the node type and whether a new parent is selected, the Wi-Fi state of the node can change. The following table shows effects of enabling self organized networking.
<table>
<thead>
<tr>
<th>Select Parent</th>
<th>Is Root Node</th>
<th>Effects</th>
</tr>
</thead>
</table>
| N            | N           | • Nodes already connected to a parent node will remain connected.  
              |              | • Nodes previously scanning for a parent node will stop scanning. Call `esp_mesh_connect()` to restart. |
| Y            |             | • A root node already connected to router will stay connected.  
              |             | • A root node disconnected from router will need to call `esp_mesh_connect()` to reconnect. |
| Y            | N           | • Nodes without a parent node will automatically select a preferred parent and connect.  
              |              | • Nodes already connected to a parent node will disconnect, reselect a preferred parent node, and connect. |
| Y            |             | • For a root node to connect to a parent node, it must give up its role as root. Therefore, a root node will disconnect from the router and all child nodes, select a preferred parent node, and connect. |

The following code snippet demonstrates how to enable self organized networking.

```c
// Enable self organized networking and select a new parent
esp_mesh_set_self_organized(true, true);
...

// Enable self organized networking and manually reconnect
esp_mesh_set_self_organized(true, false);
esp_mesh_connect();
```

**Calling Wi-Fi API** There can be instances in which an application may want to directly call Wi-Fi API whilst using ESP-WIFI-MESH. For example, an application may want to manually scan for neighboring APs. However, self organized networking must be disabled before the application calls any Wi-Fi APIs. This will prevent the ESP-WIFI-MESH stack from attempting to call any Wi-Fi APIs and potentially interfering with the application’s calls.

Therefore, application calls to Wi-Fi APIs should be placed in between calls of `esp_mesh_set_self_organized()` which disable and enable self organized networking. The following code snippet demonstrates how an application can safely call `esp_wifi_scan_start()` whilst using...
ESP-WIFI-MESH.

```c
//Disable self organized networking
esp_mesh_set_self_organized(0, 0);

//Stop any scans already in progress
esp_wifi_scan_stop();

//Manually start scan. Will automatically stop when run to completion
esp_wifi_scan_start();

//Process scan results
...

//Re-enable self organized networking if still connected
esp_mesh_set_self_organized(1, 0);
...

//Re-enable self organized networking if non-root and disconnected
esp_mesh_set_self_organized(1, 1);
...

//Re-enable self organized networking if root and disconnected
esp_mesh_set_self_organized(1, 0);  //Don't select new parent
esp_mesh_connect();  //Manually reconnect to router
```

Application Examples  ESP-IDF contains these ESP-WIFI-MESH example projects:

The Internal Communication Example demonstrates how to set up a ESP-WIFI-MESH network and have the root node send a data packet to every node within the network.

The Manual Networking Example demonstrates how to use ESP-WIFI-MESH without the self-organizing features. This example shows how to program a node to manually scan for a list of potential parent nodes and select a parent node based on custom criteria.

API Reference

Header File

- components/esp_wifi/include/esp_mesh.h

Functions

```c
 esp_err_t esp_mesh_init (void)
```

Mesh initialization.

- Check whether Wi-Fi is started.
- Initialize mesh global variables with default values.

Attention  This API shall be called after Wi-Fi is started.

Returns

- ESP_OK
- ESP_FAIL
Chapter 2. API Reference

`esp_err_t esp_mesh_deinit(void)`

Mesh de-initialization.

- Release resources and stop the mesh

Returns
- ESP_OK
- ESP_FAIL

`esp_err_t esp_mesh_start(void)`

Start mesh.

- Initialize mesh IE.
- Start mesh network management service.
- Create TX and RX queues according to the configuration.
- Register mesh packets receive callback.

Attention
This API shall be called after mesh initialization and configuration.

Returns
- ESP_OK
- ESP_FAIL
- ESP_ERR_MESH_NOT_INIT
- ESP_ERR_MESH_NOT_CONFIG
- ESP_ERR_MESH_NO_MEMORY

`esp_err_t esp_mesh_stop(void)`

Stop mesh.

- Deinitialize mesh IE.
- Disconnect with current parent.
- Disassociate all currently associated children.
- Stop mesh network management service.
- Unregister mesh packets receive callback.
- Delete TX and RX queues.
- Release resources.
- Restore Wi-Fi softAP to default settings if Wi-Fi dual mode is enabled.
- Set Wi-Fi Power Save type to WIFI_PS_NONE.

Returns
- ESP_OK
- ESP_FAIL

`esp_err_t esp_mesh_send(const mesh_addr_t *to, const mesh_data_t *data, int flag, const mesh_opt_t opt[], int opt_count)`

Send a packet over the mesh network.

- Send a packet to any device in the mesh network.
- Send a packet to external IP network.
Attention  This API is not reentrant.

Parameters

- **to**  [in] the address of the final destination of the packet
  - If the packet is to the root, set this parameter to NULL.
  - If the packet is to an external IP network, set this parameter to the IPv4:PORT combination. This packet will be delivered to the root firstly, then the root will forward this packet to the final IP server address.
- **data**  [in] pointer to a sending mesh packet
  - Field size should not exceed MESH_MPS. Note that the size of one mesh packet should not exceed MESH_MTU.
  - Field proto should be set to data protocol in use (default is MESH_PROTO_BIN for binary).
  - Field tos should be set to transmission tos (type of service) in use (default is MESH_TOS_P2P for point-to-point reliable).
- **flag**  [in] bitmap for data sent
  - Speed up the route search
    * If the packet is to the root and “to” parameter is NULL, set this parameter to 0.
    * If the packet is to an internal device, MESH_DATA_P2P should be set.
    * If the packet is to the root (“to” parameter isn’t NULL) or to external IP network, MESH_DATA_TODS should be set.
    * If the packet is from the root to an internal device, MESH_DATA_FROMDS should be set.
  - Specify whether this API is block or non-block, block by default
    * If needs non-blocking, MESH_DATA_NONBLOCK should be set. Otherwise, may use esp_mesh_send_block_time() to specify a blocking time.
  - In the situation of the root change, MESH_DATA_DROP identifies this packet can be dropped by the new root for upstream data to external IP network, we try our best to avoid data loss caused by the root change, but there is a risk that the new root is running out of memory because most of memory is occupied by the pending data which isn’t read out in time by esp_mesh_recv_toDS().
  Generally, we suggest esp_mesh_recv_toDS() is called after a connection with IP network is created. Thus data outgoing to external IP network via socket is just from reading esp_mesh_recv_toDS() which avoids unnecessary memory copy.
- **opt**  [in] options
  - In case of sending a packet to a certain group, MESH_OPT_SEND_GROUP is a good choice. In this option, the value field should be set to the target receiver addresses in this group.
  - Root sends a packet to an internal device, this packet is from external IP network in case the receiver device responds this packet, MESH_OPT_RECV_DS_ADDR is required to attach the target DS address.
- **opt_count**  [in] option count
  - Currently, this API only takes one option, so opt_count is only supported to be 1.

Returns

- ESP_OK
- ESP_FAIL
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_DISCONNECTED
- ESP_ERR_MESH_OPT_UNKNOWN
- ESP_ERR_MESH_EXCEED_MTU
- ESP_ERR_MESH_NO_MEMORY
- ESP_ERR_MESH_TIMEOUT
- ESP_ERR_MESH_QUEUE_FULL
- ESP_ERR_MESH_NO_ROUTE_FOUND
- ESP_ERR_MESH_DISCARD

`esp_err_t esp_mesh_send_block_time (uint32_t time_ms)`
Set blocking time of esp_mesh_send()

**Attention** This API shall be called before mesh is started.

**Parameters**
- `time_ms` [in] blocking time of esp_mesh_send(), unit: ms

**Returns**
- ESP_OK

```
esp_err_t esp_mesh_recv(mesh_addr_t *from, mesh_data_t *data, int timeout_ms, int *flag, mesh_opt_t opt[], int opt_count)
```

Receive a packet targeted to self over the mesh network.

flag could be MESH_DATA_FROMDS or MESH_DATA_TODS.

**Attention** Mesh RX queue should be checked regularly to avoid running out of memory.
- Use esp_mesh_get_rx_pending() to check the number of packets available in the queue waiting to be received by applications.

**Parameters**
- `from` [out] the address of the original source of the packet
- `data` [out] pointer to the received mesh packet
  - Field proto is the data protocol in use. Should follow it to parse the received data.
  - Field tos is the transmission tos (type of service) in use.
- `timeout_ms` [in] wait time if a packet isn’t immediately available (0: no wait, port-MAX_DELAY: wait forever)
- `flag` [out] bitmap for data received
  - MESH_DATA_FROMDS represents data from external IP network
  - MESH_DATA_TODS represents data directed upward within the mesh network
- `opt` [out] options desired to receive
  - MESH_OPT_RECV_DS_ADDR attaches the DS address
- `opt_count` [in] option count desired to receive
  - Currently, this API only takes one option, so opt_count is only supported to be 1.

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_TIMEOUT
- ESP_ERR_MESH_DISCARD

```
esp_err_t esp_mesh_recv_toDS(mesh_addr_t *from, mesh_addr_t *to, mesh_data_t *data, int timeout_ms, int *flag, mesh_opt_t opt[], int opt_count)
```

Receive a packet targeted to external IP network.

- Root uses this API to receive packets destined to external IP network
- Root forwards the received packets to the final destination via socket.
- If no socket connection is ready to send out the received packets and this esp_mesh_recv_toDS() hasn’t been called by applications, packets from the whole mesh network will be pending in toDS queue.

Use esp_mesh_get_rx_pending() to check the number of packets available in the queue waiting to be received by applications in case of running out of memory in the root.

Using esp_mesh_set_xon_qsize() users may configure the RX queue size, default:32. If this size is too large, and esp_mesh_recv_toDS() isn’t called in time, there is a risk that a great deal of memory is occupied by the pending packets. If this size is too small, it will impact the efficiency on upstream. How to decide this value depends on the specific application scenarios.
flag could be MESH_DATA_TODS.

**Attention** This API is only called by the root.

**Parameters**
- **from** [out] the address of the original source of the packet
- **to** [out] the address contains remote IP address and port (IPv4:PORT)
- **data** [out] pointer to the received packet
  - Contain the protocol and applications should follow it to parse the data.
- **timeout_ms** [in] wait time if a packet isn’t immediately available (0:no wait, port-MAX_DELAY:wait forever)
- **flag** [out] bitmap for data received
  - MESH_DATA_TODS represents the received data target to external IP network. Root shall forward this data to external IP network via the association with router.
- **opt** [out] options desired to receive
- **opt_count** [in] option count desired to receive

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_TIMEOUT
- ESP_ERR_MESH_DISCARD
- ESP_ERR_MESH_RECV_RELEASE

```c
esp_err_t esp_mesh_set_config(const mesh_cfg_t *config)
```
Set mesh stack configuration.

- Use MESH_INIT_CONFIG_DEFAULT() to initialize the default values, mesh IE is encrypted by default.
- Mesh network is established on a fixed channel (1-14).
- Mesh event callback is mandatory.
- Mesh ID is an identifier of an MBSS. Nodes with the same mesh ID can communicate with each other.
- Regarding to the router configuration, if the router is hidden, BSSID field is mandatory.

If BSSID field isn’t set and there exists more than one router with same SSID, there is a risk that more roots than one connected with different BSSID will appear. It means more than one mesh network is established with the same mesh ID.

Root conflict function could eliminate redundant roots connected with the same BSSID, but couldn’t handle roots connected with different BSSID. Because users might have such requirements of setting up routers with same SSID for the future replacement. But in that case, if the above situations happen, please make sure applications implement forward functions on the root to guarantee devices in different mesh networks can communicate with each other. max_connection of mesh softAP is limited by the max number of Wi-Fi softAP supported (max:10).

**Attention** This API shall be called before mesh is started after mesh is initialized.

**Parameters**
- **config** [in] pointer to mesh stack configuration

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

```c
esp_err_t esp_mesh_get_config(mesh_cfg_t *config)
```
Get mesh stack configuration.
Chapter 2. API Reference

**Parameters** config – [out] pointer to mesh stack configuration

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

`esp_err_t esp_mesh_set_router` (const mesh_router_t *router)
Get router configuration.

**Attention** This API is used to dynamically modify the router configuration after mesh is configured.

**Parameters** router – [in] pointer to router configuration

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

`esp_err_t esp_mesh_get_router` (mesh_router_t *router)
Get router configuration.

**Parameters** router – [out] pointer to router configuration

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

`esp_err_t esp_mesh_set_id` (const mesh_addr_t *id)
Set mesh network ID.

**Attention** This API is used to dynamically modify the mesh network ID.

**Parameters** id – [in] pointer to mesh network ID

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT: invalid argument

`esp_err_t esp_mesh_get_id` (mesh_addr_t *id)
Get mesh network ID.

**Parameters** id – [out] pointer to mesh network ID

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

`esp_err_t esp_mesh_set_type` (mesh_type_t type)
Designate device type over the mesh network.

- MESH_IDLE: designates a device as a self-organized node for a mesh network
- MESH_ROOT: designates the root node for a mesh network
- MESH_LEAF: designates a device as a standalone Wi-Fi station that connects to a parent
- MESH_STA: designates a device as a standalone Wi-Fi station that connects to a router

**Parameters** type – [in] device type

**Returns**
- ESP_OK
- ESP_ERR_MESH_NOT_ALLOWED
`mesh_type_t esp_mesh_get_type (void)`
Get device type over mesh network.

**Attention** This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

**Returns** mesh type

`esp_err_t esp_mesh_set_max_layer (int max_layer)`
Set network max layer value.

- for tree topology, the max is 25.
- for chain topology, the max is 1000.
- Network max layer limits the max hop count.

**Attention** This API shall be called before mesh is started.

**Parameters** `max_layer` - [in] max layer value

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

`int esp_mesh_get_max_layer (void)`
Get max layer value.

**Returns** max layer value

`esp_err_t esp_mesh_set_ap_password (const uint8_t *pwd, int len)`
Set mesh softAP password.

**Attention** This API shall be called before mesh is started.

**Parameters**
- `pwd` - [in] pointer to the password
- `len` - [in] password length

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

`esp_err_t esp_mesh_set_ap_authmode (wifi_auth_mode_t authmode)`
Set mesh softAP authentication mode.

**Attention** This API shall be called before mesh is started.

**Parameters** `authmode` - [in] authentication mode

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED
Chapter 2. API Reference

```c
wifi_auth_mode_t esp_mesh_get_ap_authmode (void)
Get mesh softAP authentication mode.
Returns authentication mode
```

```c
esp_err_t esp_mesh_set_ap_connections (int connections)
Set mesh max connection value.
```

- Set mesh softAP max connection = mesh max connection + non-mesh max connection

**Attention** This API shall be called before mesh is started.

**Parameters**
- **connections** [in] the number of max connections

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

```c
int esp_mesh_get_ap_connections (void)
Get mesh max connection configuration.
Returns the number of mesh max connections
```

```c
int esp_mesh_get_non_mesh_connections (void)
Get non-mesh max connection configuration.
Returns the number of non-mesh max connections
```

```c
int esp_mesh_get_layer (void)
Get current layer value over the mesh network.
```

**Attention** This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

**Returns** layer value

```c
esp_err_t esp_mesh_get_parent_bssid (mesh_addr_t *bssid)
Get the parent BSSID.
```

**Attention** This API shall be called after having received the event MESH_EVENT_PARENT_CONNECTED.

**Parameters**
- **bssid** [out] pointer to parent BSSID

**Returns**
- ESP_OK
- ESP_FAIL

```c
bool esp_mesh_is_root (void)
Return whether the device is the root node of the network.
```

**Returns** true/false

```c
esp_err_t esp_mesh_set_self_organized (bool enable, bool select_parent)
Enable/disable self-organized networking.
```
Self-organized networking has three main functions: select the root node; find a preferred parent; initiate reconnection if a disconnection is detected.

Self-organized networking is enabled by default.

If self-organized is disabled, users should set a parent for the device via esp_mesh_set_parent().

**Attention** This API is used to dynamically modify whether to enable the self organizing.

**Parameters**
- **enable** - [in] enable or disable self-organized networking
- **select_parent** - [in] Only valid when self-organized networking is enabled.
  - if select_parent is set to true, the root will give up its mesh root status and search for a new parent like other non-root devices.

**Returns**
- ESP_OK
- ESP_FAIL

```c
bool esp_mesh_get_self_organized (void)
```

Return whether enable self-organized networking or not.

**Returns** true/false

```c
esp_err_t esp_mesh_waive_root (const mesh_vote_t *vote, int reason)
```

Cause the root device to give up (waive) its mesh root status.

- A device is elected root primarily based on RSSI from the external router.
- If external router conditions change, users can call this API to perform a root switch.
- In this API, users could specify a desired root address to replace itself or specify an attempts value to ask current root to initiate a new round of voting. During the voting, a better root candidate would be expected to find to replace the current one.
- If no desired root candidate, the vote will try a specified number of attempts (at least 15). If no better root candidate is found, keep the current one. If a better candidate is found, the new better one will send a root switch request to the current root, current root will respond with a root switch acknowledgment.
- After that, the new candidate will connect to the router to be a new root, the previous root will disconnect with the router and choose another parent instead.

Root switch is completed with minimal disruption to the whole mesh network.

**Attention** This API is only called by the root.

**Parameters**
- **vote** - [in] vote configuration
  - If this parameter is set NULL, the vote will perform the default 15 times.
  - Field percentage threshold is 0.9 by default.
  - Field is_rc_specified shall be false.
  - Field attempts shall be at least 15 times.
- **reason** - [in] only accept MESH_VOTE_REASON_ROOT_INITIATED for now

**Returns**
- ESP_OK
- ESP_ERR_MESH_QUEUE_FULL
- ESP_ERR_MESH_DISCARD
- ESP_FAIL

```c
esp_err_t esp_mesh_set_vote_percentage (float percentage)
```

Set vote percentage threshold for approval of being a root (default:0.9)
• During the networking, only obtaining vote percentage reaches this threshold, the device could be a root.

**Attention** This API shall be called before mesh is started.

**Parameters** percentage – [in] vote percentage threshold

**Returns**
- ESP_OK
- ESP_FAIL

float *esp_mesh_get_vote_percentage* (void)
Get vote percentage threshold for approval of being a root.

**Returns** percentage threshold

**esp_err_t esp_mesh_set_ap_assoc_expire** (int seconds)
Set mesh softAP associate expired time (default: 10 seconds)

• If mesh softAP hasn’t received any data from an associated child within this time, mesh softAP will take this child inactive and disassociate it.
• If mesh softAP is encrypted, this value should be set a greater value, such as 30 seconds.

**Parameters** seconds – [in] the expired time

**Returns**
- ESP_OK
- ESP_FAIL

int *esp_mesh_get_ap_assoc_expire* (void)
Get mesh softAP associate expired time.

**Returns** seconds

int *esp_mesh_get_total_node_num* (void)
Get total number of devices in current network (including the root)

**Attention** The returned value might be incorrect when the network is changing.

**Returns** total number of devices (including the root)

int *esp_mesh_get_routing_table_size* (void)
Get the number of devices in this device’s sub-network (including self)

**Returns** the number of devices over this device’s sub-network (including self)

**esp_err_t esp_mesh_get_routing_table** (mesh_addr_t *mac, int len, int *size)
Get routing table of this device’s sub-network (including itself)

**Parameters**
- mac – [out] pointer to routing table
- len – [in] routing table size (in bytes)
- size – [out] pointer to the number of devices in routing table (including itself)

**Returns**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

**esp_err_t esp_mesh_post_toDS_state** (bool reachable)
Post the toDS state to the mesh stack.
**Attention** This API is only for the root.

**Parameters** reachable - [in] this state represents whether the root is able to access external IP network

**Returns**
- ESP_OK
- ESP_FAIL

```c
esp_err_t esp_mesh_get_tx_pending(mesh_tx_pending_t *pending)
```

Return the number of packets pending in the queue waiting to be sent by the mesh stack.

**Parameters** pending - [out] pointer to the TX pending

**Returns**
- ESP_OK
- ESP_FAIL

```c
esp_err_t esp_mesh_get_rx_pending(mesh_rx_pending_t *pending)
```

Return the number of packets available in the queue waiting to be received by applications.

**Parameters** pending - [out] pointer to the RX pending

**Returns**
- ESP_OK
- ESP_FAIL

```c
int esp_mesh_available_txupQ_num(const mesh_addr_t *addr, uint32_t *xseqno_in)
```

Return the number of packets could be accepted from the specified address.

**Parameters**
- `addr` - [in] self address or an associate children address
- `xseqno_in` - [out] sequence number of the last received packet from the specified address

**Returns** the number of upQ for a certain address

```c
esp_err_t esp_mesh_set_xon_qsize(int qsize)
```

Set the number of RX queue for the node, the average number of window allocated to one of its child node is: 
\[ \text{wnd} = \frac{xon\_qsize}{2 \times \text{max\_connection} + 1} \]. However, the window of each child node is not strictly equal to the average value, it is affected by the traffic also.

**Attention** This API shall be called before mesh is started.

**Parameters** qsize - [in] default:32 (min:16)

**Returns**
- ESP_OK
- ESP_FAIL

```c
int esp_mesh_get_xon_qsize(void)
```

Get queue size.

**Returns** the number of queue

```c
esp_err_t esp_mesh_allow_root_conflicts(bool allowed)
```

Set whether allow more than one root existing in one network.

**Parameters** allowed - [in] allow or not

**Returns**
- ESP_OK
- ESP_WIFI_ERR_NOT_INIT
- ESP_WIFI_ERR_NOT_START
bool esp_mesh_is_root_conflicts_allowed(void)
    Check whether allow more than one root to exist in one network.

    Returns true/false

esp_err_t esp_mesh_set_group_id(const mesh_addr_t *addr, int num)
    Set group ID addresses.

    Parameters
    • addr - [in] pointer to new group ID addresses
    • num - [in] the number of group ID addresses

    Returns
    • ESP_OK
    • ESP_MESH_ERR_ARGUMENT

esp_err_t esp_mesh_delete_group_id(const mesh_addr_t *addr, int num)
    Delete group ID addresses.

    Parameters
    • addr - [in] pointer to deleted group ID address
    • num - [in] the number of group ID addresses

    Returns
    • ESP_OK
    • ESP_MESH_ERR_ARGUMENT

int esp_mesh_get_group_num(void)
    Get the number of group ID addresses.

    Returns the number of group ID addresses

esp_err_t esp_mesh_get_group_list(mesh_addr_t *addr, int num)
    Get group ID addresses.

    Parameters
    • addr - [out] pointer to group ID addresses
    • num - [in] the number of group ID addresses

    Returns
    • ESP_OK
    • ESP_MESH_ERR_ARGUMENT

bool esp_mesh_is_my_group(const mesh_addr_t *addr)
    Check whether the specified group address is my group.

    Returns true/false

esp_err_t esp_mesh_set_capacity_num(int num)
    Set mesh network capacity (max:1000, default:300)

    Attention This API shall be called before mesh is started.

    Parameters num - [in] mesh network capacity

    Returns
    • ESP_OK
    • ESP_ERR_MESH_NOT_ALLOWED
    • ESP_MESH_ERR_ARGUMENT

int esp_mesh_get_capacity_num(void)
    Get mesh network capacity.

    Returns mesh network capacity
**esp_err_t** `esp_mesh_set_ie_crypto_funcs` (const mesh_crypto_funcs_t *crypto_funcs)

Set mesh IE crypto functions.

**Attention** This API can be called at any time after mesh is initialized.

**Parameters**
- `crypto_funcs` - [in] crypto functions for mesh IE
  - If `crypto_funcs` is set to NULL, mesh IE is no longer encrypted.

**Returns**
- ESP_OK

**esp_err_t** `esp_mesh_set_ie_crypto_key` (const char *key, int len)

Set mesh IE crypto key.

**Attention** This API can be called at any time after mesh is initialized.

**Parameters**
- `key` - [in] ASCII crypto key
- `len` - [in] length in bytes, range: 8~64

**Returns**
- ESP_OK
- ESP_MESH_ERR_ARGUMENT

**esp_err_t** `esp_mesh_get_ie_crypto_key` (char *key, int len)

Get mesh IE crypto key.

**Parameters**
- `key` - [out] ASCII crypto key
- `len` - [in] length in bytes, range: 8~64

**Returns**
- ESP_OK
- ESP_MESH_ERR_ARGUMENT

**esp_err_t** `esp_mesh_set_root_healing_delay` (int delay_ms)

Set delay time before starting root healing.

**Parameters**
- `delay_ms` - [in] delay time in milliseconds

**Returns**
- ESP_OK

**int** `esp_mesh_get_root_healing_delay` (void)

Get delay time before network starts root healing.

**Returns** delay time in milliseconds

**esp_err_t** `esp_mesh_fix_root` (bool enable)

Enable network Fixed Root Setting.

- Enabling fixed root disables automatic election of the root node via voting.
- All devices in the network shall use the same Fixed Root Setting (enabled or disabled).
- If Fixed Root is enabled, users should make sure a root node is designated for the network.

**Parameters**
- `enable` - [in] enable or not

**Returns**
- ESP_OK
bool esp_mesh_is_root_fixed (void)

Check whether network Fixed Root Setting is enabled.

- Enable/disable network Fixed Root Setting by API esp_mesh_fix_root().
- Network Fixed Root Setting also changes with the “flag” value in parent networking IE.

Returns true/false

esp_err_t esp_mesh_set_parent (const wifi_config_t *parent, const mesh_addr_t *parent_mesh_id, mesh_type_t my_type, int my_layer)

Set a specified parent for the device.

Attention This API can be called at any time after mesh is configured.

Parameters
- parent - [in] parent configuration, the SSID and the channel of the parent are mandatory.
  - If the BSSID is set, make sure that the SSID and BSSID represent the same parent, otherwise the device will never find this specified parent.
- parent_mesh_id - [in] parent mesh ID,
  - If this value is not set, the original mesh ID is used.
- my_type - [in] mesh type
  - MESH_STA is not supported.
  - If the parent set for the device is the same as the router in the network configuration, then my_type shall set MESH_ROOT and my_layer shall set MESH_ROOT_LAYER.
- my_layer - [in] mesh layer
  - my_layer of the device may change after joining the network.
  - If my_type is set MESH_NODE, my_layer shall be greater than MESH_ROOT_LAYER.
  - If my_type is set MESH_LEAF, the device becomes a standalone Wi-Fi station and no longer has the ability to extend the network.

Returns
- ESP_OK
- ESP_ERR_ARGUMENT
- ESP_ERR_MESH_NOT_CONFIG

esp_err_t esp_mesh_scan_get_ap_ie_len (int *len)

Get mesh networking IE length of one AP.

Parameters len - [out] mesh networking IE length

Returns
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_INVALID_ARG
- ESP_ERR_WIFI_FAIL

esp_err_t esp_mesh_scan_get_ap_record (wifi_ap_record_t *ap_record, void *buffer)

Get AP record.

Attention Different from esp_wifi_scan_get_ap_records(), this API only gets one of APs scanned each time.
See “manual_networking” example.

Parameters
- ap_record - [out] pointer to one AP record
- buffer - [out] pointer to the mesh networking IE of this AP

Returns
**Chapter 2  API Reference**

- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_INVALID_ARG
- ESP_ERR_WIFI_FAIL

```c
esp_err_t esp_mesh_flush_upstream_packets(void)
```
Flush upstream packets pending in to_parent queue and to_parent_p2p queue.

**Returns**
- ESP_OK

```c
esp_err_t esp_mesh_get_subnet_nodes_num(const mesh_addr_t *child_mac, int *nodes_num)
```
Get the number of nodes in the subnet of a specific child.

**Parameters**
- `child_mac` - [in] an associated child address of this device
- `nodes_num` - [out] pointer to the number of nodes in the subnet of a specific child

**Returns**
- ESP_OK
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_ARGUMENT

```c
esp_err_t esp_mesh_get_subnet_nodes_list(const mesh_addr_t *child_mac, mesh_addr_t *nodes, int nodes_num)
```
Get nodes in the subnet of a specific child.

**Parameters**
- `child_mac` - [in] an associated child address of this device
- `nodes` - [out] pointer to nodes in the subnet of a specific child
- `nodes_num` - [in] the number of nodes in the subnet of a specific child

**Returns**
- ESP_OK
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_ARGUMENT

```c
esp_err_t esp_mesh_disconnect(void)
```
Disconnect from current parent.

**Returns**
- ESP_OK

```c
esp_err_t esp_mesh_connect(void)
```
Connect to current parent.

**Returns**
- ESP_OK

```c
esp_err_t esp_mesh_flush_scan_result(void)
```
Flush scan result.

**Returns**
- ESP_OK

```c
esp_err_t esp_mesh_switch_channel(const uint8_t *new_bssid, int csa_newchan, int csa_count)
```
Cause the root device to add Channel Switch Announcement Element (CSA IE) to beacon.

- Set the new channel
- Set how many beacons with CSA IE will be sent before changing a new channel
- Enable the channel switch function
Attention This API is only called by the root.

Parameters

- **new_bssid** — [in] the new router BSSID if the router changes
- **csa_newchan** — [in] the new channel number to which the whole network is moving
- **csa_count** — [in] channel switch period(beacon count), unit is based on beacon interval of its softAP, the default value is 15.

Returns

- ESP_OK

```
void esp_mesh_get_router_bssid(uint8_t* router_bssid)
```

Get the router BSSID.

Parameters **router_bssid** — [out] pointer to the router BSSID

Returns

- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_INVALID_ARG

```
int64_t esp_mesh_get_tsf_time(void)
```

Get the TSF time.

Returns the TSF time

```
void esp_mesh_set_topology(esp_mesh_topology_t topo)
```

Set mesh topology. The default value is MESH_TOPO_TREE.

- MESH_TOPO_CHAIN supports up to 1000 layers

Attention This API shall be called before mesh is started.

Parameters **topo** — [in] MESH_TOPO_TREE or MESH_TOPO_CHAIN

Returns

- ESP_OK
- ESP_MESH_ERR_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

```
esp_mesh_topology_t esp_mesh_get_topology(void)
```

Get mesh topology.

Returns MESH_TOPO_TREE or MESH_TOPO_CHAIN

```
void esp_mesh_enable_ps(void)
```

Enable mesh Power Save function.

Attention This API shall be called before mesh is started.

Returns

- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_MESH_NOT_ALLOWED

```
void esp_mesh_disable_ps(void)
```

Disable mesh Power Save function.

Attention This API shall be called before mesh is started.
### Returns
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_MESH_NOT_ALLOWED

bool esp_mesh_is_ps_enabled (void)
Check whether the mesh Power Save function is enabled.

Returns true/false

bool esp_mesh_is_device_active (void)
Check whether the device is in active state.

- If the device is not in active state, it will neither transmit nor receive frames.

Returns true/false

esp_err_t esp_mesh_set_active_duty_cycle (int dev_duty, int dev_duty_type)
Set the device duty cycle and type.

- The range of dev_duty values is 1 to 100. The default value is 10.
- dev_duty = 100, the PS will be stopped.
- dev_duty is better to not less than 5.
- dev_duty_type could be MESH_PS_DEVICE_DUTY_REQUEST or MESH_PS_DEVICE_DUTY_DEMAND.
- If dev_duty_type is set to MESH_PSDEVICE_DUTY_REQUEST, the device will use a nwk_duty provided by the network.
- If dev_duty_type is set to MESH_PSDEVICE_DUTY_DEMAND, the device will use the specified dev_duty.

Attention This API can be called at any time after mesh is started.

Parameters
- dev_duty  ⚱ [in] device duty cycle
- dev_duty_type  ⚱ [in] device PS duty cycle type, not accept MESH_PS_NETWORK_DUTEY_MASTER

Returns
- ESP_OK
- ESP_FAIL

esp_err_t esp_mesh_get_active_duty_cycle (int *dev_duty, int *dev_duty_type)
Get device duty cycle and type.

Parameters
- dev_duty  ⚱ [out] device duty cycle
- dev_duty_type  ⚱ [out] device PS duty cycle type

Returns
- ESP_OK

esp_err_t esp_mesh_set_network_duty_cycle (int nwk_duty, int duration_mins, int applied_rule)
Set the network duty cycle, duration and rule.

- The range of nwk_duty values is 1 to 100. The default value is 10.
- nwk_duty is the network duty cycle the entire network or the up-link path will use. A device that successfully sets the nwk_duty is known as a NWK-DUTY-MASTER.
Chapter 2. API Reference

- duration_mins specifies how long the specified nwk_duty will be used. Once duration_mins expires, the root will take over as the NWK-DUTY-MASTER. If an existing NWK-DUTY-MASTER leaves the network, the root will take over as the NWK-DUTY-MASTER again.
- duration_mins = (-1) represents nwk_duty will be used until a new NWK-DUTY-MASTER with a different nwk_duty appears.
- Only the root can set duration_mins to (-1).
- If applied_rule is set to MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE, the nwk_duty will be used by the entire network.
- If applied_rule is set to MESH_PS_NETWORK_DUTY_APPLIED_UPLINK, the nwk_duty will only be used by the up-link path nodes.
- The root does not accept MESH_PS_NETWORK_DUTY_APPLIED_UPLINK.
- A nwk_duty with duration_mins(-1) set by the root is the default network duty cycle used by the entire network.

Attention This API can be called at any time after mesh is started.
- In self-organized network, if this API is called before mesh is started in all devices, (1)nwk_duty shall be set to the same value for all devices; (2)duration_mins shall be set to (-1); (3)applied_rule shall be set to MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE; after the voted root appears, the root will become the NWK-DUTY-MASTER and broadcast the nwk_duty and its identity of NWK-DUTY-MASTER.
- If the root is specified (FIXED-ROOT), call this API in the root to provide a default nwk_duty for the entire network.
- After joins the network, any device can call this API to change the nwk_duty, duration_mins or applied_rule.

Parameters
- nwk_duty - [in] network duty cycle
- duration_mins - [in] duration (unit: minutes)
- applied_rule - [in] only support MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE

Returns
- ESP_OK
- ESP_FAIL

`esp_err_t esp_mesh_get_network_duty_cycle(int*nwk_duty, int*duration_mins, int*dev_duty_type, int*applied_rule)`

Get the network duty cycle, duration, type and rule.

Parameters
- nwk_duty - [out] current network duty cycle
- duration_mins - [out] the duration of current nwk_duty
- dev_duty_type - [out] if it includes MESH_PS_DEVICE_DUTY_MASTER, this device is the current NWK-DUTY-MASTER.
- applied_rule - [out] MESH_PS_NETWORK_DUTY_APPLIED.EntIRE

Returns
- ESP_OK

`int esp_mesh_get_running_active_duty_cycle(void)`

Get the running active duty cycle.

- The running active duty cycle of the root is 100.
- If duty type is set to MESH_PSDEVICE_DUTY_REQUEST, the running active duty cycle is nwk_duty provided by the network.
- If duty type is set to MESH_PSDEVICE_DUTY_DEMAND, the running active duty cycle is dev_duty specified by the users.
- In a mesh network, devices are typically working with a certain duty-cycle (transmitting, receiving and sleep) to reduce the power consumption. The running active duty cycle decides the amount of awake time within a beacon interval. At each start of beacon interval, all devices wake up, broadcast beacons,
and transmit packets if they do have pending packets for their parents or for their children. Note that
Low-duty-cycle means devices may not be active in most of the time, the latency of data transmission
might be greater.

**Returns** the running active duty cycle

```c
esp_err_t esp_mesh_ps_duty_signaling(int fwd_times)
```

Duty signaling.

**Parameters**
- `fwd_times` - [in] the times of forwarding duty signaling packets

**Returns**
- ESP_OK

**Unions**

```c
union mesh_addr_t
```

`#include <esp_mesh.h>` Mesh address.

**Public Members**

```c
uint8_t addr[6]
```

mac address

```c
mip_t mip
```

mip address

**Unions**

```c
union mesh_event_info_t
```

`#include <esp_mesh.h>` Mesh event information.

**Public Members**

```c
mesh_event_channel_switch_t channel_switch
```

channel switch

```c
mesh_event_child_connected_t child_connected
```

child connected

```c
mesh_event_child_disconnected_t child_disconnected
```

child disconnected

```c
mesh_event_routing_table_change_t routing_table
```

routing table change

```c
mesh_event_connected_t connected
```

parent connected

```c
mesh_event_disconnected_t disconnected
```

parent disconnected
Chapter 2. API Reference

mesh_event_no_parent_found_t

- **no_parent**
  - no parent found

mesh_event_layer_change_t

- **layer_change**
  - layer change

mesh_event_toDS_state_t

- **toDS_state**
  - toDS state, devices shall check this state firstly before trying to send packets to external IP network. This state indicates right now whether the root is capable of sending packets out. If not, devices had better to wait until this state changes to be MESH_TODS_REACHABLE.

mesh_event_vote_started_t

- **vote_started**
  - vote started

mesh_event_root_address_t

- **root_addr**
  - root address

mesh_event_root_switch_req_t

- **switch_req**
  - root switch request

mesh_event_root_conflict_t

- **root_conflict**
  - other powerful root

mesh_event_root_fixed_t

- **root_fixed**
  - fixed root

mesh_event_scan_done_t

- **scan_done**
  - scan done

mesh_event_network_state_t

- **network_state**
  - network state, such as whether current mesh network has a root.

mesh_event_find_network_t

- **find_network**
  - network found that can join

mesh_event_router_switch_t

- **router_switch**
  - new router information

mesh_event_ps_duty_t

- **ps_duty**
  - PS duty information

union

- **mesh_rc_config_t**
  - #include <esp_mesh.h> Vote address configuration.

Public Members

- **int attempts**
  - max vote attempts before a new root is elected automatically by mesh network. (min:15, 15 by default)
mesh_addr_t rc_addr

a new root address specified by users for API esp_mesh_waive_root()

Structures

struct mip_t
IP address and port.

Public Members

disp_ip4_addr_t ip4
IP address

uint16_t port
port

struct mesh_event_channel_switch_t
Channel switch information.

Public Members

uint8_t channel
new channel

struct mesh_event_connected_t
Parent connected information.

Public Members

wifi_event_sta_connected_t connected
parent information, same as Wi-Fi event SYSTEM_EVENT_STA_CONNECTED does

uint16_t self_layer
layer

uint8_t duty
parent duty

struct mesh_event_no_parent_found_t
No parent found information.

Public Members

int scan_times
scan times being through
struct mesh_event_layer_change_t
Layer change information.

Public Members

uint16_t new_layer
new layer

struct mesh_event_vote_started_t
vote started information

Public Members

int reason
vote reason, vote could be initiated by children or by the root itself

int attempts
max vote attempts before stopped

mesh_addr_t rc_addr
root address specified by users via API esp_mesh_waive_root()

struct mesh_event_find_network_t
find a mesh network that this device can join

Public Members

uint8_t channel
channel number of the new found network

uint8_t router_bssid[6]
router BSSID

struct mesh_event_root_switch_req_t
Root switch request information.

Public Members

int reason
root switch reason, generally root switch is initialized by users via API esp_mesh_waive_root()

mesh_addr_t rc_addr
the address of root switch requester

struct mesh_event_root_conflict_t
Other powerful root address.
Public Members

```c
int8_t rssi
rssi with router
```

```c
uint16_t capacity
the number of devices in current network
```

```c
uint8_t addr[6]
other powerful root address
```

```c
struct mesh_event_routing_table_change_t
Routing table change.
```

Public Members

```c
uint16_t rt_size_new
the new value
```

```c
uint16_t rt_size_change
the changed value
```

```c
struct mesh_event_root_fixed_t
Root fixed.
```

Public Members

```c
bool is_fixed
status
```

```c
struct mesh_event_scan_done_t
Scan done event information.
```

Public Members

```c
uint8_t number
the number of APs scanned
```

```c
struct mesh_event_network_state_t
Network state information.
```

Public Members

```c
bool is_rootless
whether current mesh network has a root
```
struct mesh_event_ps_duty_t
PS duty information.

**Public Members**

uint8_t duty
parent or child duty

mesh_event_child_connected_t child_connected
child info

struct mesh_opt_t
Mesh option.

**Public Members**

uint8_t type
option type

uint16_t len
option length

uint8_t *val
option value

struct mesh_data_t
Mesh data for esp_mesh_send() and esp_mesh_recv()

**Public Members**

uint8_t *data
data

uint16_t size
data size

mesh_proto_t proto
data protocol

mesh_tos_t tos
data type of service

struct mesh_router_t
Router configuration.
Public Members

uint8_t ssid[32]
SSID

uint8_t ssid_len
length of SSID

uint8_t bssid[6]
BSSID, if this value is specified, users should also specify “allow_router_switch”.

uint8_t password[64]
password

bool allow_router_switch
if the BSSID is specified and this value is also set, when the router of this specified BSSID fails to be found after “fail” (mesh_attempts_t) times, the whole network is allowed to switch to another router with the same SSID. The new router might also be on a different channel. The default value is false. There is a risk that if the password is different between the new switched router and the previous one, the mesh network could be established but the root will never connect to the new switched router.

struct mesh_ap_cfg_t
Mesh softAP configuration.

Public Members

uint8_t password[64]
mesh softAP password

uint8_t max_connection
max number of stations allowed to connect in, default 6, max 10 = max_connection + non-mesh_max_connection max mesh connections

uint8_t nonmesh_max_connection
max non-mesh connections

struct mesh_cfg_t
Mesh initialization configuration.

Public Members

uint8_t channel
channel, the mesh network on

bool allow_channel_switch
if this value is set, when “fail” (mesh_attempts_t) times is reached, device will change to a full channel scan for a network that could join. The default value is false.
mesh_addr_t mesh_id
    mesh network identification

mesh_router_t router
    router configuration

mesh_ap_cfg_t mesh_ap
    mesh softAP configuration

const mesh_crypto_funcs_t *crypto_funcs
    crypto functions

struct mesh_vote_t
    Vote.

**Public Members**

float percentage
    vote percentage threshold for approval of being a root

bool is_rc_specified
    if true, rc_addr shall be specified (Unimplemented). if false, attempts value shall be specified to make network start root election.

mesh_rc_config_t config
    vote address configuration

struct mesh_tx_pending_t
    The number of packets pending in the queue waiting to be sent by the mesh stack.

**Public Members**

int to_parent
    to parent queue

int to_parent_p2p
    to parent (P2P) queue

int to_child
    to child queue

int to_child_p2p
    to child (P2P) queue

int mgmt
    management queue
Chapter 2. API Reference

```c
int broadcast
    broadcast and multicast queue
```

```c
struct mesh_rx_pending_t
    The number of packets available in the queue waiting to be received by applications.
```

**Public Members**

```c
int toDS
    to external DS

int toSelf
    to self
```

**Macros**

```c
MESH_ROOT_LAYER
    root layer value

MESH_MTU
    max transmit unit(in bytes)

MESH_MPS
    max payload size(in bytes)

ESP_ERR_MESH_WIFI_NOT_START
    Mesh error code definition.
    Wi-Fi isn’t started

ESP_ERR_MESH_NOT_INIT
    mesh isn’t initialized

ESP_ERR_MESH_NOT_CONFIG
    mesh isn’t configured

ESP_ERR_MESH_NOT_START
    mesh isn’t started

ESP_ERR_MESH_NOT_SUPPORT
    not supported yet

ESP_ERR_MESH_NOT_ALLOWED
    operation is not allowed

ESP_ERR_MESH_NO_MEMORY
    out of memory
```
ESP_ERR_MESH_ARGUMENT
  illegal argument

ESP_ERR_MESH_EXCEED_MTU
  packet size exceeds MTU

ESP_ERR_MESH_TIMEOUT
  timeout

ESP_ERR_MESH_DISCONNECTED
  disconnected with parent on station interface

ESP_ERR_MESH_QUEUE_FAIL
  queue fail

ESP_ERR_MESH_QUEUE_FULL
  queue full

ESP_ERR_MESH_NO_PARENT_FOUND
  no parent found to join the mesh network

ESP_ERR_MESH_NO_ROUTE_FOUND
  no route found to forward the packet

ESP_ERR_MESH_OPTION_NULL
  no option found

ESP_ERR_MESH_OPTION_UNKNOWN
  unknown option

ESP_ERR_MESH_XON_NO_WINDOW
  no window for software flow control on upstream

ESP_ERR_MESH_INTERFACE
  low-level Wi-Fi interface error

ESP_ERR_MESH_DISCARD_DUPLICATE
  discard the packet due to the duplicate sequence number

ESP_ERR_MESH_DISCARD
  discard the packet

ESP_ERR_MESH_VOTING
  vote in progress

ESP_ERR_MESH_XMIT
  XMIT
ESP_ERR_MESH_QUEUE_READ
error in reading queue

ESP_ERR_MESH_PS
mesh PS is not specified as enable or disable

ESP_ERR_MESH_RECV_RELEASE
release esp_mesh_recv_toDS

MESH_DATA_ENC
Flags bitmap for esp_mesh_send() and esp_mesh_recv()
  data encrypted (Unimplemented)

MESH_DATA_P2P
point-to-point delivery over the mesh network

MESH_DATA_FROMDS
receive from external IP network

MESH_DATA_TODS
identify this packet is target to external IP network

MESH_DATA_NONBLOCK
esp_mesh_send() non-block

MESH_DATA_DROP
in the situation of the root having been changed, identify this packet can be dropped by new root

MESH_DATA_GROUP
identify this packet is target to a group address

MESH_OPT_SEND_GROUP
Option definitions for esp_mesh_send() and esp_mesh_recv()
  data transmission by group; used with esp_mesh_send() and shall have payload

MESH_OPT_RECV_DS_ADDR
return a remote IP address; used with esp_mesh_send() and esp_mesh_recv()

MESH_ASSOC_FLAG_VOTE_IN_PROGRESS
Flag of mesh networking IE.
  vote in progress

MESH_ASSOC_FLAG_NETWORK_FREE
no root in current network

MESH_ASSOC_FLAG_ROOTS_FOUND
root conflict is found
**MESH_ASSOC_FLAG_ROOT_FIXED**

fixed root

**MESH_PS_DEVICE_DUTY_REQUEST**

Mesh PS (Power Save) duty cycle type.

requests to join a network PS without specifying a device duty cycle. After the device joins the network, a network duty cycle will be provided by the network

**MESH_PS_DEVICE_DUTY_DEMAND**

requests to join a network PS and specifies a demanded device duty cycle

**MESH_PS_NETWORK_DUTY_MASTER**

indicates the device is the NWK-DUTY-MASTER (network duty cycle master)

**MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE**

Mesh PS (Power Save) duty cycle applied rule.

**MESH_PS_NETWORK_DUTY_APPLIED_UPLINK**

**MESH_INIT_CONFIG_DEFAULT()**

**Type Definitions**

typedef `mesh_addr_t mesh_event_root_address_t`

Root address.

typedef `wifi_event_sta_disconnected_t mesh_event_disconnected_t`

Parent disconnected information.

typedef `wifi_event_ap_staconnected_t mesh_event_child_connected_t`

Child connected information.

typedef `wifi_event_ap_stadisconnected_t mesh_event_child_disconnected_t`

Child disconnected information.

typedef `wifi_event_sta_connected_t mesh_event_router_switch_t`

New router information.

**Enumerations**

enum `mesh_event_id_t`

Enumerated list of mesh event id.

Values:

enumerator `MESH_EVENT_STARTED`

mesh is started

enumerator `MESH_EVENT_STOPPED`

mesh is stopped
enumerator MESH_EVENT_CHANNEL_SWITCH
cannel switch

enumerator MESH_EVENT_CHILD_CONNECTED
a child is connected on softAP interface

enumerator MESH_EVENT_CHILD_DISCONNECTED
a child is disconnected on softAP interface

enumerator MESH_EVENT_ROUTING_TABLE_ADD
routing table is changed by adding newly joined children

enumerator MESH_EVENT_ROUTING_TABLE_REMOVE
routing table is changed by removing leave children

enumerator MESH_EVENT_PARENT_CONNECTED
parent is connected on station interface

enumerator MESH_EVENT_PARENT_DISCONNECTED
parent is disconnected on station interface

enumerator MESH_EVENT_NO_PARENT_FOUND
no parent found

enumerator MESH_EVENT_LAYER_CHANGE
layer changes over the mesh network

enumerator MESH_EVENT_TODS_STATE
state represents whether the root is able to access external IP network. This state is a manual event that needs to be triggered with esp_mesh_post_toDS_state().

enumerator MESH_EVENT_VOTE_STARTED
the process of voting a new root is started either by children or by the root

enumerator MESH_EVENT_VOTE_STOPPED
the process of voting a new root is stopped

enumerator MESH_EVENT_ROOT_ADDRESS
the root address is obtained. It is posted by mesh stack automatically.

enumerator MESH_EVENT_ROOT_SWITCH_REQ
root switch request sent from a new voted root candidate

enumerator MESH_EVENT_ROOT_SWITCH_ACK
root switch acknowledgment responds the above request sent from current root

enumerator MESH_EVENT_ROOT_ASKED_YIELD
the root is asked yield by a more powerful existing root. If self organized is disabled and this device is specified to be a root by users, users should set a new parent for this device. If self organized is enabled, this device will find a new parent by itself, users could ignore this event.
enumerator **MESH_EVENT_ROOT_FIXED**
when devices join a network, if the setting of Fixed Root for one device is different from that of its parent, the device will update the setting the same as its parent’s. Fixed Root Setting of each device is variable as that setting changes of the root.

enumerator **MESH_EVENT_SCAN_DONE**
if self-organized networking is disabled, user can call esp_wifi_scan_start() to trigger this event, and add the corresponding scan done handler in this event.

enumerator **MESH_EVENT_NETWORK_STATE**
network state, such as whether current mesh network has a root.

enumerator **MESH_EVENT_STOP_RECONNECTION**
the root stops reconnecting to the router and non-root devices stop reconnecting to their parents.

enumerator **MESH_EVENT_FIND_NETWORK**
when the channel field in mesh configuration is set to zero, mesh stack will perform a full channel scan to find a mesh network that can join, and return the channel value after finding it.

enumerator **MESH_EVENT_ROUTER_SWITCH**
if users specify BSSID of the router in mesh configuration, when the root connects to another router with the same SSID, this event will be posted and the new router information is attached.

enumerator **MESH_EVENT_PS_PARENT_DUTY**
parent duty

enumerator **MESH_EVENT_PS_CHILD_DUTY**
child duty

enumerator **MESH_EVENT_PS_DEVICE_DUTY**
device duty

enumerator **MESH_EVENT_MAX**

enum **mesh_type_t**
Device type.

*Values:*

enumerator **MESH_IDLE**
hasn’t joined the mesh network yet

enumerator **MESH_ROOT**
the only sink of the mesh network. Has the ability to access external IP network

enumerator **MESH_NODE**
intermediate device. Has the ability to forward packets over the mesh network

enumerator **MESH_LEAF**
has no forwarding ability
enumerator **MESH_STA**
connect to router with a standalone Wi-Fi station mode, no network expansion capability

enum **mesh_proto_t**
Protocol of transmitted application data.

*Values:*

enumerator **MESH_PROTO_BIN**
binary

enumerator **MESH_PROTO_HTTP**
HTTP protocol

enumerator **MESH_PROTO_JSON**
JSON format

enumerator **MESH_PROTO_MQTT**
MQTT protocol

enumerator **MESH_PROTO_AP**
IP network mesh communication of node’s AP interface

enumerator **MESH_PROTO_STA**
IP network mesh communication of node’s STA interface

enum **mesh_tos_t**
For reliable transmission, mesh stack provides three type of services.

*Values:*

enumerator **MESH_TOS_P2P**
provide P2P (point-to-point) retransmission on mesh stack by default

enumerator **MESH_TOS_E2E**
provide E2E (end-to-end) retransmission on mesh stack (Unimplemented)

enumerator **MESH_TOS_DEF**
no retransmission on mesh stack

enum **mesh_vote_reason_t**
Vote reason.

*Values:*

enumerator **MESH_VOTE_REASON_ROOT_INITIATED**
vote is initiated by the root

enumerator **MESH_VOTE_REASON_CHILD_INITIATED**
vote is initiated by children
enum mesh_disconnect_reason_t
 Mesh disconnect reason code.

Values:

enumerator MESH_REASON_CYCLIC
cyclic is detected

enumerator MESH_REASON_PARENT_IDLE
parent is idle

enumerator MESH_REASON_LEAF
the connected device is changed to a leaf

enumerator MESH_REASON_DIFF_ID
in different mesh ID

enumerator MESH_REASON_ROOTS
root conflict is detected

enumerator MESH_REASON_PARENT_STOPPED
parent has stopped the mesh

enumerator MESH_REASON_SCAN_FAIL
scan fail

enumerator MESH_REASON_IE_UNKNOWN
unknown IE

enumerator MESH_REASON_WAIVE_ROOT
waive root

enumerator MESH_REASON_PARENT_WORSE
parent with very poor RSSI

enumerator MESH_REASON_EMPTY_PASSWORD
use an empty password to connect to an encrypted parent

enumerator MESH_REASON_PARENT_UNENCRYPTED
connect to an unencrypted parent/router

enum esp_mesh_topology_t
 Mesh topology.

Values:

enumerator MESH_TOPO_TREE
tree topology
Chapter 2. API Reference

enumerator **MESH_TOPO_CHAIN**
  chain topology

enum **mesh_event_toDS_state_t**
  The reachability of the root to a DS (distribute system)
  
  **Values:**
  
  enumerator **MESH_TODS_UNREACHABLE**
  the root is not able to access external IP network
  
  enumerator **MESH_TODS_REACHABLE**
  the root is able to access external IP network

**SmartConfig**

The SmartConfig™ is a provisioning technology developed by TI to connect a new Wi-Fi device to a Wi-Fi network. It uses a mobile app to broadcast the network credentials from a smartphone, or a tablet, to an un-provisioned Wi-Fi device.

The advantage of this technology is that the device does not need to directly know SSID or password of an Access Point (AP). This information is provided using the smartphone. This is particularly important to headless device and systems, due to their lack of a user interface.

If you are looking for other options to provision your ESP32 devices, check **Provisioning API**.

**Application Example**

Connect ESP32 to target AP using SmartConfig: `wifi/smart_config`.

**API Reference**

**Header File**

- components/esp_wifi/include/esp_smartconfig.h

**Functions**

`const char *esp_smartconfig_get_version (void)`

Get the version of SmartConfig.

**Returns**

- SmartConfig version const char.

`esp_err_t esp_smartconfig_start (const smartconfig_start_config_t *config)`

Start SmartConfig, config ESP device to connect AP. You need to broadcast information by phone APP. Device sniffer special packets from the air that containing SSID and password of target AP.

**Attention**

1. This API can be called in station or softAP-station mode.
2. Can not call esp_smartconfig_start twice before it finish, please call esp_smartconfig_stop first.

**Parameters**

- `config` — pointer to smartconfig start configure structure

**Returns**

- ESP_OK: succeed
- others: fail
**esp_err_t esp_smartconfig_stop (void)**

Stop SmartConfig, free the buffer taken by esp_smartconfig_start.

**Attention** Whether connect to AP succeed or not, this API should be called to free memory taken by smart-config_start.

**Returns**
- ESP_OK: succeed
- others: fail

**esp_err_t esp_esptouch_set_timeout (uint8_t time_s)**

Set timeout of SmartConfig process.

**Attention** Timing starts from SC_STATUS_FIND_CHANNEL status. SmartConfig will restart if timeout.

**Parameters**
- **time_s** – range 15s~255s, offset: 45s.

**Returns**
- ESP_OK: succeed
- others: fail

**esp_err_t esp_smartconfig_set_type (smartconfig_type_t type)**

Set protocol type of SmartConfig.

**Attention** If users need to set the SmartConfig type, please set it before calling esp_smartconfig_start.

**Parameters**
- **type** – Choose from the smartconfig_type_t.

**Returns**
- ESP_OK: succeed
- others: fail

**esp_err_t esp_smartconfig_fast_mode (bool enable)**

Set mode of SmartConfig. default normal mode.

**Attention**
1. Please call it before API esp_smartconfig_start.
2. Fast mode have corresponding APP(phone).
3. Two mode is compatible.

**Parameters**
- **enable** – false-disable(default); true-enable;

**Returns**
- ESP_OK: succeed
- others: fail

**esp_err_t esp_smartconfig_get_rvd_data (uint8_t *rvd_data, uint8_t len)**

Get reserved data of ESPTouch v2.

**Parameters**
- **rvd_data** – reserved data
- **len** – length of reserved data

**Returns**
- ESP_OK: succeed
- others: fail
Structures

struct smartconfig_event_got_ssid_pswd_t
    Argument structure for SC_EVENT_GOT_SSID_PSWD event

    Public Members

    uint8_t ssid[32]
        SSID of the AP. Null terminated string.

    uint8_t password[64]
        Password of the AP. Null terminated string.

    bool bssid_set
        whether set MAC address of target AP or not.

    uint8_t bssid[6]
        MAC address of target AP.

    smartconfig_type_t type
        Type of smartconfig(ESPTouch or AirKiss).

    uint8_t token
        Token from cellphone which is used to send ACK to cellphone.

    uint8_t cellphone_ip[4]
        IP address of cellphone.

struct smartconfig_start_config_t
    Configure structure for esp_smartconfig_start

    Public Members

    bool enable_log
        Enable smartconfig logs.

    bool esp_touch_v2_enable_crypt
        Enable ESPTouch v2 crypt.

    char *esp_touch_v2_key
        ESPTouch v2 crypt key, len should be 16.

Macros
SMARTCONFIG_START_CONFIG_DEFAULT ()
Enumerations

enum smartconfig_type_t

Values:

enumerator SC_TYPE_ESPTOUCH
    protocol: ESPTouch

enumerator SC_TYPE_AIRKISS
    protocol: AirKiss

enumerator SC_TYPE_ESPTOUCH_AIRKISS
    protocol: ESPTouch and AirKiss

enumerator SC_TYPE_ESPTOUCH_V2
    protocol: ESPTouch v2

enum smartconfig_event_t

Smartconfig event declarations

Values:

enumerator SC_EVENT_SCAN_DONE
    Station smartconfig has finished to scan for APs

enumerator SC_EVENT_FOUND_CHANNEL
    Station smartconfig has found the channel of the target AP

enumerator SC_EVENT_GOT_SSID_PSWD
    Station smartconfig got the SSID and password

enumerator SC_EVENT_SEND_ACK_DONE
    Station smartconfig has sent ACK to cellphone

Wi-Fi

Introduction The Wi-Fi libraries provide support for configuring and monitoring the ESP32 Wi-Fi networking functionality. This includes configuration for:

• Station mode (aka STA mode or Wi-Fi client mode). ESP32 connects to an access point.
• AP mode (aka Soft-AP mode or Access Point mode). Stations connect to the ESP32.
• Station/AP-coexistence mode (ESP32 is concurrently an access point and a station connected to another access point).
• Various security modes for the above (WPA, WPA2, WPA3, etc.)
• Scanning for access points (active & passive scanning).
• Promiscuous mode for monitoring of IEEE802.11 Wi-Fi packets.

Application Examples Several application examples demonstrating the functionality of Wi-Fi library are provided in wifi directory of ESP-IDF repository. Please check the README for more details.
API Reference

Header File

- components/esp_wifi/include/esp_wifi.h

Functions

**esp_err_t esp_wifi_init(const wifi_init_config_t *config)**

Initialize WiFi Allocate resource for WiFi driver, such as WiFi control structure, RX/TX buffer, WiFi NVS structure etc. This WiFi also starts WiFi task.

**Attention 1.** This API must be called before all other WiFi API can be called

**Attention 2.** Always use WIFI_INIT_CONFIG_DEFAULT macro to initialize the configuration to default values, this can guarantee all the fields get correct value when more fields are added into wifi_init_config_t in future release. If you want to set your own initial values, overwrite the default values which are set by WIFI_INIT_CONFIG_DEFAULT. Please be notified that the field ‘magic’ of wifi_init_config_t should always be WIFI_INIT_CONFIG_MAGIC!

**Parameters**

- **config**—pointer to WiFi initialized configuration structure; can point to a temporary variable.

**Returns**

- ESP_OK: succeed
- ESP_ERR_NO_MEM: out of memory
- others: refer to error code esp_err.h

**esp_err_t esp_wifi_deinit(void)**

Deinit WiFi Free all resource allocated in esp_wifi_init and stop WiFi task.

**Attention 1.** This API should be called if you want to remove WiFi driver from the system

**Returns**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- others: refer to error code in esp_err.h

**esp_err_t esp_wifi_set_mode(wifi_mode_t mode)**

Set the WiFi operating mode.

Set the WiFi operating mode as station, soft-AP, station+soft-AP or NAN. The default mode is station mode.

**Parameters**

- **mode**—WiFi operating mode

**Returns**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- others: refer to error code in esp_err.h

**esp_err_t esp_wifi_get_mode(wifi_mode_t *mode)**

Get current operating mode of WiFi.

**Parameters**

- **mode**—[out] store current WiFi mode

**Returns**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_start (void)**

Start WiFi according to current configuration. If mode is WIFI_MODE_STA, it creates station control block and starts station. If mode is WIFI_MODE_AP, it creates soft-AP control block and starts soft-AP. If mode is WIFI_MODE_APSTA, it creates soft-AP and station control block and starts soft-AP and station. If mode is WIFI_MODE_NAN, it creates NAN control block and starts NAN.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NO_MEM: out of memory
- ESP_ERR_WIFI_CONN: WiFi internal error, station or soft-AP control block wrong
- ESP_FAIL: other WiFi internal errors

**esp_err_t esp_wifi_stop (void)**

Stop WiFi. If mode is WIFI_MODE_STA, it stops station and frees station control block. If mode is WIFI_MODE_AP, it stops soft-AP and frees soft-AP control block. If mode is WIFI_MODE_APSTA, it stops station/soft-AP and frees station/soft-AP control block. If mode is WIFI_MODE_NAN, it stops NAN and frees NAN control block.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**esp_err_t esp_wifi_restore (void)**

Restore WiFi stack persistent settings to default values.

This function will reset settings made using the following APIs:
- esp_wifi_set_bandwidth
- esp_wifi_set_protocol
- esp_wifi_set_config
- esp_wifi_set_mode

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**esp_err_t esp_wifi_connect (void)**

Connect WiFi station to the AP.

**Attention** 1. This API only impact WIFI_MODE_STA or WIFI_MODE_APSTA mode
**Attention** 2. If station interface is connected to an AP, call esp_wifi_disconnect to disconnect.
**Attention** 3. The scanning triggered by esp_wifi_scan_start() will not be effective until connection between device and the AP is established. If device is scanning and connecting at the same time, it will abort scanning and return a warning message and error number ESP_ERR_WIFI_STATE.
**Attention** 4. This API attempts to connect to an Access Point (AP) only once. To enable reconnection in case of a connection failure, please use the ‘failure_retry_cnt’ feature in the ‘wifi_sta_config_t’. Users are suggested to implement reconnection logic in their application for scenarios where the specified AP does not exist, or reconnection is desired after the device has received a disconnect event.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_WIFI_CONN: WiFi internal error, station or soft-AP control block wrong
- ESP_ERR_WIFI SSID: SSID of AP which station connects is invalid
**esp_err_t esp_wifi_disconnect** (void)

Disconnect WiFi station from the AP.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi was not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi was not started by esp_wifi_start
- ESP_FAIL: other WiFi internal errors

**esp_err_t esp_wifi_clear_fast_connect** (void)

Currently this API is just an stub API.

**Returns**
- ESP_OK: succeed
- others: fail

**esp_err_t esp_wifi_deauth_sta** (uint16_t aid)

deauthenticate all stations or associated id equals to aid

**Parameters**
- **aid** – when aid is 0, deauthenticate all stations, otherwise deauthenticate station whose associated id is aid

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi was not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_MODE: WiFi mode is wrong

**esp_err_t esp_wifi_scan_start** (const wifi_scan_config_t *config, bool block)

Scan all available APs.

**Attention** If this API is called, the found APs are stored in WiFi driver dynamic allocated memory and the will be freed in esp_wifi_scan_get_ap_records, so generally, call esp_wifi_scan_get_ap_records to cause the memory to be freed once the scan is done

**Attention** The values of maximum active scan time and passive scan time per channel are limited to 1500 milliseconds. Values above 1500ms may cause station to disconnect from AP and are not recommended.

**Parameters**
- **config** – configuration settings for scanning, if set to NULL default settings will be used of which default values are show_hidden:false, scan_type:active, scan_time.active.min:0, scan_time.active.max:120 miliseconds, scan_time.passive:360 miliseconds
- **block** – if block is true, this API will block the caller until the scan is done, otherwise it will return immediately

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi was not started by esp_wifi_start
- ESP_ERR_WIFI_TIMEOUT: blocking scan is timeout
- ESP_ERR_WIFI_STATE: wifi still connecting when invoke esp_wifi_scan_start
- others: refer to error code in esp_err.h

**esp_err_t esp_wifi_scan_stop** (void)

Stop the scan in process.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
**esp_err_t esp_wifi_scan_get_ap_num (uint16_t *number)**

Get number of APs found in last scan.

**Attention** This API can only be called when the scan is completed, otherwise it may get wrong value.

**Parameters**
- `number` - [out] store number of APs found in last scan

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_scan_get_ap_records (uint16_t *number, wifi_ap_record_t *ap_records)**

Get AP list found in last scan.

**Parameters**
- `number` - [inout] As input param, it stores max AP number ap_records can hold. As output param, it receives the actual AP number this API returns.
- `ap_records` - wifi_ap_record_t array to hold the found APs

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NO_MEM: out of memory

**esp_err_t esp_wifi_clear_ap_list (void)**

Clear AP list found in last scan.

**Attention** When the obtained ap list fails, bss info must be cleared, otherwise it may cause memory leakage.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_CONN: The station interface don’t initialized
- ESP_ERR_WIFI_NOT_CONNECTED: The station is in disconnect status

**esp_err_t esp_wifi_sta_get_ap_info (wifi_ap_record_t *ap_info)**

Get information of AP to which the device is associated with.

**Attention** When the obtained country information is empty, it means that the AP does not carry country information

**Parameters**
- `ap_info` - the wifi_ap_record_t to hold AP information sta can get the connected ap’s phy mode info through the struct member phy_11b, phy_11g, phy_11n, phy_lr in the wifi_ap_record_t struct. For example, phy_11b = 1 imply that ap support 802.11b mode

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_CONN: The station interface don’t initialized
- ESP_ERR_WIFI_NOT_CONNECTED: The station is in disconnect status

**esp_err_t esp_wifi_set_ps (wifi_ps_type_t type)**

Set current WiFi power save type.
**Attention** Default power save type is WIFI_PS_MIN_MODEM.

**Parameters**
- **type** – power save type

**Returns**
- ESP_OK: succeed

```c
esp_err_t esp_wifi_get_ps(wifi_ps_type_t *type)
```
Get current WiFi power save type.

**Attention** Default power save type is WIFI_PS_MIN_MODEM.

**Parameters**
- **type** – [out] store current power save type

**Returns**
- ESP_OK: succeed

```c
esp_err_t esp_wifi_set_protocol(wifi_interface_t ifx, uint8_t protocol_bitmap)
```
Set protocol type of specified interface. The default protocol is (WIFI_PROTOCOL_11B|WIFI_PROTOCOL_11G|WIFI_PROTOCOL_11N). If `CONFIG_SOC_WIFI_HE_SUPPORT`, the default protocol is (WIFI_PROTOCOL_11B|WIFI_PROTOCOL_11G|WIFI_PROTOCOL_11N|WIFI_PROTOCOL_11AX).

**Attention** Support 802.11b or 802.11bg or 802.11bgn or 802.11bgnax or LR mode

**Parameters**
- **ifx** – interfaces
- **protocol_bitmap** – WiFi protocol bitmap

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_IF: invalid interface
- others: refer to error codes in esp_err.h

```c
esp_err_t esp_wifi_get_protocol(wifi_interface_t ifx, uint8_t *protocol_bitmap)
```
Get the current protocol bitmap of the specified interface.

**Parameters**
- **ifx** – interface
- **protocol_bitmap** – [out] store current WiFi protocol bitmap of interface ifx

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_IF: invalid interface
- ESP_ERR_INVALID_ARG: invalid argument
- others: refer to error codes in esp_err.h

```c
esp_err_t esp_wifi_set_bandwidth(wifi_interface_t ifx, wifi_bandwidth_t bw)
```
Set the bandwidth of specified interface.

**Attention** 1. API return false if try to configure an interface that is not enabled
2. WIFI_BW_HT40 is supported only when the interface support 11N

**Parameters**
- **ifx** – interface to be configured
- **bw** – bandwidth

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_IF: invalid interface
- ESP_ERR_INVALID_ARG: invalid argument
• others: refer to error codes in esp_err.h

\texttt{esp_err_t esp_wifi_get_bandwidth(wifi_interface_t ifx, wifi_bandwidth_t *bw)}

Get the bandwidth of specified interface.

**Attention** 1. API return false if try to get a interface that is not enable

**Parameters**
• \texttt{ifx} – interface to be configured
• \texttt{bw} – [out] store bandwidth of interface ifx

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_IF: invalid interface
• ESP_ERR_INVALID_ARG: invalid argument

\texttt{esp_err_t esp_wifi_set_channel(uint8_t primary, wifi_second_chan_t second)}

Set primary/secondary channel of device.

**Attention** 1. This API should be called after esp_wifi_start() and before esp_wifi_stop()
**Attention** 2. When device is in STA mode, this API should not be called when STA is scanning or connecting to an external AP
**Attention** 3. When device is in softAP mode, this API should not be called when softAP has connected to external STAs
**Attention** 4. When device is in STA+softAP mode, this API should not be called when in the scenarios described above
**Attention** 5. The channel info set by this API will not be stored in NVS. So If you want to remember the channel used before wifi stop, you need to call this API again after wifi start, or you can call esp_wifi_set_config() to store the channel info in NVS.

**Parameters**
• \texttt{primary} – for HT20, primary is the channel number, for HT40, primary is the primary channel
• \texttt{second} – for HT20, second is ignored, for HT40, second is the second channel

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_IF: invalid interface
• ESP_ERR_INVALID_ARG: invalid argument
• ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start

\texttt{esp_err_t esp_wifi_get_channel(uint8_t *primary, wifi_second_chan_t *second)}

Get the primary/secondary channel of device.

**Attention** 1. API return false if try to get a interface that is not enable

**Parameters**
• \texttt{primary} – store current primary channel
• \texttt{second} – [out] store current second channel

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument
**esp_err_t esp_wifi_set_country (const wifi_country_t *country)**

configure country info

**Attention** 1. It is discouraged to call this API since this doesn’t validate the per-country rules, it’s up to the user to fill in all fields according to local regulations. Please use esp_wifi_set_country_code instead.

**Attention** 2. The default country is “01” (world safe mode) {.cc=“01”, .schan=1, .nchan=11, .policy=WIFI_COUNTRY_POLICY_AUTO}.

**Attention** 3. The third octet of country code string is one of the following: ‘m’, ‘O’, ‘I’, ‘X’, otherwise it is considered as ‘m’.

**Attention** 4. When the country policy is WIFI_COUNTRY_POLICY_AUTO, the country info of the AP to which the station is connected is used. E.g. if the configured country info is {.cc=“US” , .schan=1, .nchan=11} and the country info of the AP to which the station is connected is {.cc=“JP” , .schan=1, .nchan=14} then the country info that will be used is { .cc=“JP” , .schan=1, .nchan=14}. If the station disconnected from the AP the country info is set back to the country info of the station automatically, { .cc=“US” , .schan=1, .nchan=11} in the example.

**Attention** 5. When the country policy is WIFI_COUNTRY_POLICY_MANUAL, then the configured country info is used always.

**Attention** 6. When the country info is changed because of configuration or because the station connects to a different external AP, the country IE in probe response/beacon of the soft-AP is also changed.

**Attention** 7. The country configuration is stored into flash.

**Attention** 8. When this API is called, the PHY init data will switch to the PHY init data type corresponding to the country info.

**Parameters**
- **country** - the configured country info

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_get_country (wifi_country_t *country)**

get the current country info

**Parameters**
- **country** - country info

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_set_mac (wifi_interface_t ifx, const uint8_t mac[6])**

Set MAC address of WiFi station, soft-AP or NAN interface.

**Attention** 1. This API can only be called when the interface is disabled

**Attention** 2. Above mentioned interfaces have different MAC addresses, do not set them to be the same.

**Attention** 3. The bit 0 of the first byte of MAC address can not be 1. For example, the MAC address can set to be “1a:XX:XX:XX:XX:XX”, but can not be “15:XX:XX:XX:XX:XX”.

**Parameters**
- **ifx** – interface
- **mac** – the MAC address

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_IF: invalid interface
- ESP_ERR_WIFI_MAC: invalid mac address
- ESP_ERR_WIFI_MODE: WiFi mode is wrong
### Chapter 2. API Reference

- others: refer to error codes in esp_err.h

```c
esp_err_t esp_wifi_get_mac (wifi_interface_t ifx, uint8_t mac[6])
```

Get mac of specified interface.

**Parameters**
- `ifx` – interface
- `mac` – [out] store mac of the interface ifx

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_IF: invalid interface

```c
esp_err_t esp_wifi_set_promiscuous_rx_cb (wifi_promiscuous_cb_t cb)
```

Register the RX callback function in the promiscuous mode. Each time a packet is received, the registered callback function will be called.

**Parameters**
- `cb` – callback

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

```c
esp_err_t esp_wifi_set_promiscuous (bool en)
```

Enable the promiscuous mode.

**Parameters**
- `en` – false - disable, true - enable

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

```c
esp_err_t esp_wifi_get_promiscuous (bool *en)
```

Get the promiscuous mode.

**Parameters**
- `en` – [out] store the current status of promiscuous mode

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

```c
esp_err_t esp_wifi_set_promiscuous_filter (const wifi_promiscuous_filter_t *filter)
```

Enable the promiscuous mode packet type filter.

**Note:** The default filter is to filter all packets except WIFI_PKT_MISC

```c
Parameters filter – the packet type filtered in promiscuous mode.
```

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

```c
esp_err_t esp_wifi_get_promiscuous_filter (wifi_promiscuous_filter_t *filter)
```

Get the promiscuous filter.

**Parameters**
- `filter` – [out] store the current status of promiscuous filter

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
**esp_err_t esp_wifi_set_promiscuous_ctrl_filter** (const wifi_promiscuous_filter_t *filter)

Enable subtype filter of the control packet in promiscuous mode.

**Note:** The default filter is to filter none control packet.

**Parameters**
- filter – the subtype of the control packet filtered in promiscuous mode.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**esp_err_t esp_wifi_get_promiscuous_ctrl_filter** (wifi_promiscuous_filter_t *filter)

Get the subtype filter of the control packet in promiscuous mode.

**Parameters**
- filter – [out] store the current status of subtype filter of the control packet in promiscuous mode

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_set_config** (wifi_interface_t interface, wifi_config_t *conf)

Set the configuration of the STA, AP or NAN.

**Attention**
1. This API can be called only when specified interface is enabled, otherwise, API fail
2. For station configuration, bssid_set needs to be 0; and it needs to be 1 only when users need to check the MAC address of the AP.
3. ESP devices are limited to only one channel, so when in the soft-AP+station mode, the soft-AP will adjust its channel automatically to be the same as the channel of the station.
4. The configuration will be stored in NVS for station and soft-AP

**Parameters**
- interface – interface
- conf – station, soft-AP or NAN configuration

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_IF: invalid interface
- ESP_ERR_WIFI_MODE: invalid mode
- ESP_ERR_WIFI_PASSWORD: invalid password
- ESP_ERR_WIFI_NVS: WiFi internal NVS error
- others: refer to the error code in esp_err.h

**esp_err_t esp_wifi_get_config** (wifi_interface_t interface, wifi_config_t *conf)

Get configuration of specified interface.

**Parameters**
- interface – interface
- conf – [out] station or soft-AP configuration

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_IF: invalid interface
**esp_err_t esp_wifi_ap_get_sta_list** *(wifi_sta_list_t *sta)*

Get STAs associated with soft-AP.

**Attention**  SSC only API

**Parameters**  
- **sta**  [-out] station list ap can get the connected sta’s phy mode info through the struct member phy_11b, phy_11g, phy_11n, phy_lr in the wifi_sta_info_t struct. For example, phy_11b = 1 imply that sta support 802.11b mode

**Returns**  
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_WIFI_MODE: WiFi mode is wrong
- ESP_ERR_WIFI_CONN: WiFi internal error, the station/soft-AP control block is invalid

**esp_err_t esp_wifi_ap_get_sta_aid** *(const uint8_t mac[6], uint16_t *aid)*

Get AID of STA connected with soft-AP.

**Parameters**  
- **mac**  - STA’s mac address
- **aid**  [-out] Store the AID corresponding to STA mac

**Returns**  
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NOT_FOUND: Requested resource not found
- ESP_ERR_WIFI_MODE: WiFi mode is wrong
- ESP_ERR_WIFI_CONN: WiFi internal error, the station/soft-AP control block is invalid

**esp_err_t esp_wifi_set_storage** *(wifi_storage_t storage)*

Set the WiFi API configuration storage type.

**Attention**  
1. The default value is WIFI_STORAGE_FLASH

**Parameters**  
- **storage**  - : storage type

**Returns**  
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_set_vendor_ie** *(bool enable, wifi_vendor_ie_type_t type, wifi_vendor_ie_id_t idx, const void *vnd_ie)*

Set 802.11 Vendor-Specific Information Element.

**Parameters**  
- **enable**  - If true, specified IE is enabled. If false, specified IE is removed.
- **type**  - Information Element type. Determines the frame type to associate with the IE.
- **idx**  - Index to set or clear. Each IE type can be associated with up to two elements (indices 0 & 1).
- **vnd_ie**  - Pointer to vendor specific element data. First 6 bytes should be a header with fields matching vendor_ie_data_t. If enable is false, this argument is ignored and can be NULL. Data does not need to remain valid after the function returns.

**Returns**  
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init()
- ESP_ERR_INVALID_ARG: Invalid argument, including if first byte of vnd_ie is not WIFI_VENDOR_IE_ELEMENT_ID (0xDD) or second byte is an invalid length.
• ESP_ERR_NO_MEM: Out of memory

**esp_err_t esp_wifi_set_vendor_ie_cb (esp_vendor_ie_cb_t cb, void *ctx)**

Register Vendor-Specific Information Element monitoring callback.

**Parameters**
• cb – Callback function
• ctx – Context argument, passed to callback function.

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**esp_err_t esp_wifi_set_max_tx_power (int8_t power)**

Set maximum transmitting power after WiFi start.

**Attention** 1. Maximum power before wifi startup is limited by PHY init data bin.
**Attention** 2. The value set by this API will be mapped to the max_tx_power of the structure wifi_country_t variable.
**Attention** 3. Mapping Table \{Power, max_tx_power\} = {{8, 2}, {20, 5}, {28, 7}, {34, 8}, {44, 11}, {52, 13}, {56, 14}, {60, 15}, {66, 16}, {72, 18}, {80, 20}}.
**Attention** 4. Param power unit is 0.25dBm, range is [8, 84] corresponding to 2dBm - 20dBm.
**Attention** 5. Relationship between set value and actual value. As follows: \{set value range, actual value\} = {{[8, 19], 8}, {[20, 27], 20}, {[28, 33], 28}, {[34, 43], 34}, {[44, 51], 44}, {[52, 55], 52}, {[56, 59], 56}, {[60, 65], 60}, {[66, 71], 66}, {[72, 79], 72}, {[80, 84], 80}}.

**Parameters**
• power – Maximum WiFi transmitting power.

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
• ESP_ERR_INVALID_ARG: invalid argument, e.g. parameter is out of range

**esp_err_t esp_wifi_get_max_tx_power (int8_t *power)**

Get maximum transmitting power after WiFi start.

**Parameters**
• power – Maximum WiFi transmitting power, unit is 0.25dBm.

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
• ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t esp_wifi_set_event_mask (uint32_t mask)**

Set mask to enable or disable some WiFi events.

**Attention** 1. Mask can be created by logical OR of various WIFI_EVENT_MASK_ constants. Events which have corresponding bit set in the mask will not be delivered to the system event handler.
**Attention** 2. Default WiFi event mask is WIFI_EVENT_MASK_AP_PROBEREQRECVED.
**Attention** 3. There may be lots of stations sending probe request data around. Don’t unmask this event unless you need to receive probe request data.

**Parameters**
• mask – WiFi event mask.

**Returns**
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
**esp_err_t** esp_wifi_get_event_mask(uint32_t* mask)

Get mask of WiFi events.

**Parameters**
- mask – WiFi event mask.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**esp_err_t** esp_wifi_80211_tx(wifi_interface_t ifx, const void* buffer, int len, bool en_sys_seq)

Send raw ieee80211 data.

**Attention** Currently only support for sending beacon/probe request/probe response/action and non-QoS data frame

**Parameters**
- ifx – interface if the Wi-Fi mode is Station, the ifx should be WIFI_IF_STA. If the Wi-Fi mode is SoftAP, the ifx should be WIFI_IF_AP. If the Wi-Fi mode is Station+SoftAP, the ifx should be WIFI_IF_STA or WIFI_IF_AP. If the ifx is wrong, the API returns ESP_ERR_WIFI_IF.
- buffer – raw ieee80211 buffer
- len – the length of raw buffer, the len must be <= 1500 Bytes and >= 24 Bytes
- en_sys_seq – indicate whether use the internal sequence number. If en_sys_seq is false, the sequence in raw buffer is unchanged, otherwise it will be overwritten by WiFi driver with the system sequence number. Generally, if esp_wifi_80211_tx is called before the Wi-Fi connection has been set up, both en_sys_seq=true and en_sys_seq=false are fine. However, if the API is called after the Wi-Fi connection has been set up, en_sys_seq must be true, otherwise ESP_ERR_INVALID_ARG is returned.

**Returns**
- ESP_OK: success
- ESP_ERR_WIFI_IF: Invalid interface
- ESP_ERR_INVALID_ARG: Invalid parameter
- ESP_ERR_WIFI_NO_MEM: out of memory

**esp_err_t** esp_wifi_set_csi_rx_cb(wifi_csi_cb_t cb, void* ctx)

Register the RX callback function of CSI data.

Each time a CSI data is received, the callback function will be called.

**Parameters**
- cb – callback
- ctx – context argument, passed to callback function

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**esp_err_t** esp_wifi_set_csi_config(const wifi_csi_config_t *config)

Set CSI data configuration.

return

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start or promiscuous mode is not enabled
• ESP_ERR_INVALID_ARG: invalid argument

Parameters config – configuration

esp_err_t esp_wifi_set_csi(bool en)
Enable or disable CSI.

return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start or promiscuous mode is not enabled
• ESP_ERR_INVALID_ARG: invalid argument

Parameters en – true - enable, false - disable

esp_err_t esp_wifi_set_ant_gpio(const wifi_ant_gpio_config_t *config)
Set antenna GPIO configuration.

Parameters config – Antenna GPIO configuration.

Returns
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument, e.g. parameter is NULL, invalid GPIO number etc

esp_err_t esp_wifi_get_ant_gpio(wifi_ant_gpio_config_t *config)
Get current antenna GPIO configuration.

Parameters config – Antenna GPIO configuration.

Returns
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument, e.g. parameter is NULL

esp_err_t esp_wifi_set_ant(const wifi_ant_config_t *config)
Set antenna configuration.

Parameters config – Antenna configuration.

Returns
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument, e.g. parameter is NULL, invalid antenna mode or invalid GPIO number

esp_err_t esp_wifi_get_ant(wifi_ant_config_t *config)
Get current antenna configuration.

Parameters config – Antenna configuration.

Returns
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument, e.g. parameter is NULL

int64_t esp_wifi_get_tsf_time(wifi_interface_t interface)
Get the TSF time. In Station mode or SoftAP+Station mode if station is not connected or station doesn’t receive at least one beacon after connected, will return 0.
**Attention** Enabling power save may cause the return value inaccurate, except WiFi modem sleep.

**Parameters**  
interface – The interface whose tsf_time is to be retrieved.

**Returns**  
0 or the TSF time

```c
esp_err_t esp_wifi_set_inactive_time(wifi_interface_t ifx, uint16_t sec)
```

Set the inactive time of the STA or AP.

**Attention**
1. For Station, If the station does not receive a beacon frame from the connected SoftAP during the inactive time, disconnect from SoftAP. Default 6s.
2. For SoftAP, If the softAP doesn’t receive any data from the connected STA during inactive time, the softAP will force deauth the STA. Default is 300s.
3. The inactive time configuration is not stored into flash.

**Parameters**
- ifx – interface to be configured.
- sec – Inactive time. Unit seconds.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument, For Station, if sec is less than 3. For SoftAP, if sec is less than 10.

```c
esp_err_t esp_wifi_get_inactive_time(wifi_interface_t ifx, uint16_t* sec)
```

Get inactive time of specified interface.

**Parameters**
- ifx – Interface to be configured.
- sec – Inactive time. Unit seconds.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start
- ESP_ERR_INVALID_ARG: invalid argument

```c
esp_err_t esp_wifi_stats_dump(uint32_t modules)
```

Dump WiFi statistics.

**Parameters**
- modules – statistic modules to be dumped

**Returns**
- ESP_OK: succeed
- others: failed

```c
esp_err_t esp_wifi_set_rssi_threshold(int32_t rssi)
```

Set RSSI threshold, if average rssi gets lower than threshold, WiFi task will post event WIFI_EVENT_STA_BSS_RSSI_LOW.

**Attention** If the user wants to receive another WIFI_EVENT_STA_BSS_RSSI_LOW event after receiving one, this API needs to be called again with an updated/same RSSI threshold.

**Parameters**
- rssi – threshold value in dbm between -100 to 0

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument
### esp_err_t esp_wifi_ftm_initiate_session(wifi_ftm_initiator_cfg_t *cfg)

Start an FTM Initiator session by sending FTM request. If successful, event WIFI_EVENT_FTM_REPORT is generated with the result of the FTM procedure.

**Attention** 1. Use this API only in Station mode.

**Attention** 2. If FTM is initiated on a different channel than Station is connected in or internal SoftAP is started in, FTM defaults to a single burst in ASAP mode.

**Parameters**
- `cfg` - FTM Initiator session configuration

**Returns**
- ESP_OK: succeed
- others: failed

### esp_err_t esp_wifi_ftm_end_session(void)

End the ongoing FTM Initiator session.

**Attention** This API works only on FTM Initiator

**Returns**
- ESP_OK: succeed
- others: failed

### esp_err_t esp_wifi_ftm_resp_set_offset(int16_t offset_cm)

Set offset in cm for FTM Responder. An equivalent offset is calculated in picoseconds and added in TOD of FTM Measurement frame (T1).

**Attention** Use this API only in AP mode before performing FTM as responder

**Parameters**
- `offset_cm` - T1 Offset to be added in centimeters

**Returns**
- ESP_OK: succeed
- others: failed

### esp_err_t esp_wifi_config_11b_rate(wifi_interface_t ifx, bool disable)

Enable or disable 11b rate of specified interface.

**Attention** 1. This API should be called after esp_wifi_init() and before esp_wifi_start().

**Attention** 2. Only when really need to disable 11b rate call this API otherwise don’t call this.

**Parameters**
- `ifx` – Interface to be configured.
- `disable` – true means disable 11b rate while false means enable 11b rate.

**Returns**
- ESP_OK: succeed
- others: failed

### esp_err_t esp_wifi_connectionless_module_set_wake_interval(uint16_t wake_interval)

Set wake interval for connectionless modules to wake up periodically.

**Attention** 1. Only one wake interval for all connectionless modules.
Attention 2. This configuration could work at connected status. When ESP_WIFI_STA_DISCONNECTED_PM_ENABLE is enabled, this configuration could work at disconnected status.

Attention 3. Event WIFI_EVENT_CONNECTIONLESS_MODULE_WAKE_INTERVAL_START would be posted each time wake interval starts.

Attention 4. Recommend to configure interval in multiples of hundred. (e.g. 100ms)

Attention 5. Recommend to configure interval to ESP_WIFI_CONNECTIONLESS_INTERVAL_DEFAULT_MODE to get stable performance at coexistence mode.

Parameters wake_interval – Milliseconds after would the chip wake up, from 1 to 65535.

```c
esp_err_t esp_wifi_force_wakeup_acquire(void)
```

Request extra reference of Wi-Fi radio. Wi-Fi keep active state (RF opened) to be able to receive packets.

Attention Please pair the use of `esp_wifi_force_wakeup_acquire` with `esp_wifi_force_wakeup_release`.

Returns

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start

```c
esp_err_t esp_wifi_force_wakeup_release(void)
```

Release extra reference of Wi-Fi radio. Wi-Fi go to sleep state (RF closed) if no more use of radio.

Attention Please pair the use of `esp_wifi_force_wakeup_acquire` with `esp_wifi_force_wakeup_release`.

Returns

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_STARTED: WiFi is not started by esp_wifi_start

```c
esp_err_t esp_wifi_set_country_code(const char* country, bool ieee80211d_enabled)
```

configure country

Attention 1. When ieee80211d_enabled, the country info of the AP to which the station is connected is used. E.g. if the configured country is US and the country info of the AP to which the station is connected is JP then the country info that will be used is JP. If the station disconnected from the AP the country info is set back to the country info of the station automatically, US in the example.

Attention 2. When ieee80211d_enabled is disabled, then the configured country info is used always.

Attention 3. When the country info is changed because of configuration or because the station connects to a different external AP, the country IE in probe response/beacon of the soft-AP is also changed.

Attention 4. The country configuration is stored into flash.

Attention 5. When this API is called, the PHY init data will switch to the PHY init data type corresponding to the country info.


Attention 7. When country code “01” (world safe mode) is set, SoftAP mode won’t contain country IE.

Attention 8. The default country is “01” (world safe mode) and ieee80211d_enabled is TRUE.
Attention 9. The third octet of country code string is one of the following: ‘M’, ‘O’, ‘I’, ‘X’, otherwise it is considered as ‘M’.

Parameters
- country – the configured country ISO code
- ieee80211d_enabled – 802.11d is enabled or not

Returns
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

`esp_err_t esp_wifi_get_country_code(char *country)`
get the current country code

Parameters country – country code

Returns
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

`esp_err_t esp_wifi_config_80211_tx_rate(wifi_interface_t ifx, wifi_phy_rate_t rate)`
Config 80211 tx rate of specified interface.

Attention 1. This API should be called after esp_wifi_init() and before esp_wifi_start().

Parameters
- ifx – Interface to be configured.
- rate – Phy rate to be configured.

Returns
- ESP_OK: succeed
- others: failed

`esp_err_t esp_wifi_disable_pmf_config(wifi_interface_t ifx)`
Disable PMF configuration for specified interface.

Attention This API should be called after esp_wifi_set_config() and before esp_wifi_start().

Parameters ifx – Interface to be configured.

Returns
- ESP_OK: succeed
- others: failed

`esp_err_t esp_wifi_sta_get_aid(uint16_t *aid)`
Get the Association id assigned to STA by AP.

Attention aid = 0 if station is not connected to AP.

Parameters aid – [out] store the aid

Returns
- ESP_OK: succeed

`esp_err_t esp_wifi_sta_get_negotiated_phymode(wifi_phy_mode_t *phymode)`
Get the negotiated phymode after connection.

Parameters phymode – [out] store the negotiated phymode.
Returns

- ESP_OK: succeed

**esp_err_t esp_wifi_set_dynamic_cs**(bool enabled)

Config dynamic carrier sense.

**Attention** This API should be called after esp_wifi_start().

**Parameters** enabled – Dynamic carrier sense is enabled or not.

**Returns**

- ESP_OK: succeed
- others: failed

**esp_err_t esp_wifi_sta_get_rssi**(int *rssi)

Get the rssi info after station connected to AP.

**Attention** This API should be called after station connected to AP.

**Parameters** rssi – Store the rssi info received from last beacon.

**Returns**

- ESP_OK: succeed
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_FAIL: failed

**Structures**

**struct wifi_init_config_t**

WiFi stack configuration parameters passed to esp_wifi_init call.

**Public Members**

```c
wifi_osi_funcs_t *osi_funcs
```

WiFi OS functions

```c
wpa_crypto_funcs_t wpa_crypto_funcs
```

WiFi station crypto functions when connect

```c
int static_rx_buf_num
```

WiFi static RX buffer number

```c
int dynamic_rx_buf_num
```

WiFi dynamic RX buffer number

```c
int tx_buf_type
```

WiFi TX buffer type

```c
int static_tx_buf_num
```

WiFi static TX buffer number
int `dynamic_tx_buf_num`
   WiFi dynamic TX buffer number

int `rx_mgmt_buf_type`
   WiFi RX MGMT buffer type

int `rx_mgmt_buf_num`
   WiFi RX MGMT buffer number

int `cache_tx_buf_num`
   WiFi TX cache buffer number

int `csi_enable`
   WiFi channel state information enable flag

int `ampdu_rx_enable`
   WiFi AMPDU RX feature enable flag

int `ampdu_tx_enable`
   WiFi AMPDU TX feature enable flag

int `amsdu_tx_enable`
   WiFi AMSDU TX feature enable flag

int `nvs_enable`
   WiFi NVS flash enable flag

int `nano_enable`
   Nano option for printf/scan family enable flag

int `rx_ba_win`
   WiFi Block Ack RX window size

int `wifi_task_core_id`
   WiFi Task Core ID

int `beacon_max_len`
   WiFi softAP maximum length of the beacon

int `mgmt_sbuf_num`
   WiFi management short buffer number, the minimum value is 6, the maximum value is 32

uint64_t `feature_caps`
   Enables additional WiFi features and capabilities

bool `sta_disconnected_pm`
   WiFi Power Management for station at disconnected status
int espnow_max_encrypt_num
    Maximum encrypt number of peers supported by espnow

int magic
    WiFi init magic number, it should be the last field

**Macros**

**ESP_ERR_WIFI_NOT_INIT**
    WiFi driver was not installed by esp_wifi_init

**ESP_ERR_WIFI_NOT_STARTED**
    WiFi driver was not started by esp_wifi_start

**ESP_ERR_WIFI_NOT_STOPPED**
    WiFi driver was not stopped by esp_wifi_stop

**ESP_ERR_WIFI_IF**
    WiFi interface error

**ESP_ERR_WIFI_MODE**
    WiFi mode error

**ESP_ERR_WIFI_STATE**
    WiFi internal state error

**ESP_ERR_WIFI_CONN**
    WiFi internal control block of station or soft-AP error

**ESP_ERR_WIFI_NVS**
    WiFi internal NVS module error

**ESP_ERR_WIFI_MAC**
    MAC address is invalid

**ESP_ERR_WIFI_SSID**
    SSID is invalid

**ESP_ERR_WIFI_PASSWORD**
    Password is invalid

**ESP_ERR_WIFI_TIMEOUT**
    Timeout error

**ESP_ERR_WIFI_WAKE_FAIL**
    WiFi is in sleep state (RF closed) and wakeup fail

**ESP_ERR_WIFI_WOULD_BLOCK**
    The caller would block
ESP_ERR_WIFI_NOT_CONNECT
Station still in disconnect status

ESP_ERR_WIFI_POST
Failed to post the event to WiFi task

ESP_ERR_WIFI_INIT_STATE
Invalid WiFi state when init/deinit is called

ESP_ERR_WIFI_STOP_STATE
Returned when WiFi is stopping

ESP_ERR_WIFI_NOT_ASSOC
The WiFi connection is not associated

ESP_ERR_WIFI_RX_DISALLOW
The WiFi RX is disallowed

ESP_ERR_WIFI_TWT_FULL
no available flow id

ESP_ERR_WIFI_TWT_SETUP_TIMEOUT
Timeout of receiving twt setup response frame, timeout times can be set during twt setup

ESP_ERR_WIFI_TWT_SETUP_TXFAIL
TWT setup frame tx failed

ESP_ERR_WIFI_TWT_SETUP_REJECT
The twt setup request was rejected by the AP

ESP_ERR_WIFI_DISCARD
Discard frame

WIFI_STATIC_TX_BUFFER_NUM

WIFI_CACHE_TX_BUFFER_NUM

WIFI_DYNAMIC_TX_BUFFER_NUM

WIFI_RX_MGMT_BUF_NUM_DEF

WIFI_CSI_ENABLED

WIFI_AMPDU_RX_ENABLED

WIFI_AMPDU_TX_ENABLED
WIFI_AMSDU_TX_ENABLED
WIFI_NVS_ENABLED
WIFI_NANO_FORMAT_ENABLED
WIFI_INIT_CONFIG_MAGIC
WIFI_DEFAULT_RX_BA_WIN
WIFI_TASK_CORE_ID
WIFI_SOFTAP_BEACON_MAX_LEN
WIFI_MGMT_SBUF_NUM
WIFI_STA_DISCONNECTED_PM_ENABLED
CONFIG_FEATURE_WPA3_SAE_BIT
CONFIG_FEATURE_CACHE_TX_BUF_BIT
CONFIG_FEATURE_FTM_INITIATOR_BIT
CONFIG_FEATURE_FTM_RESPONDER_BIT
WIFI_INIT_CONFIG_DEFAULT()

ESP_WIFI_CONNECTIONLESS_INTERVAL_DEFAULT_MODE

Type Definitions
typedef void (*wifi_promiscuous_cb_t)(void *buf, wifi_promiscuous_pkt_type_t type)

The RX callback function in the promiscuous mode. Each time a packet is received, the callback function will
be called.

Param buf Data received. Type of data in buffer (wifi_promiscuous_pkt_t or wifi_pkt_rx_ctrl_t)
indicated by ‘type’ parameter.
Param type promiscuous packet type.
typedef void (*esp_vendor_ie_cb_t)(void *ctx, wifi_vendor_ie_type_t type, const uint8_t sa[6], const
vendor_ie_data_t *vnd_ie, int rssi)

Function signature for received Vendor-Specific Information Element callback.

Param ctx Context argument, as passed to esp_wifi_set_vendor_ie_cb() when registering call-
back.
Param type Information element type, based on frame type received.
Param sa Source 802.11 address.
Param vnd_ie Pointer to the vendor specific element data received.
Param rssi Received signal strength indication.
typedef void (*wifi_csi_cb_t)(void *ctx, wifi_csi_info_t *data)

The RX callback function of Channel State Information (CSI) data.

Each time a CSI data is received, the callback function will be called.

**Param** `ctx`  context argument, passed to esp_wifi_set_csi_rx_cb() when registering callback function.

**Param** `data`  CSI data received. The memory that it points to will be deallocated after callback function returns.

### Header File

- `components/esp_wifi/include/esp_wifi_types.h`

### Unions

union `wifi_config_t`

```c
#include <esp_wifi_types.h>  
Configuration data for device’s AP or STA or NAN.
```

The usage of this union (for ap, sta or nan configuration) is determined by the accompanying interface argument passed to esp_wifi_set_config() or esp_wifi_get_config().

### Public Members

- `wifi_ap_config_t ap`
  
  configuration of AP

- `wifi_sta_config_t sta`
  
  configuration of STA

- `wifi_nan_config_t nan`
  
  configuration of NAN

### Structures

struct `wifi_country_t`

Structure describing WiFi country-based regional restrictions.

### Public Members

- `char cc[3]`
  
  country code string

- `uint8_t schan`
  
  start channel

- `uint8_t nchan`
  
  total channel number
int8_t max_tx_power

This field is used for getting WiFi maximum transmitting power, call esp_wifi_set_max_tx_power to set the maximum transmitting power.

wifi_country_policy_t policy

country policy

struct wifi_active_scan_time_t

Range of active scan times per channel.

Public Members

uint32_t min

minimum active scan time per channel, units: millisecond

uint32_t max

maximum active scan time per channel, units: millisecond, values above 1500ms may cause station to disconnect from AP and are not recommended.

struct wifi_scan_time_t

Aggregate of active & passive scan time per channel.

Public Members

wifi_active_scan_time_t active

active scan time per channel, units: millisecond.

uint32_t passive

passive scan time per channel, units: millisecond, values above 1500ms may cause station to disconnect from AP and are not recommended.

struct wifi_scan_config_t

Parameters for an SSID scan.

Public Members

uint8_t *ssid

SSID of AP

uint8_t *bssid

MAC address of AP

uint8_t channel

channel, scan the specific channel

bool show_hidden

enable to scan AP whose SSID is hidden
**Chapter 2. API Reference**

```c
wifi_scan_type_t scan_type
    scan type, active or passive

wifi_scan_time_t scan_time
    scan time per channel

uint8_t home_chan_dwell_time
    time spent at home channel between scanning consecutive channels.
```

```c
struct wifi_he_ap_info_t
    Description of a WiFi AP HE Info.

    **Public Members**

    uint8_t bss_color
        an unsigned integer whose value is the BSS Color of the BSS corresponding to the AP

    uint8_t partial_bss_color
        indicate if an AID assignment rule based on the BSS color

    uint8_t bss_color_disabled
        indicate if the use of BSS color is disabled

    uint8_t bssid_index
        in M-BSSID set, identifies the nontransmitted BSSID
```

```c
struct wifi_ap_record_t
    Description of a WiFi AP.

    **Public Members**

    uint8_t bssid[6]
        MAC address of AP

    uint8_t ssid[33]
        SSID of AP

    uint8_t primary
        channel of AP

    wifi_second_chan_t second
        secondary channel of AP

    int8_t rssi
        signal strength of AP
```
wifi_auth_mode_t authmode
authmode of AP

wifi_cipher_type_t pairwise_cipher
pairwise cipher of AP

wifi_cipher_type_t group_cipher
group cipher of AP

wifi_ant_t ant
antenna used to receive beacon from AP

uint32_t phy_11b
bit: 0 flag to identify if 11b mode is enabled or not

uint32_t phy_11g
bit: 1 flag to identify if 11g mode is enabled or not

uint32_t phy_11n
bit: 2 flag to identify if 11n mode is enabled or not

uint32_t phy_lr
bit: 3 flag to identify if low rate is enabled or not

uint32_t phy_11ax
bit: 4 flag to identify if 11ax mode is enabled or not

uint32_t wps
bit: 5 flag to identify if WPS is supported or not

uint32_t ftm_responder
bit: 6 flag to identify if FTM is supported in responder mode

uint32_t ftm_initiator
bit: 7 flag to identify if FTM is supported in initiator mode

uint32_t reserved
bit: 8..31 reserved

wifi_country_t country
country information of AP

wifi_he_ap_info_t he_ap
HE AP info

struct wifi_scan_threshold_t
Structure describing parameters for a WiFi fast scan.
Public Members

`int8_t rssi`

The minimum rssi to accept in the fast scan mode

`wifi_auth_mode_t authmode`

The weakest authmode to accept in the fast scan mode. Note: In case this value is not set and password is set as per WPA2 standards (password length >= 8), it will be defaulted to WPA2 and device won’t connect to deprecated WEP/WPA networks. Please set authmode threshold as WIFI_AUTH_WEP/WIFI_AUTH_WPA_PSK to connect to WEP/WPA networks.

struct `wifi_pmf_config_t`

Configuration structure for Protected Management Frame

Public Members

`bool capable`

Deprecated variable. Device will always connect in PMF mode if other device also advertizes PMF capability.

`bool required`

Advertizes that Protected Management Frame is required. Device will not associate to non-PMF capable devices.

struct `wifi_ap_config_t`

Soft-AP configuration settings for the device.

Public Members

`uint8_t ssid[32]`

SSID of soft-AP. If ssid_len field is 0, this must be a Null terminated string. Otherwise, length is set according to ssid_len.

`uint8_t password[64]`

Password of soft-AP.

`uint8_t ssid_len`

Optional length of SSID field.

`uint8_t channel`

Channel of soft-AP

`wifi_auth_mode_t authmode`

Auth mode of soft-AP. Do not support AUTH_WEP, AUTH_WAPI_PSK and AUTH_OWE in soft-AP mode. When the auth mode is set to WPA2_PSK, WPA2_WPA3_PSK or WPA3_PSK, the pairwise cipher will be overwritten with WIFI_CIPHER_TYPE_CCMP.

`uint8_t ssid_hidden`

Broadcast SSID or not, default 0, broadcast the SSID
uint8_t \textit{max\_connection} \\
Max number of stations allowed to connect in

uint16_t \textit{beacon\_interval} \\
Beacon interval which should be multiples of 100. Unit: TU (time unit, 1 TU = 1024 us). Range: 100 ~ 60000. Default value: 100

\textit{wifi\_cipher\_type\_t pairwise\_cipher} \\
Pairwise cipher of SoftAP, group cipher will be derived using this. Cipher values are valid starting from WIFI_CIPHER_TYPE_TKIP, enum values before that will be considered as invalid and default cipher suites (TKIP+CCMP) will be used. Valid cipher suites in softAP mode are WIFI_CIPHER_TYPE_TKIP, WIFI_CIPHER_TYPE_CCMP and WIFI_CIPHER_TYPE_TKIP_CCMP.

bool \textit{ftm\_responder} \\
Enable FTM Responder mode

\textit{wifi\_pmf\_config\_t pmf\_cfg} \\
Configuration for Protected Management Frame

\textit{wifi\_sae\_pwe\_method\_t sae\_pwe\_h2e} \\
Configuration for SAE PWE derivation method

\textbf{Public Members}

uint8_t \textit{ssid}[32] \\
SSID of target AP.

uint8_t \textit{password}[64] \\
Password of target AP.

\textit{wifi\_scan\_method\_t scan\_method} \\
do all channel scan or fast scan

bool \textit{bssid\_set} \\
whether set MAC address of target AP or not. Generally, station_config.bssid_set needs to be 0; and it needs to be 1 only when users need to check the MAC address of the AP.

uint8_t \textit{bssid}[6] \\
MAC address of target AP

uint8_t \textit{channel} \\
channel of target AP. Set to 1~13 to scan starting from the specified channel before connecting to AP. If the channel of AP is unknown, set it to 0.
**uint16_t listen_interval**
Listen interval for ESP32 station to receive beacon when WIFI_PS_MAX_MODEM is set. Units: AP beacon intervals. Defaults to 3 if set to 0.

**wifi_sort_method_t sort_method**
sort the connect AP in the list by rssi or security mode

**wifi_scan_threshold_t threshold**
When scan_threshold is set, only APs which have an auth mode that is more secure than the selected auth mode and a signal stronger than the minimum RSSI will be used.

**wifi_pmf_config_t pmf_cfg**
Configuration for Protected Management Frame. Will be advertised in RSN Capabilities in RSN IE.

**uint32_t rm_enabled**
Whether Radio Measurements are enabled for the connection

**uint32_t btm_enabled**
Whether BSS Transition Management is enabled for the connection

**uint32_t mbo_enabled**
Whether MBO is enabled for the connection

**uint32_t ft_enabled**
Whether FT is enabled for the connection

**uint32_t owe_enabled**
Whether OWE is enabled for the connection

**uint32_t transition_disable**
Whether to enable transition disable feature

**uint32_t reserved**
Reserved for future feature set

**wifi_sae_pwe_method_t sae_pwe_h2e**
Configuration for SAE PWE derivation method

**wifi_sae_pk_mode_t sae_pk_mode**
Configuration for SAE-PK (Public Key) Authentication method

**uint8_t failure_retry_cnt**
Number of connection retries station will do before moving to next AP. scan_method should be set as WIFI_ALL_CHANNEL_SCAN to use this config. Note: Enabling this may cause connection time to increase incase best AP doesn’t behave properly.

**uint32_t he_dcm_set**
Whether DCM max.constellation for transmission and reception is set.
### Chapter 2. API Reference

#### uint32_t he_dcm_max_constellation_tx

Indicate the max constellation for DCM in TB PPDU the STA supported. 0: not supported. 1: BPSK, 2: QPSK, 3: 16-QAM. The default value is 3.

#### uint32_t he_dcm_max_constellation_rx

Indicate the max constellation for DCM in both Data field and HE-SIG-B field the STA supported. 0: not supported. 1: BPSK, 2: QPSK, 3: 16-QAM. The default value is 3.

#### uint32_t he_mcs9_enabled

Whether to support HE-MCS 0 to 9. The default value is 0.

#### uint32_t he_su_beamformee_disabled

Whether to disable support for operation as an SU beamformee.

#### uint32_t he_trig_su_bmforming_feedback_disabled

Whether to disable support the transmission of SU feedback in an HE TB sounding sequence.

#### uint32_t he_trig_mu_bmforming_partial_feedback_disabled

Whether to disable support the transmission of partial-bandwidth MU feedback in an HE TB sounding sequence.

#### uint32_t he_trig_cqi_feedback_disabled

Whether to disable support the transmission of CQI feedback in an HE TB sounding sequence.

#### uint32_t he_reserved

Reserved for future feature set

#### uint8_t sae_h2e_identifier[SAE_H2E_IDENTIFIER_LEN]

Password identifier for H2E. this needs to be null terminated string

```c
struct wifi_nan_config_t
```

NAN Discovery start configuration.

#### Public Members

```c
struct wifi_sta_info_t
```

Description of STA associated with AP.
Public Members

uint8_t mac[6]
    mac address

int8_t rssi
    current average rssi of sta connected

uint32_t phy_11b
    bit: 0 flag to identify if 11b mode is enabled or not

uint32_t phy_11g
    bit: 1 flag to identify if 11g mode is enabled or not

uint32_t phy_11n
    bit: 2 flag to identify if 11n mode is enabled or not

uint32_t phy_lr
    bit: 3 flag to identify if low rate is enabled or not

uint32_t phy_11ax
    bit: 4 flag to identify if 11ax mode is enabled or not

uint32_t is_mesh_child
    bit: 5 flag to identify mesh child

uint32_t reserved
    bit: 6..31 reserved

struct wifi_sta_list_t
    List of stations associated with the Soft-AP.

Public Members

wifi_sta_info_t sta[ESP_WIFI_MAX_CONN_NUM]
    station list

int num
    number of stations in the list (other entries are invalid)

struct vendor_ie_data_t
    Vendor Information Element header.
    The first bytes of the Information Element will match this header. Payload follows.

Public Members
**uint8_t element_id**
Should be set to WIFI_VENDOR_IE_ELEMENT_ID (0xDD)

**uint8_t length**
Length of all bytes in the element data following this field. Minimum 4.

**uint8_t vendor_oui[3]**
Vendor identifier (OUI).

**uint8_t vendor_oui_type**
Vendor-specific OUI type.

**uint8_t payload[0]**
Payload. Length is equal to value in ‘length’ field, minus 4.

**struct wifi_pkt_rx_ctrl_t**
Received packet radio metadata header, this is the common header at the beginning of all promiscuous mode RX callback buffers.

**Public Members**

**signed rssi**
Received Signal Strength Indicator (RSSI) of packet. unit: dBm

**unsigned rate**
PHY rate encoding of the packet. Only valid for non HT(11bg) packet

**unsigned __pad0__**
reserved

**unsigned sig_mode**
0: non HT(11bg) packet; 1: HT(11n) packet; 3: VHT(11ac) packet

**unsigned __pad1__**
reserved

**unsigned mcs**
Modulation Coding Scheme. If is HT(11n) packet, shows the modulation, range from 0 to 76(MSC0 ~ MCS76)

**unsigned cwb**
Channel Bandwidth of the packet. 0: 20MHz; 1: 40MHz

**unsigned __pad2__**
reserved

**unsigned smoothing**
reserved
unsigned not_sounding
    reserved
unsigned __pad3__
    reserved
unsigned aggregation
    Aggregation. 0: MPDU packet; 1: AMPDU packet
unsigned stbc
    Space Time Block Code(STBC). 0: non STBC packet; 1: STBC packet
unsigned fec_coding
    Flag is set for 11n packets which are LDPC
unsigned sgi
    Short Guide Interval(SGI). 0: Long GI; 1: Short GI
signed noise_floor
    noise floor of Radio Frequency Module(RF). unit: dBm
unsigned ampdu_cnt
    ampdu_cnt
unsigned channel
    primary channel on which this packet is received
unsigned secondary_channel
    secondary channel on which this packet is received. 0: none; 1: above; 2: below
unsigned __pad4__
    reserved
unsigned timestamp
    timestamp. The local time when this packet is received. It is precise only if modem sleep or light
    sleep is not enabled. unit: microsecond
unsigned __pad5__
    reserved
unsigned __pad6__
    reserved
unsigned ant
    antenna number from which this packet is received. 0: WiFi antenna 0; 1: WiFi antenna 1
unsigned sig_len
    length of packet including Frame Check Sequence(FCS)
unsigned __pad7__
    reserved

unsigned rx_state
    state of the packet. 0: no error; others: error numbers which are not public

struct wifi_promiscuous_pkt_t
    Payload passed to 'buf' parameter of promiscuous mode RX callback.

    Public Members

    wifi_pkt_rx_ctrl_t rx_ctrl
        metadata header

    uint8_t payload[0]
        Data or management payload. Length of payload is described by rx_ctrl.sig_len. Type of content determined by packet type argument of callback.

struct wifi_promiscuous_filter_t
    Mask for filtering different packet types in promiscuous mode.

    Public Members

    uint32_t filter_mask
        OR of one or more filter values WIFI_PROMIS_FILTER_*

struct wifi_csi_config_t
    Channel state information(CSI) configuration type.

    Public Members

    bool lltf_en
        enable to receive legacy long training field(lltf) data. Default enabled

    bool htltf_en
        enable to receive HT long training field(htltf) data. Default enabled

    bool stbc_htltf2_en
        enable to receive space time block code HT long training field(stbc-htltf2) data. Default enabled

    bool ltf_merge_en
        enable to generate htlft data by averaging lltf and ht_ltf data when receiving HT packet. Otherwise, use ht_ltf data directly. Default enabled

    bool channel_filter_en
        enable to turn on channel filter to smooth adjacent sub-carrier. Disable it to keep independence of adjacent sub-carrier. Default enabled
bool manu_scale

manually scale the CSI data by left shifting or automatically scale the CSI data. If set true, please set the shift bits. false: automatically. true: manually. Default false

uint8_t shift

manually left shift bits of the scale of the CSI data. The range of the left shift bits is 0~15

struct wifi_csi_info_t

  CSI data type.

  Public Members

    wifi_pkt_rx_ctrl_t rx_ctrl
    received packet radio metadata header of the CSI data

    uint8_t mac[6]
    source MAC address of the CSI data

    uint8_t dmac[6]
    destination MAC address of the CSI data

    bool first_word_invalid
    first four bytes of the CSI data is invalid or not

    int8_t *buf
    buffer of CSI data

    uint16_t len
    length of CSI data

struct wifi_ant_gpio_t

  WiFi GPIO configuration for antenna selection.

  Public Members

    uint8_t gpio_select
    Whether this GPIO is connected to external antenna switch

    uint8_t gpio_num
    The GPIO number that connects to external antenna switch

struct wifi_ant_gpio_config_t

  WiFi GPIOs configuration for antenna selection.

  Public Members
The configurations of GPIOs that connect to external antenna switch

```c
struct wifi_ant_gpio_t gpio_cfg[4]
```

```c
struct wifi_ant_config_t
Wi-Fi antenna configuration.

**Public Members**

```c
wifi_ant_mode_t rx_ant_mode
Wi-Fi antenna mode for receiving
```

```c
wifi_ant_mode_t rx_ant_default
Default antenna mode for receiving, it’s ignored if rx_ant_mode is not WIFI_ANT_MODE_AUTO
```

```c
wifi_ant_mode_t tx_ant_mode
Wi-Fi antenna mode for transmission, it can be set to WIFI_ANT_MODE_AUTO only if rx_ant_mode is set to WIFI_ANT_MODE_AUTO
```

```c
uint8_t enabled_ant0
Index (in antenna GPIO configuration) of enabled WIFI_ANT_MODE_ANT0
```

```c
uint8_t enabled_ant1
Index (in antenna GPIO configuration) of enabled WIFI_ANT_MODE_ANT1
```

```c
struct wifi_action_tx_req_t
Action Frame Tx Request.

**Public Members**

```c
wifi_interface_t ifx
Wi-Fi interface to send request to
```

```c
uint8_t dest_mac[6]
Destination MAC address
```

```c
bool no_ack
Indicates no ack required
```

```c
wifi_action_rx_cb_t rx_cb
Rx Callback to receive any response
```

```c
uint32_t data_len
Length of the appended Data
```

```c
uint8_t data[0]
Appended Data payload
```
struct wifi_ftm_initiator_cfg_t
  FTM Initiator configuration.

  Public Members

  uint8_t resp_mac[6]
    MAC address of the FTM Responder

  uint8_t channel
    Primary channel of the FTM Responder

  uint8_t frm_count
    No. of FTM frames requested in terms of 4 or 8 bursts (allowed values - 0(No pref), 16, 24, 32, 64)

  uint16_t burst_period
    Requested time period between consecutive FTM bursts in 100’s of milliseconds (0 - No pref)

struct wifi_beacon_monitor_config_t
  WiFi beacon monitor parameter configuration.

  Public Members

  bool enable
    Enable or disable beacon monitor

  uint8_t loss_timeout
    Beacon lost timeout

  uint8_t loss_threshold
    Maximum number of consecutive lost beacons allowed

  uint8_t delta_intr_early
    Delta early time for RF PHY on

  uint8_t delta_loss_timeout
    Delta timeout time for RF PHY off

struct wifi_nan_publish_cfg_t
  NAN Publish service configuration parameters.

  Public Members

  char service_name[ESP_WIFI_MAX_SVC_NAME_LEN]
    Service name identifier
Chapter 2. API Reference

```c
wifimnanservicetype_t type
    Service type

char matching_filter[ESP_WIFI_MAX_FILTER_LEN]
    Comma separated filters for filtering services

char svc_info[ESP_WIFI_MAX_SVC_INFO_LEN]
    Service info shared in Publish frame

uint8_t single_replied_event
    Give single Replied event or every time

uint8_t datapath_reqd
    NAN Datapath required for the service

uint8_t reserved
    Reserved
```

```c
struct wifi_nan_subscribe_cfg_t
    NAN Subscribe service configuration parameters.
```

**Public Members**

```c
char service_name[ESP_WIFI_MAX_SVC_NAME_LEN]
    Service name identifier

wifimnanservicetype_t type
    Service type

char matching_filter[ESP_WIFI_MAX_FILTER_LEN]
    Comma separated filters for filtering services

char svc_info[ESP_WIFI_MAX_SVC_INFO_LEN]
    Service info shared in Subscribe frame

uint8_t single_match_event
    Give single Match event or every time

uint8_t reserved
    Reserved
```

```c
struct wifi_nan_followup_params_t
    NAN Follow-up parameters.
```

**Public Members**
Chapter 2. API Reference

```c
uint8_t inst_id
    Own service instance id

uint8_t peer_inst_id
    Peer’s service instance id

uint8_t peer_mac[6]
    Peer’s MAC address

cchar svc_info[ESP_WIFI_MAX_SVC_INFO_LEN]
    Service info (or message) to be shared
```

```c
struct wifi_nan_datapath_req_t
    NAN Datapath Request parameters.
```

**Public Members**

```c
uint8_t pub_id
    Publisher’s service instance id

uint8_t peer_mac[6]
    Peer’s MAC address

bool confirm_required
    NDP Confirm frame required
```

```c
struct wifi_nan_datapath_resp_t
    NAN Datapath Response parameters.
```

**Public Members**

```c
bool accept
    True - Accept incoming NDP, False - Reject it

uint8_t ndp_id
    NAN Datapath Identifier

uint8_t peer_mac[6]
    Peer’s MAC address
```

```c
struct wifi_nan_datapath_end_req_t
    NAN Datapath End parameters.
```

**Public Members**
uint8_t ndp_id
    NAN Datapath Identifier

uint8_t peer_mac[6]
    Peer’s MAC address

struct wifi_event_sta_scan_done_t
    Argument structure for WIFI_EVENT_SCAN_DONE event

Public Members

uint32_t status
    status of scanning APs: 0 — success, 1 - failure

uint8_t number
    number of scan results

uint8_t scan_id
    scan sequence number, used for block scan

struct wifi_event_sta_connected_t
    Argument structure for WIFI_EVENT_STA_CONNECTED event

Public Members

uint8_t ssid[32]
    SSID of connected AP

uint8_t ssid_len
    SSID length of connected AP

uint8_t bssid[6]
    BSSID of connected AP

uint8_t channel
    channel of connected AP

wifi_auth_mode_t authmode
    authentication mode used by AP

uint16_t aid
    authentication id assigned by the connected AP

struct wifi_event_sta_disconnected_t
    Argument structure for WIFI_EVENT_STA_DISCONNECTED event

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Public Members

```c
uint8_t ssid[32]
    SSID of disconnected AP
```

```c
uint8_t ssid_len
    SSID length of disconnected AP
```

```c
uint8_t bssid[6]
    BSSID of disconnected AP
```

```c
uint8_t reason
    reason of disconnection
```

```c
int8_t rssi
    rssi of disconnection
```

```c
struct wifi_event_sta_authmode_change_t
    Argument structure for WIFI_EVENT_STA_AUTHMODE_CHANGE event
```

Public Members

```c
wifi_auth_mode_t old_mode
    the old auth mode of AP
```

```c
wifi_auth_mode_t new_mode
    the new auth mode of AP
```

```c
struct wifi_event_sta_wps_er_pin_t
    Argument structure for WIFI_EVENT_STA_WPS_ER_PIN event
```

Public Members

```c
uint8_t pin_code[8]
    PIN code of station in enrollee mode
```

```c
struct wifi_event_sta_wps_er_success_t
    Argument structure for WIFI_EVENT_STA_WPS_ER_SUCCESS event
```

Public Members

```c
uint8_t ap_cred_cnt
    Number of AP credentials received
```

```c
uint8_t ssid[MAX_SSID_LEN]
    SSID of AP
```
uint8_t passphrase[MAX_PASSPHRASE_LEN]
    Passphrase for the AP

struct wifi_event_sta_wps_er_success_t::[anonymous] ap_cred[MAX_WPS_AP_CRED]
    All AP credentials received from WPS handshake

struct wifi_event_ap_staconnected_t
    Argument structure for WIFI_EVENT_AP_STACONNECTED event

Public Members

uint8_t_t mac[6]
    MAC address of the station connected to Soft-AP

uint8_t_t aid
    the aid that soft-AP gives to the station connected to

bool is_mesh_child
    flag to identify mesh child

struct wifi_event_ap_stadisconnected_t
    Argument structure for WIFI_EVENT_AP_STADISCONNECTED event

Public Members

uint8_t_t mac[6]
    MAC address of the station disconnects to soft-AP

uint8_t_t aid
    the aid that soft-AP gave to the station disconnects to

bool is_mesh_child
    flag to identify mesh child

uint8_t_t reason
    reason of disconnection

struct wifi_event_ap_probe_req_rx_t
    Argument structure for WIFI_EVENT_AP_PROBEREQUEST event

Public Members

int rssi
    Received probe request signal strength
uint8_t mac[6]
    MAC address of the station which send probe request

struct wifi_event_bss_rssi_low_t
    Argument structure for WIFI_EVENT_STA_BSS_RSSI_LOW event

    Public Members

        int32_t rssi
            RSSI value of bss

struct wifi_ftm_report_entry_t
    Argument structure for

    Public Members

        uint8_t dlog_token
            Dialog Token of the FTM frame

        int8_t rssi
            RSSI of the FTM frame received

        uint32_t rtt
            Round Trip Time in pSec with a peer

        uint64_t t1
            Time of departure of FTM frame from FTM Responder in pSec

        uint64_t t2
            Time of arrival of FTM frame at FTM Initiator in pSec

        uint64_t t3
            Time of departure of ACK from FTM Initiator in pSec

        uint64_t t4
            Time of arrival of ACK at FTM Responder in pSec

struct wifi_event_ftm_report_t
    Argument structure for WIFI_EVENT_FTM_REPORT event

    Public Members

        uint8_t peer_mac[6]
            MAC address of the FTM Peer
**wifi_ftm_status_t** `status`  
Status of the FTM operation

uint32_t `rtt_raw`  
Raw average Round-Trip-Time with peer in Nano-Seconds

uint32_t `rtt_est`  
Estimated Round-Trip-Time with peer in Nano-Seconds

uint32_t `dist_est`  
Estimated one-way distance in Centi-Meters

**wifi_ftm_report_entry_t** `*ftm_report_data`  
Pointer to FTM Report with multiple entries, should be freed after use

uint8_t `ftm_report_num_entries`  
Number of entries in the FTM Report data

**Public Members**

**wifi_interface_t** `ifx`  
WiFi interface to send request to

uint32_t `context`  
Context to identify the request

uint8_t `da[6]`  
Destination MAC address

uint8_t `status`  
Status of the operation

**struct wifi_event_action_tx_status_t**  
Argument structure for WIFI_EVENT_ACTION_TX_STATUS event

**Public Members**

uint32_t `context`  
Context to identify the request

**struct wifi_event_roc_done_t**  
Argument structure for WIFI_EVENT_ROC_DONE event

**Public Members**

**struct wifi_event_ap_wps_rg_pin_t**  
Argument structure for WIFI_EVENT_AP_WPS_RG_PIN event
Chapter 2. API Reference

Public Members

```c
uint8_t pin_code[8]
```
PIN code of station in enrollee mode

```c
struct wifi_event_ap_wps_rg_fail_reason_t
```
Argument structure for WIFI_EVENT_AP_WPS_RG_FAILED event

Public Members

```c
wps_fail_reason_t reason
```
WPS failure reason wps_fail_reason_t

```c
uint8_t peer_macaddr[6]
```
Enrollee mac address

```c
struct wifi_event_ap_wps_rg_success_t
```
Argument structure for WIFI_EVENT_AP_WPS_RG_SUCCESS event

Public Members

```c
uint8_t peer_macaddr[6]
```
Enrollee mac address

```c
struct wifi_event_nan_svc_match_t
```
Argument structure for WIFI_EVENT_NAN_SVC_MATCH event

Public Members

```c
uint8_t subscribe_id
```
Subscribe Service Identifier

```c
uint8_t publish_id
```
Publish Service Identifier

```c
uint8_t pub_if_mac[6]
```
NAN Interface MAC of the Publisher

```c
bool update_pub_id
```
Indicates whether publisher’s service ID needs to be updated

```c
struct wifi_event_nan_replied_t
```
Argument structure for WIFI_EVENT_NAN_REPLIED event
Public Members

`uint8_t publish_id`
- Publish Service Identifier

`uint8_t subscribe_id`
- Subscribe Service Identifier

`uint8_t sub_if_mac[6]`
- NAN Interface MAC of the Subscriber

`struct wifi_event_nan_receive_t`
- Argument structure for WIFI_EVENT_NAN_RECEIVE event

Public Members

`uint8_t inst_id`
- Our Service Identifier

`uint8_t peer_inst_id`
- Peer’s Service Identifier

`uint8_t peer_if_mac[6]`
- Peer’s NAN Interface MAC

`uint8_t peer_svc_info[ESP_WIFI_MAX_SVC_INFO_LEN]`
- Peer Service Info

`struct wifi_event_ndp_indication_t`
- Argument structure for WIFI_EVENT_NDP_INDICATION event

Public Members

`uint8_t publish_id`
- Publish Id for NAN Service

`uint8_t ndp_id`
- NDP instance id

`uint8_t peer_nmi[6]`
- Peer’s NAN Management Interface MAC

`uint8_t peer_ndi[6]`
- Peer’s NAN Data Interface MAC

`uint8_t svc_info[ESP_WIFI_MAX_SVC_INFO_LEN]`
- Service Specific Info
struct wifi_event_ndp_confirm_t
    Argument structure for WIFI_EVENT_NDPCONFIRM event

Public Members

    uint8_t status
        NDP status code
    uint8_t ndp_id
        NDP instance id
    uint8_t peer_nmi[6]
        Peer’s NAN Management Interface MAC
    uint8_t peer_ndi[6]
        Peer’s NAN Data Interface MAC
    uint8_t own_ndi[6]
        Own NAN Data Interface MAC
    uint8_t svc_info[ESP_WIFI_MAX_SVC_INFO_LEN]
        Service Specific Info

struct wifi_event_ndp_terminated_t
    Argument structure for WIFI_EVENT_NDP_TERMINATED event

Public Members

    uint8_t reason
        Termination reason code
    uint8_t ndp_id
        NDP instance id
    uint8_t init_ndi[6]
        Initiator’s NAN Data Interface MAC

Macros

    WIFI_OFFCHAN_TX_REQ
    WIFI_OFFCHAN_TX_CANCEL
    WIFI_ROC_REQ
    WIFI_ROC_CANCEL
WIFI_PROTOCOL_11B

WIFI_PROTOCOL_11G

WIFI_PROTOCOL_11N

WIFI_PROTOCOL_LR

WIFI_PROTOCOL_11AX

SAE_H2E_IDENTIFIER_LEN

ESP_WIFI_MAX_CONN_NUM
max number of stations which can connect to ESP32/ESP32S3/ESP32S2 soft-AP

WIFI_VENDOR_IE_ELEMENT_ID

WIFI_PROMIS_FILTER_MASK_ALL
filter all packets

WIFI_PROMIS_FILTER_MASK_MGMT
filter the packets with type of WIFI_PKT_MGMT

WIFI_PROMIS_FILTER_MASK_CTRL
filter the packets with type of WIFI_PKT_CTRL

WIFI_PROMIS_FILTER_MASK_DATA
filter the packets with type of WIFI_PKT_DATA

WIFI_PROMIS_FILTER_MASK_MISC
filter the packets with type of WIFI_PKT_MISC

WIFI_PROMIS_FILTER_MASK_DATA_MPDU
filter the MPDU which is a kind of WIFI_PKT_DATA

WIFI_PROMIS_FILTER_MASK_DATA_AMPDU
filter the AMPDU which is a kind of WIFI_PKT_DATA

WIFI_PROMIS_FILTER_MASK_FCSFAIL
filter the FCS failed packets, do not open it in general

WIFI_PROMIS_CTRL_FILTER_MASK_ALL
filter all control packets

WIFI_PROMIS_CTRL_FILTER_MASK_WRAPPER
filter the control packets with subtype of Control Wrapper
WIFI_PROMIS_CTRL_FILTER_MASK_BAR
    filter the control packets with subtype of Block Ack Request

WIFI_PROMIS_CTRL_FILTER_MASK_BA
    filter the control packets with subtype of Block Ack

WIFI_PROMIS_CTRL_FILTER_MASK_PSPOLL
    filter the control packets with subtype of PS-Poll

WIFI_PROMIS_CTRL_FILTER_MASK_RTS
    filter the control packets with subtype of RTS

WIFI_PROMIS_CTRL_FILTER_MASK_CTS
    filter the control packets with subtype of CTS

WIFI_PROMIS_CTRL_FILTER_MASK_ACK
    filter the control packets with subtype of ACK

WIFI_PROMIS_CTRL_FILTER_MASK_CFEND
    filter the control packets with subtype of CF-END

WIFI_PROMIS_CTRL_FILTER_MASK_CFENDACK
    filter the control packets with subtype of CF-END+CF-ACK

WIFI_EVENT_MASK_ALL
    mask all WiFi events

WIFI_EVENT_MASK_NONE
    mask none of the WiFi events

WIFI_EVENT_MASK_AP_PROBEREQRECVED
    mask SYSTEM_EVENT_AP_PROBEREQRECVED event

ESP_WIFI_NAN_MAX_SVC_SUPPORTED

ESP_WIFI_NAN_DATAPATH_MAX_PEERS

ESP_WIFI_NDP_ROLE_INITIATOR

ESP_WIFI_NDP_ROLE_RESPONDER

ESP_WIFI_MAX_SVC_NAME_LEN

ESP_WIFI_MAX_FILTER_LEN

ESP_WIFI_MAX_SVC_INFO_LEN
MAX_SSID_LEN
MAX_PASSPHRASE_LEN
MAX_WPS_AP_CRED
WIFI_STATIS_BUFFER
WIFI_STATIS_RXTX
WIFI_STATIS_HW
WIFI_STATIS_DIAG
WIFI_STATIS_PS
WIFI_STATIS_ALL

Type Definitions

typedef int (*wifi_action_rx_cb_t)(uint8_t*hdr,uint8_t*payload,size_tlen,uint8_tchannel)

The Rx callback function of Action Tx operations.

- **Param hdr**: pointer to the IEEE 802.11 Header structure
- **Param payload**: pointer to the Payload following 802.11 Header
- **Param len**: length of the Payload
- **Param channel**: channel number the frame is received on

Enumerations

enum wifi_mode_t

- **Value**:
  - **enumerator WIFI_MODE_NULL**: null mode
  - **enumerator WIFI_MODE_STA**: WiFi station mode
  - **enumerator WIFI_MODE_AP**: WiFi soft-AP mode
  - **enumerator WIFI_MODE_APSTA**: WiFi station + soft-AP mode
  - **enumerator WIFI_MODE_NAN**: WiFi NAN mode
  - **enumerator WIFI_MODE_MAX**:
Chapter 2. API Reference

```c
enum wifi_interface_t

   Values:

   enumerator WIFI_IF_STA

   enumerator WIFI_IF_AP

   enumerator WIFI_IF_NAN

   enumerator WIFI_IF_MAX

enum wifi_country_policy_t

   Values:

   enumerator WIFI_COUNTRY_POLICY_AUTO
       Country policy is auto, use the country info of AP to which the station is connected

   enumerator WIFI_COUNTRY_POLICY_MANUAL
       Country policy is manual, always use the configured country info

enum wifi_auth_mode_t

   Values:

   enumerator WIFI_AUTH_OPEN
       authenticate mode: open

   enumerator WIFI_AUTH_WEP
       authenticate mode: WEP

   enumerator WIFI_AUTH_WPA_PSK
       authenticate mode: WPA_PSK

   enumerator WIFI_AUTH_WPA2_PSK
       authenticate mode: WPA2_PSK

   enumerator WIFI_AUTH_WPA_WPA2_PSK
       authenticate mode: WPA_WPA2_PSK

   enumerator WIFI_AUTH_ENTERPRISE
       authenticate mode: WiFi EAP security

   enumerator WIFI_AUTH_WPA2.ENTERPRISE
       authenticate mode: WiFi EAP security

   enumerator WIFI_AUTH_WPA3_PSK
       authenticate mode: WPA3_PSK
```

Espressif Systems 924 Release v5.1.2
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enumerator WiFi_AUTH_WPA2_WPA3_PSK
   authenticate mode: WPA2_WPA3_PSK

enumerator WiFi_AUTH_WAPI_PSK
   authenticate mode: WAPI_PSK

enumerator WiFi_AUTH_OWE
   authenticate mode: OWE

enumerator WiFi_AUTH_WPA3_ENT_192
   authenticate mode: WPA3_ENT_SUITE_B_192_BIT

enumerator WiFi_AUTH_MAX

enum wifi_err_reason_t

   Values:

enumerator WiFi_REASON_UNSPECIFIED
enumerator WiFi_REASON_AUTH_EXPIRE
enumerator WiFi_REASON_AUTH_LEAVE
enumerator WiFi_REASON_ASSOC_EXPIRE
enumerator WiFi_REASON_ASSOC_TOOMANY
enumerator WiFi_REASON_NOT_AUTHED
enumerator WiFi_REASON_NOT_ASSOCED
enumerator WiFi_REASON_ASSOC_LEAVE
enumerator WiFi_REASON_ASSOC_NOT_AUTHED
enumerator WiFi_REASON_DISASSOC_PWRCAP_BAD
enumerator WiFi_REASON_DISASSOC_SUPCHAN_BAD
enumerator WiFi_REASON_BSS_TRANSITION_DISASSOC
enumerator WiFi_REASON_IE_INVALID
enumerator WiFi_REASON_MIC_FAILURE
enumerator WiFi_REASON_4WAY_HANDSHAKE_TIMEOUT
enumerator WIFI_REASON_GROUP_KEY_UPDATE_TIMEOUT
enumerator WIFI_REASON_IE_IN_4WAY_DIFFERS
enumerator WIFI_REASON_GROUP_CIPHER_INVALID
enumerator WIFI_REASON_PAIRWISE_CIPHER_INVALID
enumerator WIFI_REASON_AKMP_INVALID
enumerator WIFI_REASON_UNSUPP_RSN_IE_VERSION
enumerator WIFI_REASON_INVALID_RSN_IE_CAP
enumerator WIFI_REASON_802_1X_AUTH_FAILED
enumerator WIFI_REASON_CIPHER_SUITE_REJECTED
enumerator WIFI_REASON_TDLS_PEER_UNREACHABLE
enumerator WIFI_REASON_TDLS_UNSPECIFIED
enumerator WIFI_REASON_SSP_REQUESTED_DISASSOC
enumerator WIFI_REASON_NO_SSP_ROAMING AGREEMENT
enumerator WIFI_REASON_BAD_CIPHER_OR_AKM
enumerator WIFI_REASON_NOT_AUTHORIZED_THIS_LOCATION
enumerator WIFI_REASON_SERVICE_CHANGE_PERCLUDES_TS
enumerator WIFI_REASON_UNSPECIFIED_QOS
enumerator WIFI_REASON_NOT_ENOUGH_BANDWIDTH
enumerator WIFI_REASON_MISSING_ACKS
enumerator WIFI_REASON_EXCEEDED_TXOP
enumerator WIFI_REASON_STA_LEAVING
enumerator WIFI_REASON_END_BA
enumerator WIFI_REASON_UNKNOWN_BA
enumerator WIFI_REASON_TIMEOUT
enumerator WIFI_REASON_PEER_INITIATED
enumerator WIFI_REASON_AP_INITIATED
enumerator WIFI_REASON_INVALID_FT_ACTION_FRAME_COUNT
enumerator WIFI_REASON_INVALID_PMKID
enumerator WIFI_REASON_INVALID_MDE
enumerator WIFI_REASON_INVALID_FTE
enumerator WIFI_REASON_TRANSMISSION_LINK_ESTABLISH_FAILED
enumerator WIFI_REASON_ALTERATIVE_CHANNEL_OCCUPIED
enumerator WIFI_REASON_BEACON_TIMEOUT
enumerator WIFI_REASON_NO_AP_FOUND
enumerator WIFI_REASON_AUTH_FAIL
enumerator WIFI_REASON_ASSOC_FAIL
enumerator WIFI_REASON_HANDSHAKE_TIMEOUT
enumerator WIFI_REASON_CONNECTION_FAIL
enumerator WIFI_REASON_AP_TSF_RESET
enumerator WIFI_REASON_ROAMING
enumerator WIFI_REASON_ASSOC_COMEBACK_TIME_TOO_LONG
enumerator WIFI_REASON_SA_QUERY_TIMEOUT

enum wifi_second_chan_t

Values:

enumerator WIFI_SECOND_CHAN_NONE
    the channel width is HT20

enumerator WIFI_SECOND_CHAN_ABOVE
    the channel width is HT40 and the secondary channel is above the primary channel
enumerator WIFI_SECOND_CHAN_BELOW
    the channel width is HT40 and the secondary channel is below the primary channel

double wifi_scan_type_t
    Values:
        enumerator WIFI_SCAN_TYPE_ACTIVE
            active scan
        enumerator WIFI_SCAN_TYPE_PASSIVE
            passive scan

double wifi_cipher_type_t
    Values:
        enumerator WIFI_CIPHER_TYPE_NONE
            the cipher type is none
        enumerator WIFI_CIPHER_TYPE_WEP40
            the cipher type is WEP40
        enumerator WIFI_CIPHER_TYPE_WEP104
            the cipher type is WEP104
        enumerator WIFI_CIPHER_TYPE_TKIP
            the cipher type is TKIP
        enumerator WIFI_CIPHER_TYPE_CCMP
            the cipher type is CCMP
        enumerator WIFI_CIPHER_TYPE_TKIP_CCMP
            the cipher type is TKIP and CCMP
        enumerator WIFI_CIPHER_TYPE_AES_CMAC128
            the cipher type is AES-CMAC-128
        enumerator WIFI_CIPHER_TYPE_SMS4
            the cipher type is SMS4
        enumerator WIFI_CIPHER_TYPE_GCMP
            the cipher type is GCMP
        enumerator WIFI_CIPHER_TYPE_GCMP256
            the cipher type is GCMP-256
        enumerator WIFI_CIPHER_TYPE_AES_GMAC128
            the cipher type is AES-GMAC-128
enumerator WiFi_CIPHER_TYPE_AES_GMAC256
  the cipher type is AES-GMAC-256

enumerator WiFi_CIPHER_TYPE_UNKNOWN
  the cipher type is unknown

enum wifi_ant_t
  WiFi antenna.
  Values:

  enumerator WIFI_ANT_ANT0
    WiFi antenna 0

  enumerator WIFI_ANT_ANT1
    WiFi antenna 1

  enumerator WIFI_ANT_MAX
    Invalid WiFi antenna

enum wifi_scan_method_t
  Values:

  enumerator WIFI_FAST_SCAN
    Do fast scan, scan will end after find SSID match AP

  enumerator WIFI_ALL_CHANNEL_SCAN
    All channel scan, scan will end after scan all the channel

enum wifi_sort_method_t
  Values:

  enumerator WIFI_CONNECT_AP_BY_SIGNAL
    Sort match AP in scan list by RSSI

  enumerator WIFI_CONNECT_AP_BY_SECURITY
    Sort match AP in scan list by security mode

enum wifi_ps_type_t
  Values:

  enumerator WIFI_PS_NONE
    No power save

  enumerator WIFI_PS_MIN_MODEM
    Minimum modem power saving. In this mode, station wakes up to receive beacon every DTIM period

  enumerator WIFI_PS_MAX_MODEM
    Maximum modem power saving. In this mode, interval to receive beacons is determined by the listen_interval parameter in wifi_sta_config_t
enum wifi_bandwidth_t
Values:

enumerator WIFI_BW_HT20
enumerator WIFI_BW_HT40

enum wifi_sae_pwe_method_t
Configuration for SAE PWE derivation
Values:

enumerator WPA3_SAE_PWE_UNSPECIFIED
enumerator WPA3_SAE_PWE_HUNT_AND_PECK
enumerator WPA3_SAE_PWE_HASH_TO_ELEMENT
enumerator WPA3_SAE_PWE_BOTH

enum wifi_sae_pk_mode_t
Configuration for SAE-PK
Values:

enumerator WPA3_SAE_PK_MODE_AUTOMATIC
enumerator WPA3_SAE_PK_MODE_ONLY
enumerator WPA3_SAE_PK_MODE_DISABLED

enum wifi_storage_t
Values:

enumerator WIFI_STORAGE_FLASH
    all configuration will store in both memory and flash
enumerator WIFI_STORAGE_RAM
    all configuration will only store in the memory

enum wifi_vendor_ie_type_t
Vendor Information Element type.
Determines the frame type that the IE will be associated with.
Values:

enumerator WIFI_VND_IE_TYPE_BEACON
enumerator WIFI_VND_IE_TYPE_PROBE_REQ
enumerator WIFI_VND_IE_TYPE_PROBE_RESP
enumerator WIFI_VND_IE_TYPE_ASSOC_REQ
enumerator WIFI_VND_IE_TYPE_ASSOC_RESP

enum wifi_vendor_ie_id_t
Vendor Information Element index.
Each IE type can have up to two associated vendor ID elements.
Values:
enumerator WIFI_VND_IE_ID_0
enumerator WIFI_VND_IE_ID_1

enum wifi_phy_mode_t
Operation Phymode.
Values:
enumerator WIFI_PHY_MODE_LR
PHY mode for Low Rate
enumerator WIFI_PHY_MODE_11B
PHY mode for 11b
enumerator WIFI_PHY_MODE_11G
PHY mode for 11g
enumerator WIFI_PHY_MODE_HT20
PHY mode for Bandwidth HT20
enumerator WIFI_PHY_MODE_HT40
PHY mode for Bandwidth HT40
enumerator WIFI_PHY_MODE_HE20
PHY mode for Bandwidth HE20

enum wifi_promiscuous_pkt_type_t
Promiscuous frame type.
Passed to promiscuous mode RX callback to indicate the type of parameter in the buffer.
Values:
enumerator WIFI_PKT_MGMT
Management frame, indicates ‘buf’ argument is wifi_promiscuous_pkt_t
enumerator WIFI_PKT_CTRL
Control frame, indicates ‘buf’ argument is wifi_promiscuous_pkt_t
enumerator WiFi_PKT_DATA
    Data frame, indicates ‘buf’ argument is wifi_promiscuous_pkt_t

everenumerator WiFi_PKT_MISC
    Other type, such as MIMO etc. ‘buf’ argument is wifi_promiscuous_pkt_t but the payload is zero length.

eenum wifi_ant_mode_t
    WiFi antenna mode.
    Values:

    enumeraton WiFi_ANT_MODE_ANT0
        Enable WiFi antenna 0 only

    enumeraton WiFi_ANT_MODE_ANT1
        Enable WiFi antenna 1 only

    enumeraton WiFi_ANT_MODE_AUTO
        Enable WiFi antenna 0 and 1, automatically select an antenna

    enumeraton WiFi_ANT_MODE_MAX
        Invalid WiFi enabled antenna

eenum wifi_nan_service_type_t
    NAN Services types.
    Values:

    enumeraton NAN_PUBLISH_SOLICITED
        Send unicast Publish frame to Subscribers that match the requirement

    enumeraton NAN_PUBLISH_UNSOLICITED
        Send broadcast Publish frames in every Discovery Window(DW)

    enumeraton NAN_SUBSCRIBE_ACTIVE
        Send broadcast Subscribe frames in every DW

    enumeraton NAN_SUBSCRIBE_PASSIVE
        Passively listens to Publish frames

eenum wifi_phy_rate_t
    WiFi PHY rate encodings.
    Values:

    enumeraton WiFi_PHY_RATE_1M_L
        1 Mbps with long preamble

    enumeraton WiFi_PHY_RATE_2M_L
        2 Mbps with long preamble
<table>
<thead>
<tr>
<th>Enumerator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIFI_PHY_RATE_5M_L</td>
<td>5.5 Mbps with long preamble</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_11M_L</td>
<td>11 Mbps with long preamble</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_2M_S</td>
<td>2 Mbps with short preamble</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_5M_S</td>
<td>5.5 Mbps with short preamble</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_11M_S</td>
<td>11 Mbps with short preamble</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_48M</td>
<td>48 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_24M</td>
<td>24 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_12M</td>
<td>12 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_6M</td>
<td>6 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_54M</td>
<td>54 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_36M</td>
<td>36 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_18M</td>
<td>18 Mbps</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_9M</td>
<td>9 Mbps rate table and guard interval information for each MCS rate</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_MCS0_LGI</td>
<td>MCS0 with long GI</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_MCS1_LGI</td>
<td>MCS1 with long GI</td>
</tr>
<tr>
<td>WIFI_PHY_RATE_MCS2_LGI</td>
<td>MCS2 with long GI</td>
</tr>
</tbody>
</table>
enumerator WIFI_PHY_RATE_MCS3_LGI
MCS3 with long GI

enumerator WIFI_PHY_RATE_MCS4_LGI
MCS4 with long GI

enumerator WIFI_PHY_RATE_MCS5_LGI
MCS5 with long GI

enumerator WIFI_PHY_RATE_MCS6_LGI
MCS6 with long GI

enumerator WIFI_PHY_RATE_MCS7_LGI
MCS7 with long GI

enumerator WIFI_PHY_RATE_MCS0_SGI
MCS0 with short GI

enumerator WIFI_PHY_RATE_MCS1_SGI
MCS1 with short GI

enumerator WIFI_PHY_RATE_MCS2_SGI
MCS2 with short GI

enumerator WIFI_PHY_RATE_MCS3_SGI
MCS3 with short GI

enumerator WIFI_PHY_RATE_MCS4_SGI
MCS4 with short GI

enumerator WIFI_PHY_RATE_MCS5_SGI
MCS5 with short GI

enumerator WIFI_PHY_RATE_MCS6_SGI
MCS6 with short GI

enumerator WIFI_PHY_RATE_MCS7_SGI
MCS7 with short GI

enumerator WIFI_PHY_RATE_LORA_250K
250 Kbps

enumerator WIFI_PHY_RATE_LORA_500K
500 Kbps

enumerator WIFI_PHY_RATE_MAX
enum wifi_event_t
    WiFi event declarations

Values:

enumerator WIFI_EVENT_WIFI_READY
    WiFi ready

enumerator WIFI_EVENT_SCAN_DONE
    Finished scanning AP

enumerator WIFI_EVENT_STA_START
    Station start

enumerator WIFI_EVENT_STA_STOP
    Station stop

enumerator WIFI_EVENT_STA_CONNECTED
    Station connected to AP

enumerator WIFI_EVENT_STA_DISCONNECTED
    Station disconnected from AP

enumerator WIFI_EVENT_STA_AUTHMODE_CHANGE
    the auth mode of AP connected by device’s station changed

enumerator WIFI_EVENT_STA_WPS_ER_SUCCESS
    Station wps succeeds in enrollee mode

enumerator WIFI_EVENT_STA_WPS_ER_FAILED
    Station wps fails in enrollee mode

enumerator WIFI_EVENT_STA_WPS_ER_TIMEOUT
    Station wps timeout in enrollee mode

enumerator WIFI_EVENT_STA_WPS_ER_PIN
    Station wps pin code in enrollee mode

enumerator WIFI_EVENT_STA_WPS_ER_PBC_OVERLAP
    Station wps overlap in enrollee mode

enumerator WIFI_EVENT_AP_START
    Soft-AP start

enumerator WIFI_EVENT_AP_STOP
    Soft-AP stop

enumerator WIFI_EVENT_AP_STACONNECTED
    a station connected to Soft-AP
enumerator WIFI_EVENT_AP_STADISCONNECTED
   a station disconnected from Soft-AP

enumerator WIFI_EVENT_AP_PROBEREQRECVED
   Receive probe request packet in soft-AP interface

enumerator WIFI_EVENT_FTM_REPORT
   Receive report of FTM procedure

enumerator WIFI_EVENT_STA_BSS_RSSI_LOW
   AP’s RSSI crossed configured threshold

enumerator WIFI_EVENT_ACTION_TX_STATUS
   Status indication of Action Tx operation

enumerator WIFI_EVENT_ROC_DONE
   Remain-on-Channel operation complete

enumerator WIFI_EVENT_STA_BEACON_TIMEOUT
   Station beacon timeout

enumerator WIFI_EVENT_CONNECTIONLESS_MODULE_WAKE_INTERVAL_START
   Connectionless module wake interval start

enumerator WIFI_EVENT_AP_WPS_RG_SUCCESS
   Soft-AP wps succeeds in registrar mode

enumerator WIFI_EVENT_AP_WPS_RG_FAILED
   Soft-AP wps fails in registrar mode

enumerator WIFI_EVENT_AP_WPS_RG_TIMEOUT
   Soft-AP wps timeout in registrar mode

enumerator WIFI_EVENT_AP_WPS_RG_PIN
   Soft-AP wps pin code in registrar mode

enumerator WIFI_EVENT_AP_WPS_RG_PBC_OVERLAP
   Soft-AP wps overlap in registrar mode

enumerator WIFI_EVENT_ITWT_SETUP
   iTWT setup

enumerator WIFI_EVENT_ITWT_TEARDOWN
   iTWT teardown

enumerator WIFI_EVENT_ITWT_PROBE
   iTWT probe
enumerator `WIFI_EVENT_ITWT_SUSPEND`
   iTWT suspend

enumerator `WIFI_EVENT_NAN_STARTED`
   NAN Discovery has started

enumerator `WIFI_EVENT_NAN_STOPPED`
   NAN Discovery has stopped

enumerator `WIFI_EVENT_NAN_SVC_MATCH`
   NAN Service Discovery match found

enumerator `WIFI_EVENT_NAN_REPLIED`
   Replied to a NAN peer with Service Discovery match

enumerator `WIFI_EVENT_NAN_RECEIVE`
   Received a Follow-up message

enumerator `WIFI_EVENT_NDP_INDICATION`
   Received NDP Request from a NAN Peer

enumerator `WIFI_EVENT_NDP_CONFIRM`
   NDP Confirm Indication

enumerator `WIFI_EVENT_NDP_TERMINATED`
   NAN Datapath terminated indication

enumerator `WIFI_EVENT_MAX`
   Invalid WiFi event ID

enum `wifi_event_sta_wps_fail_reason_t`
   Argument structure for `WIFI_EVENT_STA_WPS_ER_FAILED` event
   Values:

enumerator `WPS_FAIL_REASON_NORMAL`
   WPS normal fail reason

enumerator `WPS_FAIL_REASON_RECV_M2D`
   WPS receive M2D frame

enumerator `WPS_FAIL_REASON_MAX`

enum `wifi_ftm_status_t`
   FTM operation status types.
   Values:

enumerator `FTM_STATUS_SUCCESS`
   FTM exchange is successful
enumerator FTM_STATUS_UNSUPPORTED
Peer does not support FTM

eenumerator FTM_STATUS_CONF_REJECTED
Peer rejected FTM configuration in FTM Request

eenumerator FTM_STATUS_NO_RESPONSE
Peer did not respond to FTM Requests

eenumerator FTM_STATUS_FAIL
Unknown error during FTM exchange

enum wps_fail_reason_t

Values:

eenumerator WPS_AP_FAIL_REASON_NORMAL
WPS normal fail reason

eenumerator WPS_AP_FAIL_REASON_CONFIG
WPS failed due to incorrect config

eenumerator WPS_AP_FAIL_REASON_AUTH
WPS failed during auth

eenumerator WPS_AP_FAIL_REASON_MAX

Header File

- components/wpa_supplicant/esp_supplicant/include/esp_eap_client.h

Functions

esp_err_t esp_wifi_sta_enterprise_enable (void)
Enable EAP authentication(WiFi Enterprise) for the station mode.

This function enables Extensible Authentication Protocol (EAP) authentication for the Wi-Fi station mode. When EAP authentication is enabled, the ESP device will attempt to authenticate with the configured EAP credentials when connecting to a secure Wi-Fi network.

Note: Before calling this function, ensure that the Wi-Fi configuration and EAP credentials (such as username and password) have been properly set using the appropriate configuration APIs.

Returns

- ESP_OK: EAP authentication enabled successfully.
- ESP_ERR_NO_MEM: Failed to enable EAP authentication due to memory allocation failure.

esp_err_t esp_wifi_sta_enterprise_disable (void)
Disable EAP authentication(WiFi Enterprise) for the station mode.

This function disables Extensible Authentication Protocol (EAP) authentication for the Wi-Fi station mode. When EAP authentication is disabled, the ESP device will not attempt to authenticate using EAP credentials when connecting to a secure Wi-Fi network.
**Note:** Disabling EAP authentication may cause the device to connect to the Wi-Fi network using other available authentication methods, if configured using esp_wifi_set_config().

**Returns**
- ESP_OK: EAP authentication disabled successfully.
- ESP_ERR_INVALID_STATE: EAP client is in an invalid state for disabling.

```c
esp_err_t esp_eap_client_set_identity (const unsigned char *identity, int len)
```

Set identity for PEAP/TTLS authentication method.

**Parameters**
- len – [in] Length of the identity data (limited to 1~127 bytes).

**Returns**
- ESP_OK: The identity was set successfully.
- ESP_ERR_INVALID_ARG: Invalid argument (len <= 0 or len >= 128).
- ESP_ERR_NO_MEM: Memory allocation failure.

```c
void esp_eap_client_clear_identity (void)
```

Clear the previously set identity for PEAP/TTLS authentication.

This function clears the identity that was previously set for the EAP client. After calling this function, the EAP client will no longer use the previously configured identity during the authentication process.

```c
esp_err_t esp_eap_client_set_username (const unsigned char *username, int len)
```

Set username for PEAP/TTLS authentication method.

**Parameters**
- username – [in] Pointer to the username data.
- len – [in] Length of the username data (limited to 1~127 bytes).

**Returns**
- ESP_OK: The username was set successfully.
- ESP_ERR_INVALID_ARG: Failed due to an invalid argument (len <= 0 or len >= 128).
- ESP_ERR_NO_MEM: Failed due to memory allocation failure.

```c
void esp_eap_client_clear_username (void)
```

Clear username for PEAP/TTLS method.

This function clears the previously set username for the EAP client.

```c
esp_err_t esp_eap_client_set_password (const unsigned char *password, int len)
```

Set password for PEAP/TTLS authentication method.

This function sets the password to be used during PEAP/TTLS authentication.

**Parameters**
- password – [in] Pointer to the password data.
- len – [in] Length of the password data (len > 0).

**Returns**
- ESP_OK: The password was set successfully.
- ESP_ERR_INVALID_ARG: Failed due to an invalid argument (len <= 0).
- ESP_ERR_NO_MEM: Failed due to memory allocation failure.

```c
void esp_eap_client_clear_password (void)
```

Clear password for PEAP/TTLS method.

This function clears the previously set password for the EAP client.
**esp_err_t esp_eap_client_set_new_password** (const unsigned char *new_password, int len)

Set a new password for MSCHAPv2 authentication method.

This function sets the new password to be used during MSCHAPv2 authentication. The new password is used to substitute the old password when an eap-mschapv2 failure request message with error code ERROR_PASSWD_EXPIRED is received.

**Parameters**
- **new_password** - [in] Pointer to the new password data.
- **len** - [in] Length of the new password data.

**Returns**
- ESP_OK: The new password was set successfully.
- ESP_ERR_INVALID_ARG: Failed due to an invalid argument (len <= 0).
- ESP_ERR_NO_MEM: Failed due to memory allocation failure.

**void esp_eap_client_clear_new_password** (void)

Clear new password for MSCHAPv2 method.

This function clears the previously set new password for the EAP client.

**esp_err_t esp_eap_client_set_ca_cert** (const unsigned char *ca_cert, int ca_cert_len)

Set CA certificate for EAP authentication.

This function sets the Certificate Authority (CA) certificate to be used during EAP authentication. The CA certificate is passed to the EAP client module through a global pointer.

**Parameters**
- **ca_cert** - [in] Pointer to the CA certificate data.
- **ca_cert_len** - [in] Length of the CA certificate data.

**Returns**
- ESP_OK: The CA certificate was set successfully.

**void esp_eap_client_clear_ca_cert** (void)

Clear the previously set Certificate Authority (CA) certificate for EAP authentication.

This function clears the CA certificate that was previously set for the EAP client. After calling this function, the EAP client will no longer use the previously configured CA certificate during the authentication process.

**esp_err_t esp_eap_client_set_certificate_and_key** (const unsigned char *client_cert, int client_cert_len, const unsigned char *private_key, int private_key_len, const unsigned char *private_key_password, int private_key_passwd_len)

Set client certificate and private key for EAP authentication.

This function sets the client certificate and private key to be used during authentication. Optionally, a private key password can be provided for encrypted private keys.

**Attention** 1. The client certificate, private key, and private key password are provided as pointers to the respective data arrays.
**Attention** 2. The client_cert, private_key, and private_key_password should be zero-terminated.

**Parameters**
- **client_cert** - [in] Pointer to the client certificate data.
- **client_cert_len** - [in] Length of the client certificate data.
- **private_key** - [in] Pointer to the private key data.
- **private_key_len** - [in] Length of the private key data (limited to 1~4096 bytes).
- **private_key_password** - [in] Pointer to the private key password data (optional).
- **private_key_passwd_len** - [in] Length of the private key password data (can be 0 for no password).

**Returns**
• ESP_OK: The certificate, private key, and password (if provided) were set successfully.

void esp_eap_client_clear_certificate_and_key (void)
Clear the previously set client certificate and private key for EAP authentication.
This function clears the client certificate and private key that were previously set for the EAP client. After calling this function, the EAP client will no longer use the previously configured certificate and private key during the authentication process.

esp_err_t esp_eap_client_set_disable_time_check (bool disable)
Set EAP client certificate time check (disable or not).
This function enables or disables the time check for EAP client certificates. When disabled, the certificates’ expiration time will not be checked during the authentication process.

Parameters disable - [in] True to disable EAP client certificates time check, false to enable it.
Returns
• ESP_OK: The EAP client certificates time check setting was updated successfully.

esp_err_t esp_eap_client_get_disable_time_check (bool *disable)
Get EAP client certificates time check status.
This function retrieves the current status of the EAP client certificates time check.

Parameters disable - [out] Pointer to a boolean variable to store the disable status.
Returns
• ESP_OK: The status of EAP client certificates time check was retrieved successfully.

esp_err_t esp_eap_client_set_ttls_phase2_method (esp_eap_ttls_phase2_types type)
Set EAP-TTLS phase 2 method.
This function sets the phase 2 method to be used during EAP-TTLS authentication.

Parameters type - [in] The type of phase 2 method to be used (e.g., EAP, MSCHAPv2, MSCHAP, PAP, CHAP).
Returns
• ESP_OK: The EAP-TTLS phase 2 method was set successfully.

esp_err_t esp_eap_client_set_suiteb_192bit_certification (bool enable)
Enable or disable Suite-B 192-bit certification checks.
This function enables or disables the 192-bit Suite-B certification checks during EAP-TLS authentication. Suite-B is a set of cryptographic algorithms which generally are considered more secure.

Parameters enable - [in] True to enable 192-bit Suite-B certification checks, false to disable it.
Returns
• ESP_OK: The 192-bit Suite-B certification checks were set successfully.

esp_err_t esp_eap_client_set_pac_file (const unsigned char *pac_file, int pac_file_len)
Set the PAC (Protected Access Credential) file for EAP-FAST authentication.
EAP-FAST requires a PAC file that contains the client’s credentials.

Attention 1. For files read from the file system, length has to be decremented by 1 byte.
Attention 2. Disabling the ESP_WIFI_MBEDTLS_TLS_CLIENT config is required to use EAP-FAST.

Parameters
• pac_file - [in] Pointer to the PAC file buffer.
• pac_file_len - [in] Length of the PAC file buffer.
Returns
• ESP_OK: The PAC file for EAP-FAST authentication was set successfully.
**esp_err_t esp_eap_client_set_fast_params(esp_eap_fast_config config)**

Set the parameters for EAP-FAST Phase 1 authentication.

EAP-FAST supports Fast Provisioning, where clients can be authenticated faster using precomputed keys (PAC). This function allows configuring parameters for Fast Provisioning.

**Attention** 1. Disabling the ESP_WIFI_MBEDTLS_TLS_CLIENT config is required to use EAP-FAST.

**Parameters** config –[in] Configuration structure with Fast Provisioning parameters.

**Returns**
- ESP_OK: The parameters for EAP-FAST Phase 1 authentication were set successfully.

**esp_err_t esp_eap_client_use_default_cert_bundle(bool use_default_bundle)**

Use the default certificate bundle for EAP authentication.

By default, the EAP client uses a built-in certificate bundle for server verification. Enabling this option allows the use of the default certificate bundle.

**Parameters** use_default_bundle –[in] True to use the default certificate bundle, false to use a custom bundle.

**Returns**
- ESP_OK: The option to use the default certificate bundle was set successfully.

**Structures**

**struct esp_eap_fast_config**

Configuration settings for EAP-FAST (Extensible Authentication Protocol - Flexible Authentication via Secure Tunneling).

This structure defines the configuration options that can be used to customize the behavior of the EAP-FAST authentication protocol, specifically for Fast Provisioning and PAC (Protected Access Credential) handling.

**Public Members**

**int fast_provisioning**

Enable or disable Fast Provisioning in EAP-FAST (0 = disabled, 1 = enabled)

**int fast_max_pac_list_len**

Maximum length of the PAC (Protected Access Credential) list

**bool fast_pac_format_binary**

Set to true for binary format PAC, false for ASCII format PAC

**Enumerations**

**enum esp_eap_ttls_phase2_types**

Enumeration of phase 2 authentication types for EAP-TTLS.

This enumeration defines the supported phase 2 authentication methods that can be used in the EAP-TTLS (Extensible Authentication Protocol - Tunneled Transport Layer Security) protocol for the second authentication phase.

**Values:**
enumerator **ESP_EAP_TTLS_PHASE2_EAP**
EAP (Extensible Authentication Protocol)

enumerator **ESP_EAP_TTLS_PHASE2_MSCHAPV2**
MS-CHAPv2 (Microsoft Challenge Handshake Authentication Protocol - Version 2)

enumerator **ESP_EAP_TTLS_PHASE2_MSCHAP**
MS-CHAP (Microsoft Challenge Handshake Authentication Protocol)

enumerator **ESP_EAP_TTLS_PHASE2_PAP**
PAP (Password Authentication Protocol)

enumerator **ESP_EAP_TTLS_PHASE2_CHAP**
CHAP (Challenge Handshake Authentication Protocol)

**Header File**
- components/wpa_supplicant/esp_supplicant/include/esp_wps.h

**Functions**

`esp_err_t esp_wifi_wps_enable(const esp_wps_config_t *config)`

Enable Wi-Fi WPS function.

**Parameters**
- config: WPS config to be used in connection

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_WPS_TYPE: wps type is invalid
- ESP_ERR_WIFI_WPS_MODE: wifi not in station mode or sniffer mode is on
- ESP_FAIL: wps initialization fails

`esp_err_t esp_wifi_wps_disable(void)`

Disable Wi-Fi WPS function and release resource it taken.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_WPS_MODE: wifi not in station mode or sniffer mode is on

`esp_err_t esp_wifi_wps_start(int timeout_ms)`

Start WPS session.

**Attention**
WPS can only be used when station is enabled. WPS needs to be enabled first for using this API.

**Parameters**
- timeout_ms: deprecated: This argument’s value will have not effect in functionality of API. The argument will be removed in future. The app should start WPS and register for WIFI events to get the status. WPS status is updated through WPS events. See wifi_event_t enum for more info.

**Returns**
- ESP_OK: succeed
- ESP_ERR_WIFI_WPS_TYPE: wps type is invalid
- ESP_ERR_WIFI_WPS_MODE: wifi not in station mode or sniffer mode is on
- ESP_ERR_WIFI_WPS_SM: wps state machine is not initialized
- ESP_FAIL: wps initialization fails
**Chapter 2. API Reference**

*esp_err_t* **esp_wifi_ap_wps_enable**(const *esp_wps_config_t* *config*)

Enable Wi-Fi AP WPS function.

**Attention** WPS can only be used when softAP is enabled.

**Parameters** config – wps configuration to be used.

**Returns**

- ESP_OK : succeed
- ESP_ERR_WIFI_WPS_TYPE : wps type is invalid
- ESP_ERR_WIFI_WPS_MODE : wifi is not in station mode or sniffer mode is on
- ESP_FAIL : wps initialization fails

*esp_err_t* **esp_wifi_ap_wps_disable**(void)

Disable Wi-Fi SoftAP WPS function and release resource it taken.

**Returns**

- ESP_OK : succeed
- ESP_ERR_WIFI_WPS_MODE : wifi is not in station mode or sniffer mode is on

*esp_err_t* **esp_wifi_ap_wps_start**(const unsigned char* *pin*)

WPS starts to work.

**Attention** WPS can only be used when softAP is enabled.

**Parameters** pin –: Pin to be used in case of WPS mode is pin. If Pin is not provided, device will use the pin generated/provided during *esp_wifi_ap_wps_enable()* and reported in WIFI_EVENT_AP_WPS_RG_PIN

**Returns**

- ESP_OK : succeed
- ESP_ERR_WIFI_WPS_TYPE : wps type is invalid
- ESP_ERR_WIFI_WPS_MODE : wifi is not in station mode or sniffer mode is on
- ESP_ERR_WIFI_WPS_SM : wps state machine is not initialized
- ESP_FAIL : wps initialization fails

**Structures**

struct **wps_factory_information_t**

Structure representing WPS factory information for ESP device.

This structure holds various strings representing factory information for a device, such as the manufacturer, model number, model name, and device name. Each string is a null-terminated character array. If any of the strings are empty, the default values are used.

**Public Members**

char **manufacturer**[WPS_MAX_MANUFACTURER_LEN]

Manufacturer of the device. If empty, the default manufacturer is used.

char **model_number**[WPS_MAX_MODEL_NUMBER_LEN]

Model number of the device. If empty, the default model number is used.

char **model_name**[WPS_MAX_MODEL_NAME_LEN]

Model name of the device. If empty, the default model name is used.
char **device_name**[WPS_MAX_DEVICE_NAME_LEN]
Device name. If empty, the default device name is used.

```c
struct esp_wps_config_t
```
Structure representing configuration settings for WPS (Wi-Fi Protected Setup).
This structure encapsulates various configuration settings for WPS, including the WPS type (PBC or PIN),
factory information that will be shown in the WPS Information Element (IE), and a PIN if the WPS type is set
to PIN.

**Public Members**

```c
wps_type_t wps_type
```
The type of WPS to be used (PBC or PIN).

```c
wps_factory_information_t factory_info
```
Factory information to be shown in the WPS Information Element (IE). Vendor can choose to display
their own information.

```c
char **pin**[PIN_LEN]
```
WPS PIN (Personal Identification Number) used when wps_type is set to WPS_TYPE_PIN.

**Macros**

```c
ESP_ERR_WIFI_REGISTRAR
```
WPS registrar is not supported

```c
ESP_ERR_WIFI_WPS_TYPE
```
WPS type error

```c
ESP_ERR_WIFI_WPS_SM
```
WPS state machine is not initialized

```c
WPS_MAX_MANUFACTURER_LEN
```
Maximum length of the manufacturer name in WPS information

```c
WPS_MAX_MODEL_NUMBER_LEN
```
Maximum length of the model number in WPS information

```c
WPS_MAX_MODEL_NAME_LEN
```
Maximum length of the model name in WPS information

```c
WPS_MAX_DEVICE_NAME_LEN
```
Maximum length of the device name in WPS information

```c
PIN_LEN
```
The length of the WPS PIN (Personal Identification Number).
WPS_CONFIG_INIT_DEFAULT (type)

Initialize a default WPS configuration structure with specified WPS type.

This macro initializes a `esp_wps_config_t` structure with default values for the specified WPS type. It sets the WPS type, factory information (including default manufacturer, model number, model name, and device name), and a default PIN value if applicable.

**Parameters**

- `type` - The WPS type to be used (PBC or PIN).

**Returns**

An initialized `esp_wps_config_t` structure with the specified WPS type and default values.

**Type Definitions**

```c
typedef enum wps_type wps_type_t

Enumeration of WPS (Wi-Fi Protected Setup) types.
```

**Enumerations**

```c
enum wps_type

Enumeration of WPS (Wi-Fi Protected Setup) types.

Values:

- `WPS_TYPE_DISABLE` - WPS is disabled
- `WPS_TYPE_PBC` - WPS Push Button Configuration method
- `WPS_TYPE_PIN` - WPS PIN (Personal Identification Number) method
- `WPS_TYPE_MAX` - Maximum value for WPS type enumeration
```

**Header File**

```c
- components/wpa_supplicant/esp_supplicant/include/esp_rrm.h
```

**Functions**

```c
int esp_rrm_send_neighbor_rep_request (neighbor_rep_request_cb cb, void *cb_ctx)

Send Radio measurement neighbor report request to connected AP.

**Parameters**

- `cb` - callback function for neighbor report
- `cb_ctx` - callback context

**Returns**

- 0: success
- -1: AP does not support RRM
- -2: station not connected to AP

bool esp_rrm_is_rrm_supported_connection (void)

Check RRM capability of connected AP.

**Returns**
• true: AP supports RRM
• false: AP does not support RRM or station not connected to AP

### Type Definitions

```c
typedef void (*neighbor_rep_request_cb)(void *ctx, const uint8_t *report, size_t report_len);
```

Callback function type to get neighbor report.

- **Param ctx**: neighbor report context
- **Param report**: neighbor report
- **Param report_len**: neighbor report length
- **Return**: void

### Header File

- components/wpa_supplicant/esp_supplicant/include/esp_wnm.h

### Functions

**int esp_wnm_send_bss_transition_mgmt_query (enum btm_query_reason query_reason, const char *btm_candidates, int cand_list)**

Send bss transition query to connected AP.

- **Parameters**
  - **query_reason**: reason for sending query
  - **btm_candidates**: btm candidates list if available
  - **cand_list**: whether candidate list to be included from scan results available in supplicant’s cache.

- **Returns**
  - 0: success
  - -1: AP does not support BTM
  - -2: station not connected to AP

**bool esp_wnm_is_btm_supported_connection (void)**

Check bss trasition capability of connected AP.

- **Returns**
  - true: AP supports BTM
  - false: AP does not support BTM or station not connected to AP

### Enumerations

**enum btm_query_reason**

enum btm_query_reason: Reason code for sending btm query

- **Values**:
  - enumerator **REASON_UNSPECIFIED**
  - enumerator **REASON_FRAME_LOSS**
  - enumerator **REASON_DELAY**
  - enumerator **REASON_BANDWIDTH**
enumerator REASON_LOAD_BALANCE

enumerator REASON_RSSI

enumerator REASON_RETRANSMISSIONS

enumerator REASON_INTERFERENCE

enumerator REASON_GRAY_ZONE

enumerator REASON_PREMIUM_AP

Header File

- components/wpa_supplicant/esp_supplicant/include/esp_mbo.h

Functions

int esp_mbo_update_non_pref_chan (struct non_pref_chan_s *non_pref_chan)

Update channel preference for MBO IE.

Parameters non_pref_chan — Non preference channel list

Returns

- 0: success else failure

Structures

struct non_pref_chan

Structure representing a non-preferred channel in a wireless network.

This structure encapsulates information about a non-preferred channel including the reason for its non-preference, the operating class, channel number, and preference level.

Public Members

enum non_pref_chan_reason reason

Reason for the channel being non-preferred

uint8_t oper_class

Operating class of the channel

uint8_t chan

Channel number

uint8_t preference

Preference level of the channel

struct non_pref_chan_s

Structure representing a list of non-preferred channels in a wireless network.

This structure encapsulates information about a list of non-preferred channels including the number of non-preferred channels and an array of structures representing individual non-preferred channels.
Public Members

size_t non_pref_chan_num
   Number of non-preferred channels in the list

struct non_pref_chan chan[]
   Array of structures representing individual non-preferred channels

Enumerations

eenum non_pref_chan_reason
   Enumeration of reasons for a channel being non-preferred in a wireless network.
   This enumeration defines various reasons why a specific channel might be considered non-preferred in a wireless network configuration.
   Values:

   enumerator NON_PREF_CHAN_REASON_UNSPECIFIED
      Unspecified reason for non-preference

   enumerator NON_PREF_CHAN_REASON_RSSI
      Non-preferred due to low RSSI (Received Signal Strength Indication)

   enumerator NON_PREF_CHAN_REASON_EXT_INTERFERENCE
      Non-preferred due to external interference

   enumerator NON_PREF_CHAN_REASON_INT_INTERFERENCE
      Non-preferred due to internal interference

Wi-Fi Easy Connect™ (DPP)

Wi-Fi Easy Connect™, also known as Device Provisioning Protocol (DPP) or Easy Connect, is a provisioning protocol certified by Wi-Fi Alliance. It is a secure and standardized provisioning protocol for configuration of Wi-Fi Devices. With Easy Connect adding a new device to a network is as simple as scanning a QR Code. This reduces complexity and enhances user experience while onboarding devices without UI like Smart Home and IoT products. Unlike old protocols like WiFi Protected Setup (WPS), Wi-Fi Easy Connect incorporates strong encryption through public key cryptography to ensure networks remain secure as new devices are added. Easy Connect brings many benefits in the User Experience:

   • Simple and intuitive to use; no lengthy instructions to follow for new device setup
   • No need to remember and enter passwords into the device being provisioned
   • Works with electronic or printed QR codes, or human-readable strings
   • Supports both WPA2 and WPA3 networks

Please refer to Wi-Fi Alliance’s official page on Easy Connect for more information.

ESP32 supports Enrollee mode of Easy Connect with QR Code as the provisioning method. A display is required to display this QR Code. Users can scan this QR Code using their capable device and provision the ESP32 to their Wi-Fi network. The provisioning device needs to be connected to the AP which need not support Wi-Fi Easy Connect™. Easy Connect is still an evolving protocol. Of known platforms that support the QR Code method are some Android smartphones with Android 10 or higher. To use Easy Connect no additional App needs to be installed on the supported smartphone.
Application Example

Example on how to provision ESP32 using a supported smartphone: wifi/wifi_easy_connect/dpp-enrollee.

API Reference

Header File

- components/wpa_supplicant/esp_supplicant/include/esp_dpp.h

Functions

```c
esp_err_t esp_supp_dpp_init(esp_supp_dpp_event_cb_t evt_cb)
```

Initialize DPP Supplicant. Starts DPP Supplicant and initializes related Data Structures.

return

- ESP_OK: Success
- ESP_FAIL: Failure

Parameters

- `evt_cb` – Callback function to receive DPP related events

```c
void esp_supp_dpp_deinit(void)
```

De-initialize DPP Supplicant.

Frees memory from DPP Supplicant Data Structures.

```c
esp_err_t esp_supp_dpp_bootstrap_gen(const char* chan_list, esp_supp_dpp_bootstrap_t type, const char* key, const char* info)
```

Generates Bootstrap Information as an Enrollee. Generates Out Of Band Bootstrap information as an Enrollee which can be used by a DPP Configurator to provision the Enrollee.

Parameters

- `chan_list` – List of channels device will be available on for listening
- `type` – Bootstrap method type, only QR Code method is supported for now.
- `key` – (Optional) 32 byte Raw Private Key for generating a Bootstrapping Public Key
- `info` – (Optional) Ancilliary Device Information like Serial Number

Returns

- ESP_OK: Success
- ESP_FAIL: Failure

```c
esp_err_t esp_supp_dpp_start_listen(void)
```

Start listening on Channels provided during esp_supp_dpp_bootstrap_gen.

Listens on every Channel from Channel List for a pre-defined wait time.

Returns
Chapter 2. API Reference

- ESP_OK: Success
- ESP_FAIL: Generic Failure
- ESP_ERR_INVALID_STATE: ROC attempted before WiFi is started
- ESP_ERR_NO_MEM: Memory allocation failed while posting ROC request

```c
void esp_supp_dpp_stop_listen(void)
    Stop listening on Channels.
```

**Macros**

- **ESP_ERR_DPP_FAILURE**
  Generic failure during DPP Operation

- **ESP_ERR_DPP_TX_FAILURE**
  DPP Frame Tx failed OR not Aced

- **ESP_ERR_DPP_INVALID_ATTR**
  Encountered invalid DPP Attribute

**Type Definitions**

typedef enum dpp_bootstrap_type esp_supp_dpp_bootstrap_t
Types of Bootstrap Methods for DPP.

typedef void (*esp_supp_dpp_event_cb_t)(esp_supp_dpp_event_t evt, void *data)
Callback function for receiving DPP Events from Supplicant.

```c
Callback function will be called with DPP related information.
```

**Enumerations**

type enum dpp_bootstrap_type
Types of Bootstrap Methods for DPP.

- **DPP_BOOTSTRAP_QR_CODE**
  QR Code Method

- **DPP_BOOTSTRAP_PKEX**
  Proof of Knowledge Method

- **DPP_BOOTSTRAP_NFC_URI**
  NFC URI record Method
### Chapter 2. API Reference

**enum esp_supp_dpp_event_t**

Types of Callback Events received from DPP Supplicant.

*Values*:

- **enumerator ESP_SUPP_DPP_URI_READY**
  
  URI is ready through Bootstrapping

- **enumerator ESP_SUPP_DPP_CFG_RECVD**
  
  Config received via DPP Authentication

- **enumerator ESP_SUPP_DPP_FAIL**
  
  DPP Authentication failure

---

**Wi-Fi Aware™ (NAN)**

Wi-Fi Aware™ or NAN (Neighbor Awareness Networking) is a protocol that allows Wi-Fi devices to discover services in their proximity. Typically, location-based services are based on querying servers for information about the environment and the location knowledge is based on GPS or other location reckoning techniques. However, NAN does not require real-time connection to servers, GPS or other geo-location, but instead uses direct device-to-device Wi-Fi to discover and exchange information. NAN scales effectively in dense Wi-Fi environments and complements the connectivity of Wi-Fi by providing information about people and services in the proximity.

Multiple NAN devices which are in the vicinity will form a NAN cluster which allows them to communicate with each other. Devices within a NAN cluster can advertise (Publish method) or look for (Subscribe method) services using NAN Service Discovery protocols. Matching of services is done by service name, once a match is found a device can either send a message or establish an IPv6 datapath with the peer.

ESP32 supports Wi-Fi Aware in standalone mode with support for both Service Discovery and Datapath. Wi-Fi Aware is still an evolving protocol. Please refer to Wi-Fi Alliance’s official page on Wi-Fi Aware for more information. Many Android smartphones with Android 8 or higher support Wi-Fi Aware. Refer to Android’s developer guide on Wi-Fi Aware for more information.

**Application Example** A pair of examples for a Publisher-Subscriber use case: wifi/wifi_aware/nan_publisher and wifi/wifi_aware/nan_subscriber. A user interactive console example to explore full functionality of Wi-Fi Aware: wifi/wifi_aware/nan_console. Please check the README for more details in respective example directories.

---

**API Reference**

**Header File**

- components/esp_wifi/wifi_apps/include/esp_nan.h

**Functions**

```c
esp_err_t esp_wifi_nan_start(const wifi_nan_config_t *nan_cfg)
```

Start NAN Discovery with provided configuration.

**Attention** This API should be called after esp_wifi_init().

**Parameters**

- **nan_cfg** - NAN related parameters to be configured.

**Returns**

- ESP_OK: succeed
- others: failed
**esp_err_t esp_wifi_nan_stop**(void)

Stop NAN Discovery, end NAN Services and Datapaths.

**Returns**
- ESP_OK: succeed
- others: failed

**uint8_t esp_wifi_nan_publish_service**(const wifi_nan_publish_cfg_t *publish_cfg, bool ndp_resp_needed)

Start Publishing a service to the NAN Peers in vicinity.

**Attention** This API should be called after esp_wifi_nan_start().

**Parameters**
- **publish_cfg** – Configuration parameters for publishing a service.
- **ndp_resp_needed** – Setting this true will require user response for every NDP Req using esp_wifi_nan_datapath_resp API.

**Returns**
- non-zero: Publish service identifier
- zero: failed

**uint8_t esp_wifi_nan_subscribe_service**(const wifi_nan_subscribe_cfg_t *subscribe_cfg)

Subscribe for a service within the NAN cluster.

**Attention** This API should be called after esp_wifi_nan_start().

**Parameters**
- **subscribe_cfg** – Configuration parameters for subscribing for a service.

**Returns**
- non-zero: Subscribe service identifier
- zero: failed

**esp_err_t esp_wifi_nan_send_message**(wifi_nan_followup_params_t *fup_params)

Send a follow-up message to the NAN Peer with matched service.

**Attention** This API should be called after a NAN service is discovered due to a match.

**Parameters**
- **fup_params** – Configuration parameters for sending a Follow-up message.

**Returns**
- ESP_OK: succeed
- others: failed

**esp_err_t esp_wifi_nan_cancel_service**(uint8_t service_id)

Cancel a NAN service.

**Parameters**
- **service_id** – Publish/Subscribe service id to be cancelled.

**Returns**
- ESP_OK: succeed
- others: failed

**uint8_t esp_wifi_nan_datapath_req**(wifi_nan_datapath_req_t *req)

Send NAN Datapath Request to a NAN Publisher with matched service.

**Attention** This API should be called by the Subscriber after a match occurs with a Publisher.

**Parameters**
- **req** – NAN Datapath Request parameters.
Returns

- non-zero NAN Datapath identifier: If NAN datapath req was accepted by publisher
- zero: If NAN datapath req was rejected by publisher or a timeout occurs

```
void esp_wifi_nan_get_ipv6_linklocal_from_mac(ip6_addr_t* ip6, uint8_t* mac_addr)
```

Get IPv6 Link Local address using MAC address.

```
esp_err_t esp_wifi_nan_get_peer_records(int* num_peer_records, uint8_t own_svc_id, struct nan_peer_record *peer_record)
```

brief Get a list of Peers discovered by the given Service.

```
void esp_wifi_nan_get_ipv6_linklocal_from_mac(ip6_addr_t* ip6, uint8_t* mac_addr)
```

Get IPv6 Link Local address using MAC address.

```
esp_err_t esp_wifi_nan_get_peer_records(int* num_peer_records, uint8_t own_svc_id, struct nan_peer_record *peer_record)
```

brief Get a list of Peers discovered by the given Service.
Chapter 2. API Reference

- ESP_FAIL: failed

*esp_err_t* `esp_wifi_nan_get_peer_info` (char *svc_name, uint8_t *peer_mac, struct `nan_peer_record` *peer_info)

Brief: Find Peer’s Service information using Peer MAC and optionally Service Name.

**Parameters**

- `svc_name` - Service Name of the published/subscribed service.
- `peer_mac` - Peer’s NAN Management Interface MAC address.
- `peer_info` - [out] Peer’s service information structure.

**Returns**

- ESP_OK: succeed
- ESP_FAIL: failed

**Structures**

struct `nan_peer_record`

Parameters of a peer service record

**Public Members**

- `uint8_t peer_svc_id`
  Identifier of Peer’s service

- `uint8_t own_svc_id`
  Identifier of own service associated with Peer

- `uint8_t peer_nmi[6]`
  Peer’s NAN Management Interface address

- `uint8_t peer_svc_type`
  Peer’s service type (Publish/Subscribe)

- `uint8_t ndp_id`
  Specifies if the peer has any active datapath

- `uint8_t peer_ndi[6]`
  Peer’s NAN Data Interface address, only valid when ndp_id is non-zero

**Macros**

- `WIFI_NAN_CONFIG_DEFAULT`

- `NDP_STATUS_ACCEPTED`

- `NDP_STATUS_REJECTED`

- `NAN_MAX_PEERS_RECORD`

- `ESP_NAN_PUBLISH`
Chapter 2. API Reference

ESP_NAN_SUBSCRIBE

Code examples for the Wi-Fi API are provided in the wifi directory of ESP-IDF examples. Code examples for ESP-WIFI-MESH are provided in the mesh directory of ESP-IDF examples.

2.5.2 Ethernet

Overview

ESP-IDF provides a set of consistent and flexible APIs to support both internal Ethernet MAC (EMAC) controller and external SPI-Ethernet modules.

This programming guide is split into the following sections:

1. Basic Ethernet Concepts
2. Configure MAC and PHY
3. Connect Driver to TCP/IP Stack
4. Misc Control of Ethernet Driver

Basic Ethernet Concepts

Ethernet is an asynchronous Carrier Sense Multiple Access with Collision Detect (CSMA/CD) protocol/interface. It is generally not well suited for low-power applications. However, with ubiquitous deployment, internet connectivity, high data rates, and limitless-range expandability, Ethernet can accommodate nearly all wired communications.

Normal IEEE 802.3 compliant Ethernet frames are between 64 and 1518 bytes in length. They are made up of five or six different fields: a destination MAC address (DA), a source MAC address (SA), a type/length field, a data payload, an optional padding field and a Cyclic Redundancy Check (CRC). Additionally, when transmitted on the Ethernet medium, a 7-byte preamble field and Start-of-Frame (SOF) delimiter byte are appended to the beginning of the Ethernet packet.

Thus the traffic on the twist-pair cabling will appear as shown below:

Preamble and Start-of-Frame Delimiter

The preamble contains seven bytes of 55H. It allows the receiver to lock onto the stream of data before the actual frame arrives.

The Start-of-Frame Delimiter (SFD) is a binary sequence 10101011 (as seen on the physical medium). It is sometimes considered to be part of the preamble.

When transmitting and receiving data, the preamble and SFD bytes will automatically be generated or stripped from the packets.

Destination Address

The destination address field contains a 6-byte length MAC address of the device that the packet is directed to. If the Least Significant bit in the first byte of the MAC address is set, the address is a multicast destination. For example, 01-00-00-00-F0-00 and 33-45-67-89-AB-CD are multi-cast addresses, while 00-00-00-00-F0-00 and 32-45-67-89-AB-CD are not.

Packets with multi-cast destination addresses are designed to arrive and be important to a selected group of Ethernet nodes. If the destination address field is the reserved multicast address, i.e. FF-FF-FF-FF-FF-FF, the packet is a broadcast packet and it will be directed to everyone sharing the network. If the Least Significant bit in the first byte of the MAC address is clear, the address is a unicast address and will be designed for usage by only the addressed node.

Normally the EMAC controller incorporates receive filters which can be used to discard or accept packets with multi-cast, broadcast and/or unicast destination addresses. When transmitting packets, the host controller is responsible for writing the desired destination address into the transmit buffer.
The source address field contains a 6-byte length MAC address of the node which created the Ethernet packet. Users of Ethernet must generate a unique MAC address for each controller used. MAC addresses consist of two portions. The first three bytes are known as the Organizationally Unique Identifier (OUI). OUIs are distributed by the IEEE. The last three bytes are address bytes at the discretion of the company that purchased the OUI. For more information about MAC Address used in ESP-IDF, please see [MAC Address Allocation](#).

When transmitting packets, the assigned source MAC address must be written into the transmit buffer by the host controller.

**Type/Length** The type/length field is a 2-byte field. If the value in this field is \( \leq 1500 \) (decimal), it is considered a length field and it specifies the amount of non-padding data which follows in the data field. If the value is \( \geq 1536 \), it represents the protocol the following packet data belongs to. The followings are the most common type values:

- IPv4 = 0800H
- IPv6 = 86DDH
- ARP = 0806H

Users implementing proprietary networks may choose to treat this field as a length field, while applications implementing protocols such as the Internet Protocol (IP) or Address Resolution Protocol (ARP), should program this field with the appropriate type defined by the protocol’s specification when transmitting packets.

**Payload** The payload field is a variable length field, anywhere from 0 to 1500 bytes. Larger data packets will violate Ethernet standards and will be dropped by most Ethernet nodes.

This field contains the client data, such as an IP datagram.

**Padding and FCS** The padding field is a variable length field added to meet the IEEE 802.3 specification requirements when small data payloads are used.
The DA, SA, type, payload, and padding of an Ethernet packet must be no smaller than 60 bytes in total. If the required 4-byte FCS field is added, packets must be no smaller than 64 bytes. If the payload field is less than 46-byte long, a padding field is required.

The FCS field is a 4-byte field that contains an industry-standard 32-bit CRC calculated with the data from the DA, SA, type, payload, and padding fields. Given the complexity of calculating a CRC, the hardware normally will automatically generate a valid CRC and transmit it. Otherwise, the host controller must generate the CRC and place it in the transmit buffer.

Normally, the host controller does not need to concern itself with padding and the CRC which the hardware EMAC will also be able to automatically generate when transmitting and verify when receiving. However, the padding and CRC fields will be written into the receive buffer when packets arrive, so they may be evaluated by the host controller if needed.

**Note:** Besides the basic data frame described above, there’re two other common frame types in 10/100 Mbps Ethernet: control frames and VLAN-tagged frames. They’re not supported in ESP-IDF.

### Configure MAC and PHY

The Ethernet driver is composed of two parts: MAC and PHY.

The communication between MAC and PHY can have diverse choices: MII (Media Independent Interface), RMII (Reduced Media Independent Interface), etc.

One of the obvious differences between MII and RMII is signal consumption. MII usually costs up to 18 signals, while the RMII interface can reduce the consumption to 9.

In RMII mode, both the receiver and transmitter signals are referenced to the REF_CLK. **REF_CLK must be stable during any access to PHY and MAC.** Generally, there are three ways to generate the REF_CLK depending on the PHY device in your design:

- Some PHY chips can derive the REF_CLK from its externally connected 25 MHz crystal oscillator (as seen the option a in the picture). In this case, you should select `CONFIG_ETH_RMII_CLK_INPUT` in `CONFIG_ETH_RMII_CLK_MODE`.
- Some PHY chip uses an externally connected 50MHz crystal oscillator or other clock sources, which can also be used as the REF_CLK for the MAC side (as seen the option b in the picture). In this case, you still need to select `CONFIG_ETH_RMII_CLK_INPUT` in `CONFIG_ETH_RMII_CLK_MODE`.
- Some EMAC controllers can generate the REF_CLK using an internal high-precision PLL (as seen the option c in the picture). In this case, you should select `CONFIG_ETH_RMII_CLK_OUTPUT` in `CONFIG_ETH_RMII_CLK_MODE`.

**Note:** REF_CLK is configured via Project Configuration as described above by default. However, it can be overwritten from user application code by appropriately setting `eth.esp32_emac_config_t::interface` and `eth.esp32_emac_config_t::clock_config` members. See `emac_rmii_clock_mode_t` and `emac_rmii_clock_gpio_t` for more details.

**Warning:** If the RMII clock mode is selected to `CONFIG_ETH_RMII_CLK_OUTPUT`, then GPIO0 can be used to output the REF_CLK signal. See `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0` for more information.

What’s more, if you’re not using PSRAM in your design, GPIO16 and GPIO17 are also available to output the reference clock. See `CONFIG_ETH_RMII_CLK_OUT_GPIO` for more information.

If the RMII clock mode is selected to `CONFIG_ETH_RMII_CLK_INPUT`, then GPIO0 is the only choice to input the REF_CLK signal. Please note that GPIO0 is also an important strapping GPIO on ESP32. If GPIO0 samples a low level during power-up, ESP32 will go into download mode. The system will get halted until a manually reset. The workaround for this issue is disabling the REF_CLK in hardware by default so that the strapping pin won’t be interfered by other signals in the boot stage. Then, re-enable the REF_CLK in the Ethernet driver installation stage.

The ways to disable the REF_CLK signal can be:
Fig. 5: Ethernet RMII Interface
Chapter 2. API Reference

- Disable or power down the crystal oscillator (as the case b in the picture).
- Force the PHY device to reset status (as the case a in the picture). **This could fail for some PHY device** (i.e. it still outputs signals to GPIO0 even in reset state).

No matter which RMII clock mode you select, you really need to take care of the signal integrity of REF_CLK in your hardware design! Keep the trace as short as possible. Keep it away from RF devices and inductor elements.

**Note:** ESP-IDF only supports the RMII interface (i.e. always select `CONFIG_ETH_PHY_INTERFACE_RMII` in the Kconfig option `CONFIG_ETH_PHY_INTERFACE`).

Signals used in the data plane are fixed to specific GPIOs via MUX, they can’t be modified to other GPIOs. Signals used in the control plane can be routed to any free GPIOs via Matrix. Please refer to ESP32-Ethernet-Kit for hardware design example.

You need to set up the necessary parameters for MAC and PHY respectively based on your Ethernet board design, and then combine the two together to complete the driver installation.

Configuration for MAC is described in `eth_mac_config_t`, including:

- `eth_mac_config_t::sw_reset_timeout_ms`: software reset timeout value, in milliseconds. Typically, MAC reset should be finished within 100 ms.
- `eth_mac_config_t::rx_task_stack_size` and `eth_mac_config_t::rx_task_prio`: the MAC driver creates a dedicated task to process incoming packets. These two parameters are used to set the stack size and priority of the task.
- `eth_mac_config_t::flags`: specifying extra features that the MAC driver should have, it could be useful in some special situations. The value of this field can be OR’d with macros prefixed with `ETH_MAC_FLAG_`. For example, if the MAC driver should work when the cache is disabled, then you should configure this field with `ETH_MAC_FLAG_WORK_WITH_CACHE_DISABLE`.
- `eth_esp32_emac_config_t::smi_mdc_gpio_num` and `eth_esp32_emac_config_t::smi_mdio_gpio_num`: the GPIO number used to connect the SMI signals.
- `eth_esp32_emac_config_t::interface`: configuration of MAC Data interface to PHY (MII/RMII).
- `eth_esp32_emac_config_t::clock_config`: configuration of EMAC Interface clock (REF_CLK mode and GPIO number in case of RMII).

Configuration for PHY is described in `eth_phy_config_t`, including:

- `eth_phy_config_t::phy_addr`: multiple PHY devices can share the same SMI bus, so each PHY needs a unique address. Usually, this address is configured during hardware design by pulling up/down some PHY strapping pins. You can set the value from 0 to 15 based on your Ethernet board. Especially, if the SMI bus is shared by only one PHY device, setting this value to -1 can enable the driver to detect the PHY address automatically.
- `eth_phy_config_t::reset_timeout_ms`: reset timeout value, in milliseconds. Typically, PHY reset should be finished within 100 ms.
- `eth_phy_config_t::autonego_timeout_ms`: auto-negotiation timeout value, in milliseconds. The Ethernet driver will start negotiation with the peer Ethernet node automatically, to determine to duplex and speed mode. This value usually depends on the ability of the PHY device on your board.
- `eth_phy_config_t::reset_gpio_num`: if your board also connects the PHY reset pin to one of the GPIO, then set it here. Otherwise, set this field to -1.

ESP-IDF provides a default configuration for MAC and PHY in macro `ETH_MAC_DEFAULT_CONFIG` and `ETH_PHY_DEFAULT_CONFIG`.

**Create MAC and PHY Instance** The Ethernet driver is implemented in an Object-Oriented style. Any operation on MAC and PHY should be based on the instance of the two.
Internal EMAC + External PHY

```c
eth_mac_config_t mac_config = ETH_MAC_DEFAULT_CONFIG();  // apply default common MAC configuration
eth_esp32_emac_config_t esp32_emac_config = ETH_ESP32_EMAC_DEFAULT_CONFIG();  // apply default vendor-specific MAC configuration
esp32_emac_config.smi_mdc_gpio_num = CONFIG EXAMPLE ETH MDC GPIO;  // alter the GPIO used for MDC signal
esp32_emac_config.smi_mdio_gpio_num = CONFIG EXAMPLE ETH MDIO GPIO;  // alter the GPIO used for MDIO signal
esp_eth_mac_t *mac = esp_eth_mac_new_esp32(&esp32_emac_config, &mac_config);  // create MAC instance
```

```
eth_phy_config_t phy_config = ETH_PHY_DEFAULT_CONFIG();  // apply default PHY configuration
phy_config.phy_addr = CONFIG EXAMPLE ETH PHY ADDR;  // alter the PHY address according to your board design
phy_config.reset_gpio_num = CONFIG EXAMPLE ETH PHY_RST_GPIO;  // alter the GPIO used for PHY reset
esp_eth_phy_t *phy = esp_eth_phy_new_ip101(&phy_config);  // create PHY instance
```

Optional Runtime MAC Clock Configuration  

```c
esp32_emac_config.interface = EMAC_DATA_INTERFACE_RMII;  // alter EMAC Data Interface
esp32_emac_config.clock_config.rmii.clock_mode = EMAC_CLK_OUT;  // select EMAC REF_CLK mode
esp32_emac_config.clock_config.rmii.clock_gpio = EMAC_CLK_OUT_GPIO;  // select GPIO number used to input/output EMAC REF_CLK
esp_eth_mac_t *mac = esp_eth_mac_new_esp32(&esp32_emac_config, &mac_config);  // create MAC instance
```

SPI-Ethernet Module

```c
eth_mac_config_t mac_config = ETH_MAC_DEFAULT_CONFIG();  // apply default MAC configuration
eth_phy_config_t phy_config = ETH_PHY_DEFAULT_CONFIG();  // apply default PHY configuration
phy_config.phy_addr = CONFIG EXAMPLE ETH PHY ADDR;  // alter the PHY address according to your board design
phy_config.reset_gpio_num = CONFIG EXAMPLE ETH PHY_RST_GPIO;  // alter the GPIO used for PHY reset
// Install GPIO interrupt service (as the SPI-Ethernet module is interrupt-driven)
gpio_install_isr_service(0);
// SPI bus configuration
spi_device_handle_t spi_handle = NULL;
spi_bus_config_t buscfg = {
    .miso_io_num = CONFIG EXAMPLE ETH_SPI_MISO_GPIO,
    .mosi_io_num = CONFIG EXAMPLE ETH_SPI_MOSI_GPIO,
    .sclk_io_num = CONFIG EXAMPLE ETH_SPI_SCLK_GPIO,
    .quadwp_io_num = -1,
};
```

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Chapter 2. API Reference

(continued from previous page)

```c
.quadhd_io_num = -1,
};
ESP_ERROR_CHECK(spi_bus_initialize(CONFIG_EXAMPLE_ETH_SPI_HOST, &buscfg, 1));
// Configure SPI device
spi_device_interface_config_t spi_devcfg = {
  .mode = 0,
  .clock_speed_hz = CONFIG_EXAMPLE_ETH_SPI_CLOCK_MHZ * 1000 * 1000,
  .spics_io_num = CONFIG_EXAMPLE_ETH_SPI_CS_GPIO,
  .queue_size = 20
};
/* dm9051 ethernet driver is based on spi driver */
eth_dm9051_config_t dm9051_config = ETH_DM9051_DEFAULT_CONFIG(CONFIG_EXAMPLE_ETH_~SPI_HOST, &spi_devcfg);
dm9051_config.int_gpio_num = CONFIG_EXAMPLE_ETH_SPI_INT_GPIO;
esp_eth_mac_t *mac = esp_eth_mac_new_dm9051(&dm9051_config, &mac_config);
esp_eth_phy_t *phy = esp_eth_phy_new_dm9051(sphy_config);
```

Note:

- When creating MAC and PHY instances for SPI-Ethernet modules (e.g. DM9051), the constructor function must have the same suffix (e.g. esp_eth_mac_new_dm9051 and esp_eth_phy_new_dm9051). This is because we don’t have other choices but the integrated PHY.
- The SPI device configuration (i.e. spi_device_interface_config_t) may slightly differ for other Ethernet modules or to meet SPI timing on specific PCB. Please check out your module’s specs and the examples in ESP-IDF.

**Install Driver**  
To install the Ethernet driver, we need to combine the instance of MAC and PHY and set some additional high-level configurations (i.e. not specific to either MAC or PHY) in `esp_eth_config_t`:

- `esp_eth_config_t::mac`: instance that created from MAC generator (e.g. esp_eth_mac_new_dm9051()
- `esp_eth_config_t::phy`: instance that created from PHY generator (e.g. esp_eth_phy_new_dm9051()
- `esp_eth_config_t::check_link_period_ms`: Ethernet driver starts an OS timer to check the link status periodically, this field is used to set the interval, in milliseconds.
- `esp_eth_config_t::stack_input`: In most Ethernet IoT applications, any Ethernet frame received by a driver should be passed to the upper layer (e.g. TCP/IP stack). This field is set to a function that is responsible to deal with the incoming frames. You can even update this field at runtime via function esp_eth_update_input_path() after driver installation.
- `esp_eth_config_t::on_lowlevel_init_done` and `esp_eth_config_t::on_lowlevel_deinit_done`: These two fields are used to specify the hooks which get invoked when low-level hardware has been initialized or de-initialized.

ESP-IDF provides a default configuration for driver installation in macro `ETH_DEFAULT_CONFIG`.

```c
esp_eth_config_t config = ETH_DEFAULT_CONFIG(mac, phy); // apply default driver...
--configuration
esp_eth_handle_t eth_handle = NULL; // after the driver is installed, we will get...
--the handle of the driver
esp_eth_driver_install(&config, &eth_handle); // install driver
```

The Ethernet driver also includes an event-driven model, which will send useful and important events to user space. We need to initialize the event loop before installing the Ethernet driver. For more information about event-driven programming, please refer to ESP Event.

```c
/** Event handler for Ethernet events */
static void eth_event_handler(void *arg, esp_event_base_t event_base,
 int32_t event_id, void *event_data)
```

(continues on next page)
{
    uint8_t mac_addr[6] = {0};
    /* we can get the ethernet driver handle from event data */
    esp_eth_handle_t eth_handle = *(esp_eth_handle_t *)event_data;

    switch (event_id) {
    case ETHERNET_EVENT_CONNECTED:
        esp_eth_ioctl(eth_handle, ETH_CMD_G_MAC_ADDR, mac_addr);
        ESP_LOGI(TAG, "Ethernet Link Up");
        ESP_LOGI(TAG, "Ethernet HW Addr %02x:%02x:%02x:%02x:%02x:%02x",
                 mac_addr[0], mac_addr[1], mac_addr[2], mac_addr[3], mac_-
0->addr[4], mac_addr[5]);
        break;
    case ETHERNET_EVENT_DISCONNECTED:
        ESP_LOGI(TAG, "Ethernet Link Down");
        break;
    case ETHERNET_EVENT_START:
        ESP_LOGI(TAG, "Ethernet Started");
        break;
    case ETHERNET_EVENT_STOP:
        ESP_LOGI(TAG, "Ethernet Stopped");
        break;
    default:
        break;
    }

    esp_event_loop_create_default(); // create a default event loop that runs in the_-
0->background
    esp_event_handler_register(ETH_EVENT, ESP_EVENT_ANY_ID, &eth_event_handler, NULL);-
0->// register Ethernet event handler (to deal with user-specific stuff when events_-
0->like link up/down happened)

Start Ethernet Driver  After driver installation, we can start Ethernet immediately.

    esp_eth_start(eth_handle); // start Ethernet driver state machine

Connect Driver to TCP/IP Stack  Up until now, we have installed the Ethernet driver. From the view of OSI (Open System Interconnection), we’re still on level 2 (i.e. Data Link Layer). While we can detect link up and down events and gain MAC address in user space, it’s infeasible to obtain the IP address, let alone send an HTTP request. The TCP/IP stack used in ESP-IDF is called LwIP. For more information about it, please refer to LwIP.

To connect the Ethernet driver to TCP/IP stack, follow these three steps:
1. Create a network interface for the Ethernet driver
2. Attach the network interface to the Ethernet driver
3. Register IP event handlers

For more information about the network interface, please refer to Network Interface.

/** Event handler for IP_EVENT_ETH_GOT_IP */
static void got_ip_event_handler(void *arg, esp_event_base_t event_base, 
int32_t event_id, void *event_data)
{
    ip_event_got_ip_t *event = (ip_event_got_ip_t *) event_data;
    const esp_netif_ip_info_t *ip_info = &event->ip_info;

    ESP_LOGI(TAG, "Ethernet Got IP Address");
    ESP_LOGI(TAG, "~~~~~~~~~~~");
}
ESP_LOGI(TAG, "ETHIP:" IPSTR, IP2STR(ip_info->ip));
ESP_LOGI(TAG, "ETHMASK:" IPSTR, IP2STR(ip_info->netmask));
ESP_LOGI(TAG, "ETHGW:" IPSTR, IP2STR(ip_info->gw));
ESP_LOGI(TAG, "~~~~~~~~~~~");
}

esp_netif_init(); // Initialize TCP/IP network interface (should be called only
once in application)
esp_netif_config_t cfg = ESP_NETIF_DEFAULT_ETH(); // apply default network
interface configuration for Ethernet
esp_netif_t *eth_netif = esp_netif_new(&cfg); // create network interface for
Ethernet driver

esp_netif_attach(eth_netif, esp_eth_new_netif_glue(eth_handle)); // attach
Ethernet driver to TCP/IP stack
esp_event_handler_register(IP_EVENT, IP_EVENT_ETH_GOT_IP, got_ip_event_handler,
NULL); // register user defined IP event handlers
esp_eth_start(eth_handle); // start Ethernet driver state machine

Warning: It is recommended to fully initialize the Ethernet driver and network interface before registering the user’s Ethernet/IP event handlers, i.e. register the event handlers as the last thing prior to starting the Ethernet driver. Such an approach ensures that Ethernet/IP events get executed first by the Ethernet driver or network interface so the system is in the expected state when executing the user’s handlers.

Misc Control of Ethernet Driver The following functions should only be invoked after the Ethernet driver has been installed.

- Stop Ethernet driver: esp_eth_stop()
- Update Ethernet data input path: esp_eth_update_input_path()
- Misc get/set of Ethernet driver attributes: esp_eth_ioctl()

/* get MAC address */
uint8_t mac_addr[6];
memset(mac_addr, 0, sizeof(mac_addr));
esp_eth_ioctl(eth_handle, ETH_CMD_G_MAC_ADDR, mac_addr);
ESP_LOGI(TAG, "Ethernet MAC Address: %02x:%02x:%02x:%02x:%02x:%02x",
mac_addr[0], mac_addr[1], mac_addr[2], mac_addr[3], mac_addr[4], mac_addr[5]);

/* get PHY address */
int phy_addr = -1;
esp_eth_ioctl(eth_handle, ETH_CMD_G_PHY_ADDR, &phy_addr);
ESP_LOGI(TAG, "Ethernet PHY Address: %d", phy_addr);

Flow Control Ethernet on MCU usually has a limitation in the number of frames it can handle during network congestion, because of the limitation in RAM size. A sending station might be transmitting data faster than the peer end can accept it. The ethernet flow control mechanism allows the receiving node to signal the sender requesting the suspension of transmissions until the receiver catches up. The magic behind that is the pause frame, which was defined in IEEE 802.3x.

Pause frame is a special Ethernet frame used to carry the pause command, whose EtherType field is 0x8808, with the Control opcode set to 0x0001. Only stations configured for full-duplex operation may send pause frames. When a station wishes to pause the other end of a link, it sends a pause frame to the 48-bit reserved multicast address of 01-80-C2-00-00-01. The pause frame also includes the period of pause time being requested, in the form of a two-byte integer, ranging from 0 to 65535.

After the Ethernet driver installation, the flow control feature is disabled by default. You can enable it by:
bool flow_ctrl_enable = true;
esp_eth_ioctl(eth_handle, ETH_CMD_S_FLOW_CTRL, &flow_ctrl_enable);

One thing that should be kept in mind is that the pause frame ability will be advertised to the peer end by PHY during auto-negotiation. The Ethernet driver sends a pause frame only when both sides of the link support it.

**Application Examples**

- Ethernet basic example: `ethernet/basic`
- Ethernet iperf example: `ethernet/iperf`
- Ethernet to Wi-Fi AP “router” : `ethernet/eth2ap`
- Most protocol examples should also work for Ethernet: `protocols`

**Advanced Topics**

**Custom PHY Driver**  There are multiple PHY manufacturers with wide portfolios of chips available. The ESP-IDF already supports several PHY chips however one can easily get to a point where none of them satisfies the user’s actual needs due to price, features, stock availability, etc.

Luckily, a management interface between EMAC and PHY is standardized by IEEE 802.3 in Section 22.2.4 Management Functions. It defines provisions of the so-called “MII Management Interface” to control the PHY and gather status from the PHY. A set of management registers is defined to control chip behavior, link properties, auto-negotiation configuration, etc. This basic management functionality is addressed by `esp_eth/src/esp_eth_phy_802_3.c` in ESP-IDF and so it makes the creation of a new custom PHY chip driver quite a simple task.

**Note:** Always consult with PHY datasheet since some PHY chips may not comply with IEEE 802.3, Section 22.2.4. It does not mean you are not able to create a custom PHY driver, it will just require more effort. You will have to define all PHY management functions.

The majority of PHY management functionality required by the ESP-IDF Ethernet driver is covered by the `esp_eth/src/esp_eth_phy_802_3.c`. However, the following may require developing chip-specific management functions:

- Link status which is almost always chip-specific
- Chip initialization, even though not strictly required, should be customized to at least ensure that the expected chip is used
- Chip-specific features configuration

**Steps to create a custom PHY driver:**

1. Define vendor-specific registry layout based on the PHY datasheet. See `esp_eth/src/esp_eth_phy_ip101.c` as an example.
2. Prepare derived PHY management object info structure which:
   - must contain at least parent IEEE 802.3 `phy_802_3_t` object
   - optionally contain additional variables needed to support non-IEEE 802.3 or customized functionality.
   See `esp_eth/src/esp_eth_phy_ksz80xx.c` as an example.
3. Define chip-specific management call-back functions.
4. Initialize parent IEEE 802.3 object and re-assign chip-specific management call-back functions.

Once you finish the new custom PHY driver implementation, consider sharing it among other users via IDF Component Registry.

**API Reference**

**Header File**

- `components/esp_eth/include/esp_eth.h`
### Header File

- components/esp_eth/include/esp_eth_driver.h

### Functions

#### esp_err_t esp_eth_driver_install (const esp_eth_config_t *config, esp_eth_handle_t *out_hdl)

Install Ethernet driver.

**Parameters**
- `config` [in] configuration of the Ethernet driver
- `out_hdl` [out] handle of Ethernet driver

**Returns**
- ESP_OK: install esp_eth driver successfully
- ESP_ERR_INVALID_ARG: install esp_eth driver failed because of some invalid argument
- ESP_ERR_NO_MEM: install esp_eth driver failed because there’s no memory for driver
- ESP_FAIL: install esp_eth driver failed because some other error occurred

#### esp_err_t esp_eth_driver_uninstall (esp_eth_handle_t hdl)

Uninstall Ethernet driver.

**Note:** It’s not recommended to uninstall Ethernet driver unless it won’t get used any more in application code. To uninstall Ethernet driver, you have to make sure, all references to the driver are released. Ethernet driver can only be uninstalled successfully when reference counter equals to one.

**Parameters**
- `hdl` [in] handle of Ethernet driver

**Returns**
- ESP_OK: uninstall esp_eth driver successfully
- ESP_ERR_INVALID_ARG: uninstall esp_eth driver failed because of some invalid argument
- ESP_ERR_INVALID_STATE: uninstall esp_eth driver failed because it has more than one reference
- ESP_FAIL: uninstall esp_eth driver failed because some other error occurred

#### esp_err_t esp_eth_start (esp_eth_handle_t hdl)

Start Ethernet driver ONLY in standalonemode (i.e. without TCP/IP stack)

**Note:** This API will start driver state machine and internal software timer (for checking link status).

**Parameters**
- `hdl` [in] handle of Ethernet driver

**Returns**
- ESP_OK: start esp_eth driver successfully
- ESP_ERR_INVALID_ARG: start esp_eth driver failed because of some invalid argument
- ESP_ERR_INVALID_STATE: start esp_eth driver failed because driver has started already
- ESP_FAIL: start esp_eth driver failed because some other error occurred

#### esp_err_t esp_eth_stop (esp_eth_handle_t hdl)

Stop Ethernet driver.

**Note:** This function does the opposite operation of esp_eth_start.

**Parameters**
- `hdl` [in] handle of Ethernet driver

**Returns**
- ESP_OK: start esp_eth driver successfully
- ESP_ERR_INVALID_ARG: start esp_eth driver failed because of some invalid argument
- ESP_ERR_INVALID_STATE: start esp_eth driver failed because driver has started already
- ESP_FAIL: start esp_eth driver failed because some other error occurred
**Chapter 2. API Reference**

- ESP_OK: stop esp_eth driver successfully
- ESP_ERR_INVALID_ARG: stop esp_eth driver failed because of some invalid argument
- ESP_ERR_INVALID_STATE: stop esp_eth driver failed because driver has not started yet
- ESP_FAIL: stop esp_eth driver failed because some other error occurred

```c
esp_err_t esp_eth_update_input_path(esp_eth_handle_t hdl, esp_err_t (*stack_input)(esp_eth_handle_t hdl, uint8_t *buffer, uint32_t length, void *priv), void *priv)
```

Update Ethernet data input path (i.e. specify where to pass the input buffer)

**Note:** After install driver, Ethernet still don’t know where to deliver the input buffer. In fact, this API registers a callback function which get invoked when Ethernet received new packets.

**Parameters**
- **hdl** – [in] handle of Ethernet driver
- **stack_input** – [in] function pointer, which does the actual process on incoming packets
- **priv** – [in] private resource, which gets passed to `stack_input` callback without any modification

**Returns**
- ESP_OK: update input path successfully
- ESP_ERR_INVALID_ARG: update input path failed because of some invalid argument
- ESP_FAIL: update input path failed because some other error occurred

```c
esp_err_t esp_eth_transmit(esp_eth_handle_t hdl, void *buf, size_t length)
```

General Transmit.

**Parameters**
- **hdl** – [in] handle of Ethernet driver
- **buf** – [in] buffer of the packet to transfer
- **length** – [in] length of the buffer to transfer

**Returns**
- ESP_OK: transmit frame buffer successfully
- ESP_ERR_INVALID_ARG: transmit frame buffer failed because of some invalid argument
- ESP_ERR_INVALID_STATE: invalid driver state (e.i. driver is not started)
- ESP_ERR_TIMEOUT: transmit frame buffer failed because HW was not get available in predefined period
- ESP_FAIL: transmit frame buffer failed because some other error occurred

```c
esp_err_t esp_eth_transmit_vargs(esp_eth_handle_t hdl, uint32_t argc, ...
```

Special Transmit with variable number of arguments.

**Parameters**
- **hdl** – [in] handle of Ethernet driver
- **argc** – [in] number variable arguments
- **...** – variable arguments

**Returns**
- ESP_OK: transmit successfull
- ESP_ERR_INVALID_STATE: invalid driver state (e.i. driver is not started)
- ESP_ERR_TIMEOUT: transmit frame buffer failed because HW was not get available in predefined period
- ESP_FAIL: transmit frame buffer failed because some other error occurred

```c
esp_err_t esp_eth_ioctl(esp_eth_handle_t hdl, esp_eth_io_cmd_t cmd, void *data)
```

Misc IO function of Etherent driver.
The following common IO control commands are supported:

- **ETH_CMD_S_MAC_ADDR** sets Ethernet interface MAC address. data argument is pointer to MAC address buffer with expected size of 6 bytes.
- **ETH_CMD_G_MAC_ADDR** gets Ethernet interface MAC address. data argument is pointer to a buffer to which MAC address is to be copied. The buffer size must be at least 6 bytes.
- **ETH_CMD_S_PHY_ADDR** sets PHY address in range of <0-31>. data argument is pointer to memory of uint32_t datatype from where the configuration option is read.
- **ETH_CMD_G_PHY_ADDR** gets PHY address. data argument is pointer to memory of uint32_t datatype to which the PHY address is to be stored.
- **ETH_CMD_S_AUTONEGO** enables or disables Ethernet link speed and duplex mode autonegotiation. data argument is pointer to memory of bool datatype from which the configuration option is read. Preconditions: Ethernet driver needs to be stopped.
- **ETH_CMD_G_AUTONEGO** gets current configuration of the Ethernet link speed and duplex mode autonegotiation. data argument is pointer to memory of bool datatype to which the current configuration is to be stored.
- **ETH_CMD_S_SPEED** sets the Ethernet link speed. data argument is pointer to memory of eth_speed_t datatype from which the configuration option is read. Preconditions: Ethernet driver needs to be stopped and auto-negotiation disabled.
- **ETH_CMD_G_SPEED** gets current Ethernet link speed. data argument is pointer to memory of eth_speed_t datatype to which the speed is to be stored.
- **ETH_CMD_S_PROMISCUOUS** sets/resets Ethernet interface promiscuous mode. data argument is pointer to memory of bool datatype from which the configuration option is read.
- **ETH_CMD_S_FLOW_CTRL** sets/resets Ethernet interface flow control. data argument is pointer to memory of bool datatype from which the configuration option is read.
- **ETH_CMD_S_DUPLEX_MODE** sets the Ethernet duplex mode. data argument is pointer to memory of eth_duplex_t datatype from which the configuration option is read. Preconditions: Ethernet driver needs to be stopped and auto-negotiation disabled.
- **ETH_CMD_G_DUPLEX_MODE** gets current Ethernet link duplex mode. data argument is pointer to memory of eth_duplex_t datatype to which the duplex mode is to be stored.
- **ETH_CMD_S_PHY_LOOPBACK** sets/resets PHY to/from loopback mode. data argument is pointer to memory of bool datatype from which the configuration option is read.

Note that additional control commands may be available for specific MAC or PHY chips. Please consult specific MAC or PHY documentation or driver code.

### Parameters

- **hdl** [in] handle of Ethernet driver
- **cmd** [in] IO control command
- **data** [in/out] address of data for set command or address where to store the data when used with get command

### Returns

- ESP_OK: process io command successfully
- ESP_ERR_INVALID_ARG: process io command failed because of some invalid argument
- ESP_FAIL: process io command failed because some other error occurred
- ESP_ERR_NOT_SUPPORTED: requested feature is not supported

```c
esp_err_t esp_eth_increase_reference(esp_eth_handle_t hdl)
```

Increase Ethernet driver reference.

### Note:

Ethernet driver handle can be obtained by os timer, netif, etc. It’s dangerous when thread A is using Ethernet but thread B uninstall the driver. Using reference counter can prevent such risk, but care should be taken, when you obtain Ethernet driver, this API must be invoked so that the driver won’t be uninstalled during your using time.

### Parameters

- **hdl** [in] handle of Ethernet driver
Returns

- ESP_OK: increase reference successfully
- ESP_ERR_INVALID_ARG: increase reference failed because of some invalid argument

`esp_err_t esp_eth_decrease_reference(esp_eth_handle_t hdl)`

Decrease Ethernet driver reference.

**Parameters**
- `hdl` [in] handle of Ethernet driver

**Returns**

- ESP_OK: increase reference successfully
- ESP_ERR_INVALID_ARG: increase reference failed because of some invalid argument

Structures

**struct esp_eth_config_t**

Configuration of Ethernet driver.

**Public Members**

- `esp_eth_mac_t *mac`
  Ethernet MAC object.

- `esp_eth_phy_t *phy`
  Ethernet PHY object.

- `uint32_t check_link_period_ms`
  Period time of checking Ethernet link status.

- `esp_err_t(*stack_input)(esp_eth_handle_t eth_handle, uint8_t*buffer, uint32_t length, void *priv)`
  Input frame buffer to user’s stack.

  **Param**
  - `eth_handle` [in] handle of Ethernet driver
  - `buffer` [in] frame buffer that will get input to upper stack
  - `length` [in] length of the frame buffer

  **Return**
  - ESP_OK: input frame buffer to upper stack successfully
  - ESP_FAIL: error occurred when inputting buffer to upper stack

- `esp_err_t(*on_lowlevel_init_done)(esp_eth_handle_t eth_handle)`
  Callback function invoked when lowlevel initialization is finished.

  **Param**
  - `eth_handle` [in] handle of Ethernet driver

  **Return**
  - ESP_OK: process extra lowlevel initialization successfully
  - ESP_FAIL: error occurred when processing extra lowlevel initialization

- `esp_err_t(*on_lowlevel_deinit_done)(esp_eth_handle_t eth_handle)`
  Callback function invoked when lowlevel deinitialization is finished.

  **Param**
  - `eth_handle` [in] handle of Ethernet driver

  **Return**
  - ESP_OK: process extra lowlevel deinitialization successfully
  - ESP_FAIL: error occurred when processing extra lowlevel deinitialization
esp_err_t (*read_phy_reg)(esp_eth_handle_t eth_handle, uint32_t phy_addr, uint32_t phy_reg, uint32_t *reg_value)

Read PHY register.

Note: Usually the PHY register read/write function is provided by MAC (SMI interface), but if the PHY device is managed by other interface (e.g. I2C), then user needs to implement the corresponding read/write. Setting this to NULL means your PHY device is managed by MAC’s SMI interface.

Param eth_handle [in] handle of Ethernet driver
Param phy_addr [in] PHY chip address (0~31)
Param phy_reg [in] PHY register index code
Param reg_value [out] PHY register value

Return
• ESP_OK: read PHY register successfully
• ESP_ERR_INVALID_ARG: read PHY register failed because of invalid argument
• ESP_ERR_TIMEOUT: read PHY register failed because of timeout
• ESP_FAIL: read PHY register failed because some other error occurred

esp_err_t (*write_phy_reg)(esp_eth_handle_t eth_handle, uint32_t phy_addr, uint32_t phy_reg, uint32_t reg_value)

Write PHY register.

Note: Usually the PHY register read/write function is provided by MAC (SMI interface), but if the PHY device is managed by other interface (e.g. I2C), then user needs to implement the corresponding read/write. Setting this to NULL means your PHY device is managed by MAC’s SMI interface.

Param eth_handle [in] handle of Ethernet driver
Param phy_addr [in] PHY chip address (0~31)
Param phy_reg [in] PHY register index code
Param reg_value [in] PHY register value

Return
• ESP_OK: write PHY register successfully
• ESP_ERR_INVALID_ARG: write PHY register failed because of invalid argument
• ESP_ERR_TIMEOUT: write PHY register failed because of timeout
• ESP_FAIL: write PHY register failed because some other error occurred

Macros
ETH_DEFAULT_CONFIG (emac, ephy)
Default configuration for Ethernet driver.

Type Definitions
typedef void *esp_eth_handle_t
Handle of Ethernet driver.

Enumerations
enum esp_eth_io_cmd_t
Command list for ioctl API.

Values:
enumerator ETH_CMD_G_MAC_ADDR
    Get MAC address

enumerator ETH_CMD_S_MAC_ADDR
    Set MAC address

enumerator ETH_CMD_G_PHY_ADDR
    Get PHY address

enumerator ETH_CMD_S_PHY_ADDR
    Set PHY address

enumerator ETH_CMD_G_AUTONEGO
    Get PHY Auto Negotiation

enumerator ETH_CMD_S_AUTONEGO
    Set PHY Auto Negotiation

enumerator ETH_CMD_G_SPEED
    Get Speed

enumerator ETH_CMD_S_SPEED
    Set Speed

enumerator ETH_CMD_S_PROMISCUOUS
    Set promiscuous mode

enumerator ETH_CMD_S_FLOW_CTRL
    Set flow control

enumerator ETH_CMD_G_DUPLEX_MODE
    Get Duplex mode

enumerator ETH_CMD_S_DUPLEX_MODE
    Set Duplex mode

enumerator ETH_CMD_S_PHY_LOOPBACK
    Set PHY loopback

enumerator ETH_CMD_CUSTOM_MAC_CMDS

enumerator ETH_CMD_CUSTOM_PHY_CMDS

Header File

- components/esp_eth/include/esp_eth_com.h
**Chapter 2. API Reference**

**Structures**

struct `esp_eth_mediator_s`

Ethernet mediator.

**Public Members**

```c
esp_err_t (*phy_reg_read)(esp_eth_mediator_t *eth, uint32_t phy_addr, uint32_t phy_reg, uint32_t *reg_value)
```

Read PHY register.

- **Param** `eth` [in] mediator of Ethernet driver
- **Param** `phy_addr` [in] PHY Chip address (0~31)
- **Param** `phy_reg` [in] PHY register index code
- **Param** `reg_value` [out] PHY register value

**Return**

- ESP_OK: read PHY register successfully
- ESP_FAIL: read PHY register failed because some error occurred

```c
esp_err_t (*phy_reg_write)(esp_eth_mediator_t *eth, uint32_t phy_addr, uint32_t phy_reg, uint32_t reg_value)
```

Write PHY register.

- **Param** `eth` [in] mediator of Ethernet driver
- **Param** `phy_addr` [in] PHY Chip address (0~31)
- **Param** `phy_reg` [in] PHY register index code
- **Param** `reg_value` [in] PHY register value

**Return**

- ESP_OK: write PHY register successfully
- ESP_FAIL: write PHY register failed because some error occurred

```c
esp_err_t (*stack_input)(esp_eth_mediator_t *eth, uint8_t *buffer, uint32_t length)
```

Deliver packet to upper stack.

- **Param** `eth` [in] mediator of Ethernet driver
- **Param** `buffer` [in] packet buffer
- **Param** `length` [in] length of the packet

**Return**

- ESP_OK: deliver packet to upper stack successfully
- ESP_FAIL: deliver packet failed because some error occurred

```c
esp_err_t (*on_state_changed)(esp_eth_mediator_t *eth, esp_eth_state_t state, void *args)
```

Callback on Ethernet state changed.

- **Param** `eth` [in] mediator of Ethernet driver
- **Param** `state` [in] new state
- **Param** `args` [in] optional argument for the new state

**Return**

- ESP_OK: process the new state successfully
- ESP_FAIL: process the new state failed because some error occurred

**Type Definitions**

typedef struct `esp_eth_mediator_s` `esp_eth_mediator_t`

Ethernet mediator.
Enumerations

enum esp_eth_state_t

Ethernet driver state.

Values:

enumerator ETH_STATE_LLINIT
Low level init done

enumerator ETH_STATE_DEINIT
Deinit done

enumerator ETH_STATE_LINK
Link status changed

enumerator ETH_STATE_SPEED
Speed updated

enumerator ETH_STATE_DUPLEX
Duplex updated

enumerator ETH_STATE_PAUSE
Pause ability updated

enum eth_event_t

Ethernet event declarations.

Values:

enumerator ETHERNET_EVENT_START
Ethernet driver start

enumerator ETHERNET_EVENT_STOP
Ethernet driver stop

enumerator ETHERNET_EVENT_CONNECTED
Ethernet got a valid link

enumerator ETHERNET_EVENT_DISCONNECTED
Ethernet lost a valid link

Header File

• components/esp_eth/include/esp_eth_mac.h

Functions

esp_eth_mac_t *esp_eth_mac_new_esp32

Create ESP32 Ethernet MAC instance.

Parameters

• esp32_config — EMAC specific configuration
**config** — Ethernet MAC configuration

**Returns**
- instance: create MAC instance successfully
- NULL: create MAC instance failed because some error occurred

**Unions**

union **eth_mac_clock_config_t**

```
#include <esp_eth_mac.h> Ethernet MAC Clock Configuration.
```

**Public Members**

```c
struct eth_mac_clock_config_t::[anonymous] mii
    EMAC MII Clock Configuration
```

```c
emac_rmii_clock_mode_t clock_mode
    RMII Clock Mode Configuration
```

```c
emac_rmii_clock_gpio_t clock_gpio
    RMII Clock GPIO Configuration
```

```c
struct eth_mac_clock_config_t::[anonymous] rmii
    EMAC RMII Clock Configuration
```

**Structures**

```c
struct esp_eth_mac_s
    Ethernet MAC.
```

**Public Members**

```c
esp_err_t (*set_mediator)(esp_eth_mac_t *mac, esp_eth_mediator_t *eth)
    Set mediator for Ethernet MAC.
```

- **Param mac** [in] Ethernet MAC instance
- **Param eth** [in] Ethernet mediator
- **Return**
  - ESP_OK: set mediator for Ethernet MAC successfully
  - ESP_ERR_INVALID_ARG: set mediator for Ethernet MAC failed because of invalid argument

```c
esp_err_t (*init)(esp_eth_mac_t *mac)
    Initialize Ethernet MAC.
```

- **Param mac** [in] Ethernet MAC instance
- **Return**
  - ESP_OK: initialize Ethernet MAC successfully
  - ESP_ERR_TIMEOUT: initialize Ethernet MAC failed because of timeout
  - ESP_FAIL: initialize Ethernet MAC failed because some other error occurred
**esp_err_t** (*deinit*)(esp_eth_mac_t *mac)

Deinitialize Ethernet MAC.

**Param** mac [in] Ethernet MAC instance

**Return**
- ESP_OK: deinitialize Ethernet MAC successfully
- ESP_FAIL: deinitialize Ethernet MAC failed because some error occurred

**esp_err_t** (*start*)(esp_eth_mac_t *mac)

Start Ethernet MAC.

**Param** mac [in] Ethernet MAC instance

**Return**
- ESP_OK: start Ethernet MAC successfully
- ESP_FAIL: start Ethernet MAC failed because some other error occurred

**esp_err_t** (*stop*)(esp_eth_mac_t *mac)

Stop Ethernet MAC.

**Param** mac [in] Ethernet MAC instance

**Return**
- ESP_OK: stop Ethernet MAC successfully
- ESP_FAIL: stop Ethernet MAC failed because some other error occurred

**esp_err_t** (*transmit*)(esp_eth_mac_t *mac, uint8_t* buf, uint32_t length)

Transmit packet from Ethernet MAC.

**Note:** Returned error codes may differ for each specific MAC chip.

**Param** mac [in] Ethernet MAC instance

**Param** buf [in] packet buffer to transmit

**Param** length [in] length of packet

**Return**
- ESP_OK: transmit packet successfully
- ESP_ERR_INVALID_SIZE: number of actually sent bytes differs to expected
- ESP_FAIL: transmit packet failed because some other error occurred

**esp_err_t** (*transmit_vargs*)(esp_eth_mac_t *mac, uint32_t argc, va_list args)

Transmit packet from Ethernet MAC constructed with special parameters at Layer2.

**Note:** Typical intended use case is to make possible to construct a frame from multiple higher layer buffers without a need of buffer reallocations. However, other use cases are not limited.

**Note:** Returned error codes may differ for each specific MAC chip.

**Param** mac [in] Ethernet MAC instance

**Param** argc [in] number variable arguments

**Param** args [in] variable arguments

**Return**
- ESP_OK: transmit packet successfully
- ESP_ERR_INVALID_SIZE: number of actually sent bytes differs to expected
- ESP_FAIL: transmit packet failed because some other error occurred
```

\textit{esp_err_t} (\textbf{*receive})\textit{(esp_eth_mac_t *mac, uint8_t *buf, uint32_t *length)}

Receive packet from Ethernet MAC.

\textbf{Note:} Memory of \texttt{buf} is allocated in the Layer2, make sure it get free after process.

\textbf{Note:} Before this function got invoked, the value of \texttt{"length"} should set by user, equals the size of buffer. After the function returned, the value of \texttt{"length"} means the real length of received data.

\begin{itemize}
  \item \texttt{Param mac [in]} Ethernet MAC instance
  \item \texttt{Param buf [out]} packet buffer which will preserve the received frame
  \item \texttt{Param length [out]} length of the received packet
\end{itemize}

\textbf{Return}

\begin{itemize}
  \item \texttt{ESP_OK:} receive packet successfully
  \item \texttt{ESP_ERR_INVALID_ARG:} receive packet failed because of invalid argument
  \item \texttt{ESP_ERR_INVALID_SIZE:} input buffer size is not enough to hold the incoming data. in this case, value of returned \texttt{"length"} indicates the real size of incoming data.
  \item \texttt{ESP_FAIL:} receive packet failed because some other error occurred
\end{itemize}

\textit{esp_err_t} (\textbf{*read_phy_reg})\textit{(esp_eth_mac_t *mac, uint32_t phy_addr, uint32_t phy_reg, uint32_t *reg_value)}

Read PHY register.

\begin{itemize}
  \item \texttt{Param mac [in]} Ethernet MAC instance
  \item \texttt{Param phy_addr [in]} PHY chip address (0~31)
  \item \texttt{Param phy_reg [in]} PHY register index code
  \item \texttt{Param reg_value [out]} PHY register value
\end{itemize}

\textbf{Return}

\begin{itemize}
  \item \texttt{ESP_OK:} read PHY register successfully
  \item \texttt{ESP_ERR_INVALID_ARG:} read PHY register failed because of invalid argument
  \item \texttt{ESP_ERR_INVALID_STATE:} read PHY register failed because of wrong state of MAC
  \item \texttt{ESP_ERR_TIMEOUT:} read PHY register failed because of timeout
  \item \texttt{ESP_FAIL:} read PHY register failed because some other error occurred
\end{itemize}

\textit{esp_err_t} (\textbf{*write_phy_reg})\textit{(esp_eth_mac_t *mac, uint32_t phy_addr, uint32_t phy_reg, uint32_t reg_value)}

Write PHY register.

\begin{itemize}
  \item \texttt{Param mac [in]} Ethernet MAC instance
  \item \texttt{Param phy_addr [in]} PHY chip address (0~31)
  \item \texttt{Param phy_reg [in]} PHY register index code
  \item \texttt{Param reg_value [in]} PHY register value
\end{itemize}

\textbf{Return}

\begin{itemize}
  \item \texttt{ESP_OK:} write PHY register successfully
  \item \texttt{ESP_ERR_INVALID_ARG:} write PHY register failed because of invalid argument
  \item \texttt{ESP_ERR_INVALID_STATE:} write PHY register failed because of wrong state of MAC
  \item \texttt{ESP_ERR_TIMEOUT:} write PHY register failed because of timeout
  \item \texttt{ESP_FAIL:} write PHY register failed because some other error occurred
\end{itemize}

\textit{esp_err_t} (\textbf{*set_addr})\textit{(esp_eth_mac_t *mac, uint8_t *addr)}

Set MAC address.

\begin{itemize}
  \item \texttt{Param mac [in]} Ethernet MAC instance
  \item \texttt{Param addr [in]} MAC address
\end{itemize}

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Release v5.1.2
Chapter 2. API Reference

Return
- ESP_OK: set MAC address successfully
- ESP_ERR_INVALID_ARG: set MAC address failed because of invalid argument
- ESP_FAIL: set MAC address failed because some other error occurred

```c
esp_err_t (*get_addr)(esp_eth_mac_t *mac, uint8_t *addr)
```
Get MAC address.

- **Param mac** [in] Ethernet MAC instance
- **Param addr** [out] MAC address

Return
- ESP_OK: get MAC address successfully
- ESP_ERR_INVALID_ARG: get MAC address failed because of invalid argument
- ESP_FAIL: get MAC address failed because some other error occurred

```c
esp_err_t (*set_speed)(esp_eth_mac_t *mac, eth_speed_t speed)
```
Set speed of MAC.

- **Param mac** [in] Ethernet MAC instance
- **Param speed** [in] MAC speed

Return
- ESP_OK: set MAC speed successfully
- ESP_ERR_INVALID_ARG: set MAC speed failed because of invalid argument
- ESP_FAIL: set MAC speed failed because some other error occurred

```c
esp_err_t (*set_duplex)(esp_eth_mac_t *mac, eth_duplex_t duplex)
```
Set duplex mode of MAC.

- **Param mac** [in] Ethernet MAC instance
- **Param duplex** [in] MAC duplex

Return
- ESP_OK: set MAC duplex mode successfully
- ESP_ERR_INVALID_ARG: set MAC duplex failed because of invalid argument
- ESP_FAIL: set MAC duplex failed because some other error occurred

```c
esp_err_t (*set_link)(esp_eth_mac_t *mac, eth_link_t link)
```
Set link status of MAC.

- **Param mac** [in] Ethernet MAC instance
- **Param link** [in] Link status

Return
- ESP_OK: set link status successfully
- ESP_ERR_INVALID_ARG: set link status failed because of invalid argument
- ESP_FAIL: set link status failed because some other error occurred

```c
esp_err_t (*set_promiscuous)(esp_eth_mac_t *mac, bool enable)
```
Set promiscuous of MAC.

- **Param mac** [in] Ethernet MAC instance
- **Param enable** [in] set true to enable promiscuous mode; set false to disable promiscuous mode

Return
- ESP_OK: set promiscuous mode successfully
- ESP_FAIL: set promiscuous mode failed because some other error occurred

```c
esp_err_t (*enable_flow_ctrl)(esp_eth_mac_t *mac, bool enable)
```
Enable flow control on MAC layer or not.

- **Param mac** [in] Ethernet MAC instance
Param enable  [in] set true to enable flow control; set false to disable flow control
Return
• ESP_OK: set flow control successfully
• ESP_FAIL: set flow control failed because some error occurred

```
esp_err_t (*set_peer_pause_ability)(esp_eth_mac_t *mac, uint32_t ability)
```
Set the PAUSE ability of peer node.

Param mac  [in] Ethernet MAC instance
Param ability  [in] zero indicates that pause function is supported by link partner; non-zero indicates that pause function is not supported by link partner
Return
• ESP_OK: set peer pause ability successfully
• ESP_FAIL: set peer pause ability failed because some error occurred

```
esp_err_t (*custom_ioctl)(esp_eth_mac_t *mac, uint32_t cmd, void *data)
```
Custom IO function of MAC driver. This function is intended to extend common options of esp_eth_ioctl to cover specifics of MAC chip.

Note: This function may not be assigned when the MAC chip supports only most common set of configuration options.

```
Param mac  [in] Ethernet MAC instance
Param cmd  [in] IO control command
Param data  [inout] address of data for set command or address where to store the data when used with get command
Return
• ESP_OK: process io command successfully
• ESP_ERR_INVALID_ARG: process io command failed because of some invalid argument
• ESP_FAIL: process io command failed because some other error occurred
• ESP_ERR_NOT_SUPPORTED: requested feature is not supported
```

```
esp_err_t (*del)(esp_eth_mac_t *mac)
```
Free memory of Ethernet MAC.

Param mac  [in] Ethernet MAC instance
Return
• ESP_OK: free Ethernet MAC instance successfully
• ESP_FAIL: free Ethernet MAC instance failed because some error occurred

```
struct eth_mac_config_t
```
Configuration of Ethernet MAC object.

Public Members

```
uint32_t sw_reset_timeout_ms
```
Software reset timeout value (Unit: ms)

```
uint32_t rx_task_stack_size
```
Stack size of the receive task
uint32_t rx_task_prio
   Priority of the receive task

uint32_t flags
   Flags that specify extra capability for mac driver

struct eth_esp32_emac_config_t
   EMAC specific configuration.

Public Members

int smi_mdc_gpio_num
   SMI MDC GPIO number, set to -1 could bypass the SMI GPIO configuration

int smi_mdio_gpio_num
   SMI MDIO GPIO number, set to -1 could bypass the SMI GPIO configuration

eth_data_interface_t interface
   EMAC Data interface to PHY (MII/RMII)

typedef struct
   eth_mac_clock_config_t
   EMAC Interface clock configuration

typedef struct
   eth_mac_dma_burst_len_t
   EMAC DMA burst length for both Tx and Rx

Macros

ETH_MAC_FLAG_WORK_WITH_CACHE_DISABLE
   MAC driver can work when cache is disabled

ETH_MAC_FLAG_PIN_TO_CORE
   Pin MAC task to the CPU core where driver installation happened

ETH_MAC_DEFAULT_CONFIG()
   Default configuration for Ethernet MAC object.

ETH_ESP32_EMAC_DEFAULT_CONFIG()
   Default ESP32’s EMAC specific configuration.

Type Definitions

typedef struct esp_eth_mac_s esp_eth_mac_t
   Ethernet MAC.

Enumerations

enum emac_rmii_clock_mode_t
   RMII Clock Mode Options.

Values:
enumerator **EMAC_CLK_DEFAULT**

Default values configured using Kconfig are going to be used when "Default" selected.

enumerator **EMAC_CLK_EXT_IN**

Input RMII Clock from external. EMAC Clock GPIO number needs to be configured when this option is selected.

**Note:** MAC will get RMII clock from outside. Note that ESP32 only supports GPIO0 to input the RMII clock.

enumerator **EMAC_CLK_OUT**

Output RMII Clock from internal APLL Clock. EMAC Clock GPIO number needs to be configured when this option is selected.

enum **emac_rmii_clock_gpio_t**

RMII Clock GPIO number Options.

**Values:**

enumerator **EMAC_CLK_IN_GPIO**

MAC will get RMII clock from outside at this GPIO.

**Note:** ESP32 only supports GPIO0 to input the RMII clock.

enumerator **EMAC_APPL_CLK_OUT_GPIO**

Output RMII Clock from internal APLL Clock available at GPIO0.

**Note:** GPIO0 can be set to output a pre-divided PLL clock (test only!). Enabling this option will configure GPIO0 to output a 50MHz clock. In fact this clock doesn’t have directly relationship with EMAC peripheral. Sometimes this clock won’t work well with your PHY chip. You might need to add some extra devices after GPIO0 (e.g. inverter). Note that outputting RMII clock on GPIO0 is an experimental practice. If you want the Ethernet to work with WiFi, don’t select GPIO0 output mode for stability.

enumerator **EMAC_CLK_OUT_GPIO**

Output RMII Clock from internal APLL Clock available at GPIO16.

enumerator **EMAC_CLK_OUT_180_GPIO**

Inverted Output RMII Clock from internal APLL Clock available at GPIO17.

**Header File**

* components/esp_eth/include/esp_eth_phy.h

**Functions**

```c
esp_eth_phy_t *esp_eth_phy_new_ip101 (const eth_phy_config_t *config)
```

Create a PHY instance of IP101.

**Parameters**

*config - [in] configuration of PHY
Returns

- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

`esp_eth_phy_t *esp_eth_phy_new_rtl8201 (const eth_phy_config_t *config)`
Create a PHY instance of RTL8201.

**Parameters**

- config [in] configuration of PHY

**Returns**

- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

`esp_eth_phy_t *esp_eth_phy_new_lan87xx (const eth_phy_config_t *config)`
Create a PHY instance of LAN87xx.

**Parameters**

- config [in] configuration of PHY

**Returns**

- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

`esp_eth_phy_t *esp_eth_phy_new_dp83848 (const eth_phy_config_t *config)`
Create a PHY instance of DP83848.

**Parameters**

- config [in] configuration of PHY

**Returns**

- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

`esp_eth_phy_t *esp_eth_phy_new_ksz80xx (const eth_phy_config_t *config)`
Create a PHY instance of KSZ80xx.

The phy model from the KSZ80xx series is detected automatically. If the driver is unable to detect a supported model, NULL is returned.

Currently, the following models are supported: KSZ8001, KSZ8021, KSZ8031, KSZ8041, KSZ8051, KSZ8061, KSZ8081, KSZ8091

**Parameters**

- config [in] configuration of PHY

**Returns**

- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

**Structures**

```c
struct esp_eth_phy_s
```

Ethernet PHY.

**Public Members**

```c
esp_err_t (*set_mediator)(esp_eth_phy_t *phy, esp_eth_mediator_t *mediator)
```
Set mediator for PHY.

**Param**

- phy [in] Ethernet PHY instance
- mediator [in] mediator of Ethernet driver

**Return**

- ESP_OK: set mediator for Ethernet PHY instance successfully
- ESP_ERR_INVALID_ARG: set mediator for Ethernet PHY instance failed because of some invalid arguments
The `reset` function:

```c
esp_err_t (*reset)(esp_eth_phy_t *phy)
```

- **Description:** Software reset Ethernet PHY.
- **Parameters:**
  - `in` Ethernet PHY instance
- **Return:**
  - `ESP_OK`: reset Ethernet PHY successfully
  - `ESP_FAIL`: reset Ethernet PHY failed because some error occurred

The `reset_hw` function:

```c
esp_err_t (*reset_hw)(esp_eth_phy_t *phy)
```

- **Description:** Hardware reset Ethernet PHY.
- **Parameters:**
  - `in` Ethernet PHY instance
- **Note:** Hardware reset is mostly done by pull down and up PHY’s nRST pin
- **Return:**
  - `ESP_OK`: reset Ethernet PHY successfully
  - `ESP_FAIL`: reset Ethernet PHY failed because some error occurred

The `init` function:

```c
esp_err_t (*init)(esp_eth_phy_t *phy)
```

- **Description:** Initialize Ethernet PHY.
- **Parameters:**
  - `in` Ethernet PHY instance
- **Return:**
  - `ESP_OK`: initialize Ethernet PHY successfully
  - `ESP_FAIL`: initialize Ethernet PHY failed because some error occurred

The `deinit` function:

```c
esp_err_t (*deinit)(esp_eth_phy_t *phy)
```

- **Description:** Deinitialize Ethernet PHY.
- **Parameters:**
  - `in` Ethernet PHY instance
- **Return:**
  - `ESP_OK`: deinitialize Ethernet PHY successfully
  - `ESP_FAIL`: deinitialize Ethernet PHY failed because some error occurred

The `autonego_ctrl` function:

```c
esp_err_t (*autonego_ctrl)(esp_eth_phy_t *phy, eth_phy_autoneg_cmd_t cmd, bool *autonego_en_stat)
```

- **Description:** Configure auto negotiation.
- **Parameters:**
  - `in` Ethernet PHY instance
  - `in` Configuration command, it is possible to Enable (restart), Disable or get current status of PHY auto negotiation
  - `out` Address where to store current status of auto negotiation configuration
- **Return:**
  - `ESP_OK`: restart auto negotiation successfully
  - `ESP_FAIL`: restart auto negotiation failed because some error occurred
  - `ESP_ERR_INVALID_ARG`: invalid command

The `get_link` function:

```c
esp_err_t (*get_link)(esp_eth_phy_t *phy)
```

- **Description:** Get Ethernet PHY link status.
- **Parameters:**
  - `in` Ethernet PHY instance
- **Return:**
  - `ESP_OK`: get Ethernet PHY link status successfully
  - `ESP_FAIL`: get Ethernet PHY link status failed because some error occurred
### Chapter 2. API Reference

#### esp_err_t (*pwrctl)(esp_eth_phy_t *phy, bool enable)

Power control of Ethernet PHY.

**Param**
- **phy** [in] Ethernet PHY instance
- **enable** [in] set true to power on Ethernet PHY; set false to power off Ethernet PHY

**Return**
- ESP_OK: control Ethernet PHY power successfully
- ESP_FAIL: control Ethernet PHY power failed because some error occurred

#### esp_err_t (*set_addr)(esp_eth_phy_t *phy, uint32_t addr)

Set PHY chip address.

**Param**
- **phy** [in] Ethernet PHY instance
- **addr** [in] PHY chip address

**Return**
- ESP_OK: set Ethernet PHY address successfully
- ESP_FAIL: set Ethernet PHY address failed because some error occurred

#### esp_err_t (*get_addr)(esp_eth_phy_t *phy, uint32_t *addr)

Get PHY chip address.

**Param**
- **phy** [in] Ethernet PHY instance
- **addr** [out] PHY chip address

**Return**
- ESP_OK: get Ethernet PHY address successfully
- ESP_ERR_INVALID_ARG: get Ethernet PHY address failed because of invalid argument

#### esp_err_t (*advertise_pause_ability)(esp_eth_phy_t *phy, uint32_t ability)

Advertise pause function supported by MAC layer.

**Param**
- **phy** [in] Ethernet PHY instance
- **addr** [out] Pause ability

**Return**
- ESP_OK: Advertise pause ability successfully
- ESP_ERR_INVALID_ARG: Advertise pause ability failed because of invalid argument

#### esp_err_t (*loopback)(esp_eth_phy_t *phy, bool enable)

Sets the PHY to loopback mode.

**Param**
- **phy** [in] Ethernet PHY instance
- **enable** [in] enables or disables PHY loopback

**Return**
- ESP_OK: PHY instance loopback mode has been configured successfully
- ESP_FAIL: PHY instance loopback configuration failed because some error occurred

#### esp_err_t (*set_speed)(esp_eth_phy_t *phy, eth_speed_t speed)

Sets PHY speed mode.

**Note:** Autonegotiation feature needs to be disabled prior to calling this function for the new setting to be applied.

**Param**
- **phy** [in] Ethernet PHY instance
- **speed** [in] Speed mode to be set

**Return**
- ESP_OK: PHY instance speed mode has been configured successfully
# Chapter 2. API Reference

- ESP_FAIL: PHY instance speed mode configuration failed because some error occurred

```c
esp_err_t (*set_duplex)(esp_eth_phy_t *phy, eth_duplex_t duplex)
```
Sets PHY duplex mode.

**Note:** Autonegotiation feature needs to be disabled prior to calling this function for the new setting to be applied.

- Param `phy` [in] Ethernet PHY instance
- Param `duplex` [in] Duplex mode to be set
- Return
  - ESP_OK: PHY instance duplex mode has been configured successfully
  - ESP_FAIL: PHY instance duplex mode configuration failed because some error occurred

```c
esp_err_t (*custom_ioctl)(esp_eth_phy_t *phy, uint32_t cmd, void *data)
```
Custom IO function of PHY driver. This function is intended to extend common options of esp_eth_ioctl to cover specifics of PHY chip.

**Note:** This function may not be assigned when the PHY chip supports only most common set of configuration options.

- Param `phy` [in] Ethernet PHY instance
- Param `cmd` [in] IO control command
- Param `data` [inout] address of data for `set` command or address where to store the data when used with `get` command
- Return
  - ESP_OK: process io command successfully
  - ESP_ERR_INVALID_ARG: process io command failed because of some invalid argument
  - ESP_FAIL: process io command failed because some other error occurred
  - ESP_ERR_NOT_SUPPORTED: requested feature is not supported

```c
esp_err_t (*del)(esp_eth_phy_t *phy)
```
Free memory of Ethernet PHY instance.

- Param `phy` [in] Ethernet PHY instance
- Return
  - ESP_OK: free PHY instance successfully
  - ESP_FAIL: free PHY instance failed because some error occurred

```c
struct eth_phy_config_t
```
Ethernet PHY configuration.

## Public Members

- `int32_t phy_addr`
  PHY address, set -1 to enable PHY address detection at initialization stage
### Chapter 2. API Reference

`uint32_t reset_timeout_ms`
Reset timeout value (Unit: ms)

`uint32_t autonego_timeout_ms`
Auto-negotiation timeout value (Unit: ms)

`int reset_gpio_num`
Reset GPIO number, -1 means no hardware reset

#### Macros

- **ESP_ETH_PHY_ADDR_AUTO**
- **ETH_PHY_DEFAULT_CONFIG()**
  
  Default configuration for Ethernet PHY object.

#### Type Definitions

```c
typedef struct esp_eth_phy_s esp_eth_phy_t
```

Ethernet PHY.

#### Enumerations

```c
enum eth_phy_autoneg_cmd_t
```
Auto-negotiation control commands.

**Values:**

- **enumerator ESP_ETH_PHY_AUTONEGO_RESTART**
- **enumerator ESP_ETH_PHY_AUTONEGO_EN**
- **enumerator ESP_ETH_PHY_AUTONEGO_DIS**
- **enumerator ESP_ETH_PHY_AUTONEGO_G_STAT**

#### Header File

- components/esp_eth/include/esp_eth_phy_802_3.h

#### Functions

```c
esp_err_t esp_eth_phy_802_3_reset_hw (phy_802_3_t *phy_802_3, uint32_t reset_assert_us)
```

Performs hardware reset with specific reset pin assertion time.

**Parameters**

- **phy_802_3** – IEEE 802.3 PHY object infostructure
- **reset_assert_us** – Hardware reset pin assertion time

**Returns**

- ESP_OK: reset Ethernet PHY successfully


```c
esp_err_t esp_eth_phy_802_3_detect_phy_addr (esp_eth_mediator_t *eth, int *detected_addr)
```

Detect PHY address.

**Parameters**

- `eth` – Mediator of Ethernet driver
- `detected_addr` – [out] a valid address after detection

**Returns**

- ESP_OK: detect phy address successfully
- ESP_ERR_INVALID_ARG: invalid parameter
- ESP_ERR_NOT_FOUND: can’t detect any PHY device
- ESP_FAIL: detect phy address failed because some error occurred

```c
esp_err_t esp_eth_phy_802_3_basic_phy_init (phy_802_3_t *phy_802_3)
```

Performs basic PHY chip initialization.

**Note:** It should be called as the first function in PHY specific driver instance

**Parameters** `phy_802_3` – IEEE 802.3 PHY object infostructure

**Returns**

- ESP_OK: initialized Ethernet PHY successfully
- ESP_FAIL: initialization of Ethernet PHY failed because some error occurred
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NOT_FOUND: PHY device not detected
- ESP_ERR_TIMEOUT: MII Management read/write operation timeout
- ESP_ERR_INVALID_STATE: PHY is in invalid state to perform requested operation

```c
esp_err_t esp_eth_phy_802_3_basic_phy_deinit (phy_802_3_t *phy_802_3)
```

Performs basic PHY chip de-initialization.

**Note:** It should be called as the last function in PHY specific driver instance

**Parameters** `phy_802_3` – IEEE 802.3 PHY object infostructure

**Returns**

- ESP_OK: de-initialized Ethernet PHY successfully
- ESP_FAIL: de-initialization of Ethernet PHY failed because some error occurred
- ESP_ERR_TIMEOUT: MII Management read/write operation timeout
- ESP_ERR_INVALID_STATE: PHY is in invalid state to perform requested operation

```c
esp_err_t esp_eth_phy_802_3_read_oui (phy_802_3_t *phy_802_3, uint32_t *oui)
```

Reads raw content of OUI field.

**Parameters**

- `phy_802_3` – IEEE 802.3 PHY object infostructure
- `oui` – [out] OUI value

**Returns**

- ESP_OK: OUI field read successfully
- ESP_FAIL: OUI field read failed because some error occurred
- ESP_ERR_INVALID_ARG: invalid oui argument
- ESP_ERR_TIMEOUT: MII Management read/write operation timeout
- ESP_ERR_INVALID_STATE: PHY is in invalid state to perform requested operation

```c
esp_err_t esp_eth_phy_802_3_read_manufac_info (phy_802_3_t *phy_802_3, uint8_t *model, uint8_t *rev)
```

Reads manufacturer’s model and revision number.

**Parameters**
Chapter 2. API Reference

- **phy_802_3** - IEEE 802.3 PHY object info structure
- **model** [out] Manufacturer’s model number (can be NULL when not required)
- **rev** [out] Manufacturer’s revision number (can be NULL when not required)

**Returns**
- ESP_OK: Manufacturer’s info read successfully
- ESP_FAIL: Manufacturer’s info read failed because some error occurred
- ESP_ERR_TIMEOUT: MII Management read/write operation timeout
- ESP_ERR_INVALID_STATE: PHY is in invalid state to perform requested operation

```c
phy_802_3_t *esp_eth_phy_into_phy_802_3 (esp_eth_phy_t *phy)
```

Returns address to parent IEEE 802.3 PHY object infostructure.

**Parameters**
- `phy` - Ethernet PHY instance

**Returns**
- `phy_802_3_t*` address to parent IEEE 802.3 PHY object infostructure

```c
esp_err_t esp_eth_phy_802_3_obj_config_init (phy_802_3_t *phy_802_3, const eth_phy_config_t *config)
```

Initializes configuration of parent IEEE 802.3 PHY object infostructure.

**Parameters**
- `phy_802_3` - Address to IEEE 802.3 PHY object infostructure
- `config` - Configuration of the IEEE 802.3 PHY object

**Returns**
- ESP_OK: configuration initialized successfully
- ESP_ERR_INVALID_ARG: invalid `config` argument

**Structures**

```c
struct phy_802_3_t
```

IEEE 802.3 PHY object infostructure.

**Public Members**

```c
esp_eth_phy_t *parent
```

Parent Ethernet PHY instance

```c
esp_eth_mediator_t *eth
```

Mediator of Ethernet driver

```c
int addr
```

PHY address

```c
uint32_t reset_timeout_ms
```

Reset timeout value (Unit: ms)

```c
uint32_t autonego_timeout_ms
```

Auto-negotiation timeout value (Unit: ms)

```c
eth_link_t link_status
```

Current Link status

```c
int reset_gpio_num
```

Reset GPIO number, -1 means no hardware reset
Chapter 2. API Reference

Header File

- components/esp_eth/include/esp_eth_netif_glue.h

Functions

`esp_eth_netif_glue_handle_t esp_eth_new_netif_glue(esp_eth_handle_t eth_hdl)`

Create a netif glue for Ethernet driver.

**Note:** netif glue is used to attach io driver to TCP/IP netif

**Parameters**

- `eth_hdl` - Ethernet driver handle

**Returns**

- `glue object`, which inherits `esp_netif_driver_base_t`

`esp_err_t esp_eth_del_netif_glue(esp_eth_netif_glue_handle_t eth_netif_glue)`

Delete netif glue of Ethernet driver.

**Parameters**

- `eth_netif_glue` - netif glue

**Returns**

- `-ESP_OK`: delete netif glue successfully

Type Definitions

typedef struct esp_eth_netif_glue_t *esp_eth_netif_glue_handle_t

- Handle of netif glue - an intermediate layer between netif and Ethernet driver.

Code examples for the Ethernet API are provided in the `ethernet` directory of ESP-IDF examples.

2.5.3 Thread

Thread

**Introduction**

Thread is an IP-based mesh networking protocol. It’s based on the 802.15.4 physical and MAC layer.

**Application Examples**

The `openthread` directory of ESP-IDF examples contains the following applications:

- The OpenThread interactive shell `openthread/ot_cli`.
- The Thread border router `openthread/ot_br`.
- The Thread radio co-processor `openthread/ot_rcp`.

**API Reference**

For manipulating the Thread network, the OpenThread api shall be used. The OpenThread api docs can be found at the OpenThread official website.

ESP-IDF provides extra apis for launching and managing the OpenThread stack, binding to network interfaces and border routing features.

**Header File**

- components/openthread/include/esp_openthread.h

**Functions**

Submit Document Feedback
**esp_err_t esp_openthread_init**(const esp_openthread_platform_config_t *init_config)

Initializes the full OpenThread stack.

**Note:** The OpenThread instance will also be initialized in this function.

**Parameters** init_config [in] The initialization configuration.

**Returns**
- ESP_OK on success
- ESP_ERR_NO_MEM if allocation has failed
- ESP_ERR_INVALID_ARG if radio or host connection mode not supported
- ESP_ERR_INVALID_STATE if already initialized

**esp_err_t esp_openthread_auto_start**(otOperationalDatasetTlvs *datasetTlvs)

Starts the Thread protocol operation and attaches to a Thread network.

**Parameters** datasetTlvs [in] The operational dataset (TLV encoded), if it’s NULL, the function will generate the dataset based on the configurations from kconfig.

**Returns**
- ESP_OK on success
- ESP_FAIL on failures

**esp_err_t esp_openthread_launch_mainloop**(void)

Launches the OpenThread main loop.

**Note:** This function will not return unless error happens when running the OpenThread stack.

**Returns**
- ESP_OK on success
- ESP_ERR_NO_MEM if allocation has failed
- ESP_FAIL on other failures

**esp_err_t esp_openthread_deinit**(void)

This function performs OpenThread stack and platform driver deinitialization.

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if not initialized

**esp_openthread_get_instance**(void)

This function acquires the underlying OpenThread instance.

**Note:** This function can be called on other tasks without lock.

**Returns** The OpenThread instance pointer

**Header File**
- components/openthread/include/esp_openthread_types.h

**Structures**

**struct esp_openthread_role_changed_event_t**

OpenThread role changed event data.
Public Members

otDeviceRole previous_role
  Previous Thread role

otDeviceRole current_role
  Current Thread role

struct esp_openthread_mainloop_context_t
  This structure represents a context for a select() based mainloop.

Public Members

fd_set read_fds
  The read file descriptors

fd_set write_fds
  The write file descriptors

fd_set error_fds
  The error file descriptors

int max_fd
  The max file descriptor

struct timeval timeout
  The timeout

struct esp_openthread_uart_config_t
  The uart port config for OpenThread.

Public Members

uart_port_t port
  UART port number

uart_config_t uart_config
  UART configuration, see uart_config_t docs

gpio_num_t rx_pin
  UART RX pin

gpio_num_t tx_pin
  UART TX pin

struct esp_openthread_spi_host_config_t
  The spi port config for OpenThread.
Public Members

`spi_host_device_t` **host_device**
SPI host device

`spi_dma_chan_t` **dma_channel**
DMA channel

`spi_bus_config_t` **spi_interface**
SPI bus

`spi_device_interface_config_t` **spi_device**
SPI peripheral device

`gpio_num_t` **intr_pin**
SPI interrupt pin

struct **esp_openthread_spi_slave_config_t**
The spi slave config for OpenThread.

Public Members

`spi_host_device_t` **host_device**
SPI host device

`spi_bus_config_t` **bus_config**
SPI bus config

`spi_slave_interface_config_t` **slave_config**
SPI slave config

`gpio_num_t` **intr_pin**
SPI interrupt pin

struct **esp_openthread_radio_config_t**
The OpenThread radio configuration.

Public Members

`esp_openthread_radio_mode_t` **radio_mode**
The radio mode

`esp_openthread_uart_config_t` **radio_uart_config**
The uart configuration to RCP

`esp_openthread_spi_host_config_t` **radio_spi_config**
The spi configuration to RCP
Chapter 2. API Reference

struct esp_openthread_host_connection_config_t
The OpenThread host connection configuration.

Public Members

esp_openthread_host_connection_mode_t host_connection_mode
The host connection mode

esp_openthread_uart_config_t host_uart_conf gin
The uart configuration to host

usb_serial_jtag_driver_config_t host_usb_config
The usb configuration to host

esp_openthread_spi_slave_config_t spi_slave_config
The spi configuration to host

struct esp_openthread_port_config_t
The OpenThread port specific configuration.

Public Members

const char *storage_partition_name
The partition for storing OpenThread dataset

uint8_t netif_queue_size
The packet queue size for the network interface

uint8_t task_queue_size
The task queue size

struct esp_openthread_platform_config_t
The OpenThread platform configuration.

Public Members

esp_openthread_radio_config_t radio_config
The radio configuration

esp_openthread_host_connection_config_t host_config
The host connection configuration

esp_openthread_port_config_t port_config
The port configuration
Type Definitions

typedef void (*esp_openthread_rcp_failure_handler)(void)

Enumerations

enum esp_openthread_event_t

OpenThread event declarations.

Values:

enumerator OPENTHREAD_EVENT_START
  OpenThread stack start

enumerator OPENTHREAD_EVENT_STOP
  OpenThread stack stop

enumerator OPENTHREAD_EVENT_DETACHED
  OpenThread detached

enumerator OPENTHREAD_EVENT_ATTACHED
  OpenThread attached

enumerator OPENTHREAD_EVENT_ROLE_CHANGED
  OpenThread role changed

enumerator OPENTHREAD_EVENT_IF_UP
  OpenThread network interface up

enumerator OPENTHREAD_EVENT_IF_DOWN
  OpenThread network interface down

enumerator OPENTHREAD_EVENT_GOT_IP6
  OpenThread stack added IPv6 address

enumerator OPENTHREAD_EVENT_LOST_IP6
  OpenThread stack removed IPv6 address

enumerator OPENTHREAD_EVENT_MULTICAST_GROUP_JOIN
  OpenThread stack joined IPv6 multicast group

enumerator OPENTHREAD_EVENT_MULTICAST_GROUP_LEAVE
  OpenThread stack left IPv6 multicast group

enumerator OPENTHREAD_EVENT_TREL_ADD_IP6
  OpenThread stack added TREL IPv6 address

enumerator OPENTHREAD_EVENT_TREL_REMOVE_IP6
  OpenThread stack removed TREL IPv6 address
enumerator **OPENTHREAD_EVENT_TREL_MULTICAST_GROUP_JOIN**
OpenThread stack joined TREL IPv6 multicast group

enumerator **OPENTHREAD_EVENT_SET_DNS_SERVER**
OpenThread stack set DNS server

enum **esp_openthread_radio_mode_t**
The radio mode of OpenThread.

*Values:*

enumerator **RADIO_MODE_NATIVE**
Use the native 15.4 radio

enumerator **RADIO_MODE_UART_RCP**
UART connection to a 15.4 capable radio co-processor (RCP)

enumerator **RADIO_MODE_SPI_RCP**
SPI connection to a 15.4 capable radio co-processor (RCP)

enumerator **RADIO_MODE_MAX**
Using for parameter check

enum **esp_openthread_host_connection_mode_t**
How OpenThread connects to the host.

*Values:*

enumerator **HOST_CONNECTION_MODE_NONE**
Disable host connection

enumerator **HOST_CONNECTION_MODE_CLI_UART**
CLI UART connection to the host

enumerator **HOST_CONNECTION_MODE_CLI_USB**
CLI USB connection to the host

enumerator **HOST_CONNECTION_MODE_RCP_UART**
RCP UART connection to the host

enumerator **HOST_CONNECTION_MODE_RCP_SPI**
RCP SPI connection to the host

enumerator **HOST_CONNECTION_MODE_MAX**
Using for parameter check

**Header File**

- components/openthread/include/esp_openthread_lock.h
## Functions

### `esp_err_t esp_openthread_lock_init (void)`

This function initializes the OpenThread API lock.

**Returns**
- ESP_OK on success
- ESP_ERR_NO_MEM if allocation has failed
- ESP_ERR_INVALID_STATE if already initialized

### void `esp_openthread_lock_deinit (void)`

This function deinitializes the OpenThread API lock.

### bool `esp_openthread_lock_acquire (TickType_t block_ticks)`

This function acquires the OpenThread API lock.

**Parameters**
- `block_ticks` - [in] The maximum number of RTOS ticks to wait for the lock.

**Returns**
- True on lock acquired
- False on failing to acquire the lock with the timeout.

### void `esp_openthread_lock_release (void)`

This function releases the OpenThread API lock.

### bool `esp_openthread_task_switching_lock_acquire (TickType_t block_ticks)`

This function acquires the OpenThread API task switching lock.

**Note:** In OpenThread API context, it waits for some actions to be done in other tasks (like lwip), after task switching, it needs to call OpenThread API again. Normally it’s not allowed, since the previous OpenThread API lock is not released yet. This task_switching lock allows the OpenThread API can be called in this case.

**Note:** Please use `esp_openthread_lock_acquire()` for normal cases.

**Parameters**
- `block_ticks` - [in] The maximum number of RTOS ticks to wait for the lock.

**Returns**
- True on lock acquired
- False on failing to acquire the lock with the timeout.

### void `esp_openthread_task_switching_lock_release (void)`

This function releases the OpenThread API task switching lock.

**Header File**
- components/openthread/include/esp_openthread_netif_glue.h

### Functions

### `void * esp_openthread_netif_glue_init (const esp_openthread_platform_config_t *config)`

This function initializes the OpenThread network interface glue.

**Parameters**
- `config` - [in] The platform configuration.

**Returns**
- glue pointer on success
Chapter 2. API Reference

- NULL on failure

```c
void esp_openthread_netif_glue_deinit (void)
```

This function deinitializes the OpenThread network interface glue.

```c
esp_netif_t *esp_openthread_get_netif (void)
```

This function acquires the OpenThread netif.

**Returns** The OpenThread netif or NULL if not initialized.

### Macros

- `ESP_NETIF_INHERENT_DEFAULT_OPENTHREAD ()`
  
  Default configuration reference of OT esp-netif.

- `ESP_NETIF_DEFAULT_OPENTHREAD ()`

### Header File

- `components/openthread/include/esp_openthread_border_router.h`

### Functions

- `void esp_openthread_set Backbone_netif (esp_netif_t *backbone_netif)`
  
  Sets the backbone interface used for border routing.
  
  **Note:** This function must be called before `esp_openthread_init`

  **Parameters**
  
  - `backbone_netif` [in] The backbone network interface (WiFi or ethernet)

- `esp_err_t esp_openthread_border_router_init (void)`
  
  Initializes the border router features of OpenThread.
  
  **Note:** Calling this function will make the device behave as an OpenThread border router. Kconfig option `CONFIG_OPENTHREAD_BORDER_ROUTER` is required.

  **Returns**
  
  - ESP_OK on success
  - ESP_ERR_NOT_SUPPORTED if feature not supported
  - ESP_ERR_INVALID_STATE if already initialized
  - ESP_FAIL on other failures

- `esp_err_t esp_openthread_border_router_deinit (void)`
  
  Deinitializes the border router features of OpenThread.

  **Returns**
  
  - ESP_OK on success
  - ESP_ERR_INVALID_STATE if not initialized
  - ESP_FAIL on other failures

- `esp_netif_t *esp_openthread_get Backbone_netif (void)`
  
  Gets the backbone interface of OpenThread border router.

  **Returns** The backbone interface or NULL if border router not initialized.

- `void esp_openthread_register_rcp_failure_handler (esp_openthread_rcp_failure_handler handler)`

  Registers the callback for RCP failure.
void esp_openthread_rcp_deinit (void)

Deinitializes the connection to RCP.

Thread is an IPv6-based mesh networking technology for IoT. Code examples for the Thread API are provided in the openthread directory of ESP-IDF examples.

2.5.4 ESP-NETIF

ESP-NETIF

The purpose of ESP-NETIF library is twofold:

- It provides an abstraction layer for the application on top of the TCP/IP stack. This will allow applications to choose between IP stacks in the future.
- The APIs it provides are thread safe, even if the underlying TCP/IP stack APIs are not.

ESP-IDF currently implements ESP-NETIF for the lwIP TCP/IP stack only. However, the adapter itself is TCP/IP implementation agnostic and different implementations are possible.

It is also possible to use a custom TCP/IP stack with ESP-IDF, provided it implements BSD API. For more information on building ESP-IDF without lwIP, please refer to `components/esp_netif_stack/README.md`.

Some ESP-NETIF API functions are intended to be called by application code, for example to get/set interface IP addresses, configure DHCP. Other functions are intended for internal ESP-IDF use by the network driver layer.

In many cases, applications do not need to call ESP-NETIF APIs directly as they are called from the default network event handlers.

ESP-NETIF architecture

```
| (A) USER CODE |
| Apps |

................. init settings events |
+-------------------------------+ * |
| * | |

---------------------

| new/config get/set/apps |
| * | init |

...*

| | Apps (DHCP, SNTF) |

| | | *

| | init |

**|

| start |******* event handler |*******| DHCP |

| | stop |

| | NETIF |

| | +-----|

| glue|--<-| esp_netif_transmit |--<------| netif_output |

| | netif_input |

| | netif_input |
```

(continues on next page)
Data and event flow in the diagram

- Initialization line from user code to ESP-NETIF and communication driver
- Data packets going from communication media to TCP/IP stack and back
- Events aggregated in ESP-NETIF propagates to driver, user code and network stack
- User settings and runtime configuration

ESP-NETIF interaction

A) User code, boiler plate  Overall application interaction with a specific IO driver for communication media and configured TCP/IP network stack is abstracted using ESP-NETIF APIs and outlined as below:

A) Initialization code

1) Initializes IO driver
2) Creates a new instance of ESP-NETIF and configure with
   - ESP-NETIF specific options (flags, behaviour, name)
   - Network stack options (netif init and input functions, not publicly available)
   - IO driver specific options (transmit, free rx buffer functions, IO driver handle)
3) Attaches the IO driver handle to the ESP-NETIF instance created in the above steps
4) Configures event handlers
   - use default handlers for common interfaces defined in IO drivers; or define a specific handlers for customised behaviour/new interfaces
   - register handlers for app related events (such as IP lost/acquired)

B) Interaction with network interfaces using ESP-NETIF API

- Getting and setting TCP/IP related parameters (DHCP, IP, etc)
- Receiving IP events (connect/disconnect)
- Controlling application lifecycle (set interface up/down)
B) Communication driver, IO driver, media driver  Communication driver plays these two important roles in relation with ESP-NETIF:

1) Event handlers: Define behaviour patterns of interaction with ESP-NETIF (for example: ethernet link-up -> turn netif on)
2) Glue IO layer: Adapts the input/output functions to use ESP-NETIF transmit, receive and free receive buffer
   • Installs driver_transmit to appropriate ESP-NETIF object, so that outgoing packets from network stack are passed to the IO driver
   • Calls esp_netif_receive() to pass incoming data to network stack

C) ESP-NETIF  ESP-NETIF is an intermediary between an IO driver and a network stack, connecting packet data path between these two. As that it provides a set of interfaces for attaching a driver to ESP-NETIF object (runtime) and configuring a network stack (compile time). In addition to that a set of API is provided to control network interface lifecycle and its TCP/IP properties. As an overview, the ESP-NETIF public interface could be divided into these 6 groups:

1) Initialization APIs (to create and configure ESP-NETIF instance)
2) Input/Output API (for passing data between IO driver and network stack)
3) Event or Action API
   • Used for network interface lifecycle management
   • ESP-NETIF provides building blocks for designing event handlers
4) Setters and Getters for basic network interface properties
5) Network stack abstraction: enabling user interaction with TCP/IP stack
   • Set interface up or down
   • DHCP server and client API
   • DNS API
   • \textit{SNTP API}
6) Driver conversion utilities

D) Network stack  Network stack has no public interaction with application code with regard to public interfaces and shall be fully abstracted by ESP-NETIF API.

E) ESP-NETIF L2 TAP Interface  The ESP-NETIF L2 TAP interface is ESP-IDF mechanism utilized to access Data Link Layer (L2 per OSI/ISO) for frame reception and transmission from user application. Its typical usage in embedded world might be implementation of non-IP related protocols such as PTP, Wake on LAN and others. Note that only Ethernet (IEEE 802.3) is currently supported.

From user perspective, the ESP-NETIF L2 TAP interface is accessed using file descriptors of VFS which provides a file-like interfacing (using functions like \texttt{open()}, \texttt{read()}, \texttt{write()}, etc). Refer to \textit{Virtual filesystem component} to learn more.

There is only one ESP-NETIF L2 TAP interface device (pathname) available. However multiple file descriptors with different configuration can be opened at a time since the ESP-NETIF L2 TAP interface can be understood as generic entry point to Layer 2 infrastructure. Important is then specific configuration of particular file descriptor. It can be configured to give an access to specific Network Interface identified by \texttt{if\_key} (e.g. \texttt{ETH\_DEF}) and to filter only specific frames based on their type (e.g. Ethernet type in case of IEEE 802.3). Filtering only specific frames is crucial since the ESP-NETIF L2 TAP needs to exist along with IP stack and so the IP related traffic (IP, ARP, etc.) should not be passed directly to the user application. Even though such option is still configurable, it is not recommended in standard use cases. Filtering is also advantageous from a perspective the user’s application gets access only to frame types it is interested in and the remaining traffic is either passed to other L2 TAP file descriptors or to IP stack.

\textbf{ESP-NETIF L2 TAP Interface Usage Manual}
Initialization

To be able to use the ESP-NETIF L2 TAP interface, it needs to be enabled in Kconfig by `CONFIG_ESP_NETIF_L2_TAP` first and then registered by `esp_vfs_l2tap_intf_register()` prior usage of any VFS function.

**open()**

Once the ESP-NETIF L2 TAP is registered, it can be opened at path name “/dev/net/tap”. The same path name can be opened multiple times up to `CONFIG_ESP_NETIF_L2_TAP_MAX_FDS` and multiple file descriptors with different configuration may access the Data Link Layer frames.

The ESP-NETIF L2 TAP can be opened with `O_NONBLOCK` file status flag to the `read()` does not block. Note that the `write()` may block in current implementation when accessing a Network interface since it is a shared resource among multiple ESP-NETIF L2 TAP file descriptors and IP stack, and there is currently no queuing mechanism deployed. The file status flag can be retrieved and modified using `fcntl()`.

On success, `open()` returns the new file descriptor (a nonnegative integer). On error, `-1` is returned and `errno` is set to indicate the error.

**ioctl()**

The newly opened ESP-NETIF L2 TAP file descriptor needs to be configured prior its usage since it is not bounded to any specific Network Interface and no frame type filter is configured. The following configuration options are available to do so:

- `L2TAP_S_INTF_DEVICE` - bounds the file descriptor to specific Network Interface which is identified by its `if_key`. ESP-NETIF Network Interface `if_key` is passed to `ioctl()` as the third parameter. Note that default Network Interfaces `if_key`s used in ESP-IDF can be found in `esp_netif/include/esp_netif_defaults.h`.
- `L2TAP_S_DEVICE_DRV_HNDL` - is other way how to bound the file descriptor to specific Network Interface. In this case the Network interface is identified directly by IO Driver handle (e.g. `esp_eth_handle_t` in case of Ethernet). The IO Driver handle is passed to `ioctl()` as the third parameter.
- `L2TAP_S_RCV_FILTER` - sets the filter to frames with this type to be passed to the file descriptor. In case of Ethernet frames, the frames are to be filtered based on Length/Ethernet type field. In case the filter value is set less than or equal to 0x05DC, the Ethernet type field is considered to represent IEEE802.3 Length Field and all frames with values in interval <0, 0x05DC> at that field are to be passed to the file descriptor. The IEEE802.2 logical link control (LLC) resolution is then expected to be performed by user’s application. In case the filter value is set greater than 0x05DC, the Ethernet type field is considered to represent protocol identification and only frames which are equal to the set value are to be passed to the file descriptor.

All above set configuration options have getter counterpart option to read the current settings.

**Warning:** The file descriptor needs to be firstly bounded to specific Network Interface by `L2TAP_S_INTFDEVICE` or `L2TAP_S_DEVICE_DRV_HNDL` to be `L2TAP_S_RCV_FILTER` option available.

**Note:** VLAN tagged frames are currently not recognized. If user needs to process VLAN tagged frames, they need set filter to be equal to VLAN tag (i.e. 0x8100 or 0x88A8) and process the VLAN tagged frames in user application.

**Note:** `L2TAP_S_DEVICE_DRV_HNDL` is particularly useful when user’s application does not require usage of IP stack and so ESP-NETIF is not required to be initialized too. As a result, Network Interface cannot be identified by its `if_key` and hence it needs to be identified directly by its IO Driver handle.

On success, `ioctl()` returns 0. On error, `-1` is returned, and `errno` is set to indicate the error.

**EBADF** - not a valid file descriptor.

**EACCES** - option change is denied in this state (e.g. file descriptor has not be bounded to Network interface yet).

**EINVAL** - invalid configuration argument. Ethernet type filter is already used by other file descriptor on that same Network interface.
ENODEV - no such Network Interface which is tried to be assigned to the file descriptor exists.
ENOSYS - unsupported operation, passed configuration option does not exists.

fcntl()  
fcntl() is used to manipulate with properties of opened ESP-NETIF L2 TAP file descriptor.

The following commands manipulate the status flags associated with file descriptor:

• F_GETFD - the function returns the file descriptor flags, the third argument is ignored.
• F_SETFD - sets the file descriptor flags to the value specified by the third argument. Zero is returned.

On error, -1 is returned, and errno is set to indicate the error.
EBADF - not a valid file descriptor.
ENOSYS - unsupported command.

read()  
Opened and configured ESP-NETIF L2 TAP file descriptor can be accessed by read() to get inbound frames. The read operation can be either blocking or non-blocking based on actual state of O_NONBLOCK file status flag. When the file status flag is set blocking, the read operation waits until a frame is received and context is switched to other task. When the file status flag is set non-blocking, the read operation returns immediately. In such case, either a frame is returned if it was already queued or the function indicates the queue is empty. The number of queued frames associated with one file descriptor is limited by CONFIG_ESP_NETIF_L2_TAP_RX_QUEUE_SIZE Kconfig option. Once the number of queued frames reach configured threshold, the newly arriving frames are dropped until the queue has enough room to accept incoming traffic (Tail Drop queue management).

On success, read() returns the number of bytes read. Zero is returned when size of the destination buffer is 0. On error, -1 is returned, and errno is set to indicate the error.
EBADF - not a valid file descriptor.
EAGAIN - the file descriptor has been marked non-blocking (O_NONBLOCK), and the read would block.

write()  
A raw Data Link Layer frame can be sent to Network Interface via opened and configured ESP-NETIF L2 TAP file descriptor. User’s application is responsible to construct the whole frame except for fields which are added automatically by the physical interface device. The following fields need to be constructed by the user’s application in case of Ethernet link: source/destination MAC addresses, Ethernet type, actual protocol header and user data. See below for more information about Ethernet frame structure.

<table>
<thead>
<tr>
<th>Destination MAC</th>
<th>Source MAC</th>
<th>Type/Length</th>
<th>Payload (protocol header/ data) ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>6B</td>
<td>6B</td>
<td>2B</td>
<td>0-1486B</td>
</tr>
</tbody>
</table>

In other words, there is no additional frame processing performed by the ESP-NETIF L2 TAP interface. It only checks the Ethernet type of the frame is the same as the filter configured in the file descriptor. If the Ethernet type is different, an error is returned and the frame is not sent. Note that the write() may block in current implementation when accessing a Network interface since it is a shared resource among multiple ESP-NETIF L2 TAP file descriptors and IP stack, and there is currently no queuing mechanism deployed.

On success, write() returns the number of bytes written. Zero is returned when size of the input buffer is 0. On error, -1 is returned, and errno is set to indicate the error.
EBADF - not a valid file descriptor.
EBADMSG - Ethernet type of the frame is different then file descriptor configured filter.
EIO - Network interface not available or busy.
close()  Opened ESP-NETIF L2 TAP file descriptor can be closed by the close() to free its allocated resources. The ESP-NETIF L2 TAP implementation of close() may block. On the other hand, it is thread safe and can be called from different task than the file descriptor is actually used. If such situation occurs and one task is blocked in I/O operation and another task tries to close the file descriptor, the first task is unblocked. The first’s task read operation then ends with error.

On success, close() returns zero. On error, -1 is returned, and errno is set to indicate the error.

EBADF - not a valid file descriptor.

select()  Select is used in a standard way, just CONFIG_VFS_SUPPORT_SELECT needs to be enabled to be the select() function available.

SNTP API  You can find a brief introduction to SNTP in general, its initialization code and basic modes in SNTP Time Synchronization section in the System Time Document.

This section provides more details about specific use cases of SNTP service, with statically configured servers, or using DHCP provided servers, or both. The workflow is usually very simple:

1) Initialize and configure the service using esp_netif_sntp_init().
2) Start the service via esp_netif_sntp_start(). This step is not needed if we auto-started the service in the previous step (default). It’s useful to start the service explicitly after connecting, if we want to use DHCP obtained NTP servers. (This option needs to be enabled before connecting, but SNTP service should be started after)
3) Wait for the system time to synchronize using esp_netif_sntp_sync_wait() (only if needed).
4) Stop and destroy the service using esp_netif_sntp_deinit().

Basic mode with statically defined server(s)  Initialize the module with the default configuration after connecting to network. Note that it’s possible to provide multiple NTP servers in the configuration struct:

```c
esp_sntp_config_t config = ESP_NETIF_SNTP_DEFAULT_CONFIG_MULTIPLE(2,
    ESP_SNTP_SERVER_LIST("time.windows.com", "pool.ntp.org"),
    ESP_NETIF_SNTP_DEFAULT_CONFIG_MULTIPLE(1,
    ESP_SNTP_SERVER_LIST("time.windows.com", "pool.ntp.org"),
    esp_netif_sntp_init(&config);
```

Note:  If we want to configure multiple SNTP servers, we have to update lwIP configuration CON-
FIG_LWIP_SNTP_MAX_SERVERS.

Use DHCP obtained SNTP server(s)  First of all, we have to enable lwIP configuration option CON-
FIG_LWIP_DHCP_GET_NTP_SRV. Then we have to initialize the SNTP module with the DHCP option and no NTP server:

```c
esp_sntp_config_t config = ESP_NETIF_SNTP_DEFAULT_CONFIG_MULTIPLE(0, {});
config.start = false; // start SNTP service explicitly
config.server_from_dhcp = true; // accept NTP offer from DHCP server
esp_netif_sntp_init(&config);
```

Then, once we’re connected, we could start the service using:

```c
esp_netif_sntp_start();
```

Note:  It’s also possible to start the service during initialization (default config.start=true). This would likely cause the initial SNTP request to fail (since we are not connected yet) and thus some backoff time for subsequent requests.
Use both static and dynamic servers

Very similar to the scenario above (DHCP provided SNTP server), but in this configuration we need to make sure that the static server configuration is refreshed when obtaining NTP servers by DHCP. The underlying lwIP code cleans up the rest of the list of NTP servers when DHCP provided information gets accepted. Thus the ESP-NETIF SNTP module saves the statically configured server(s) and reconfigures them after obtaining DHCP lease.

The typical configuration now looks as per below, providing the specific IP EVENT to update the config and index of the first server to reconfigure (for example setting config.index_of_first_server=1 would keep DHCP provided server at index 0, and the statically configured server at index 1).

```c
esp_sntp_config_t config = ESP_NETIF_SNTP_DEFAULT_CONFIG("pool.ntp.org");
config.start = false; // start SNTP service explicitly
~(after connecting)
config.server_from_dhcp = true; // accept NTP offers from DHCP server
config.renew_servers_after_new_IP = true; // let esp-netif update configured
~SNTP server(s) after receiving DHCP lease
config.index_of_first_server = 1; // updates from server num 1, leaving
~server 0 (from DHCP) intact
config.ip_event_to_renew = IP_EVENT_STA_GOT_IP; // IP event on which we refresh
~the configuration
```

Then we start the service normally with `esp_netif_sntp_start()`.

ESP-NETIF programmer’s manual

Please refer to the example section for basic initialization of default interfaces:

- WiFi Station: wifi/getting_started/station/main/station_example_main.c
- Ethernet: ethernet/basic/main/ethernet_example_main.c
- L2TAP: protocols/l2tap/main/l2tap_main.c
- WiFi Access Point: wifi/getting_started/softAP/main/softap_example_main.c

For more specific cases please consult this guide: ESP-NETIF Custom I/O Driver.

WiFi default initialization

The initialization code as well as registering event handlers for default interfaces, such as softAP and station, are provided in separate APIs to facilitate simple startup code for most applications:

- `esp_netif_create_default_wifi_sta()`  
- `esp_netif_create_default_wifi_ap()`

Please note that these functions return the `esp_netif` handle, i.e. a pointer to a network interface object allocated and configured with default settings, which as a consequence, means that:

- The created object has to be destroyed if a network de-initialization is provided by an application using `esp_netif_destroy_default_wifi()`.
- These default interfaces must not be created multiple times, unless the created handle is deleted using `esp_netif_destroy()`.
- When using WiFi in AP+STA mode, both these interfaces has to be created.

API Reference

Header File

- `components/esp_netif/include/esp_netif.h`
Chapter 2. API Reference

Functions

```c
esp_err_t esp_netif_init (void)
```

Initialize the underlying TCP/IP stack.

**Note:** This function should be called exactly once from application code, when the application starts up.

**Returns**

- ESP_OK on success
- ESP_FAIL if initializing failed

```c
esp_err_t esp_netif_deinit (void)
```

Deinitialize the esp-netif component (and the underlying TCP/IP stack)

**Note:** Deinitialization is not supported yet

**Returns**

- ESP_ERR_INVALID_STATE if esp_netif not initialized
- ESP_ERR_NOT_SUPPORTED otherwise

```c
esp_netif_t* esp_netif_new (const esp_netif_config_t* esp_netif_config)
```

Creates an instance of new esp-netif object based on provided config.

**Parameters**

- `esp_netif_config` - pointer to the esp-netif configuration

**Returns**

- pointer to esp-netif object on success
- NULL otherwise

```c
void esp_netif_destroy (esp_netif_t* esp_netif)
```

Destroys the esp_netif object.

**Parameters**

- `esp_netif` - [in] pointer to the object to be deleted

```c
esp_err_t esp_netif_set_driver_config (esp_netif_t* esp_netif, const esp_netif_driver_ifconfig_t* driver_config)
```

Configures driver related options of esp_netif object.

**Parameters**

- `esp_netif` - [inout] pointer to the object to be configured
- `driver_config` - [in] pointer esp-netif io driver related configuration

**Returns**

- ESP_OK on success
- ESP_ERR_ESP_NETIF_INVALID_PARAMS if invalid parameters provided

```c
esp_err_t esp_netif_attach (esp_netif_t* esp_netif, esp_netif_iodriver_handle driver_handle)
```

Attaches esp_netif instance to the io driver handle.

Calling this function enables connecting specific esp_netif object with already initialized io driver to update esp_netif object with driver specific configuration (i.e. calls post_attach callback, which typically sets io driver callbacks to esp_netif instance and starts the driver)

**Parameters**

- `esp_netif` - [inout] pointer to esp_netif object to be attached
- `driver_handle` - [in] pointer to the driver handle

**Returns**

- ESP_OK on success
- ESP_ERR_ESP_NETIF_DRIVER_ATTACH_FAILED if driver’s post_attach callback failed
`esp_err_t esp_netif_receive (esp_netif_t *esp_netif, void *buffer, size_t len, void *eb)`

Passes the raw packets from communication media to the appropriate TCP/IP stack.

This function is called from the configured (peripheral) driver layer. The data are then forwarded as frames to the TCP/IP stack.

**Parameters**
- `esp_netif` — [in] Handle to esp-netif instance
- `buffer` — [in] Received data
- `len` — [in] Length of the data frame
- `eb` — [in] Pointer to internal buffer (used in Wi-Fi driver)

**Returns**
- ESP_OK

`void esp_netif_action_start (void* esp_netif, esp_event_base_t base, int32_t event_id, void* data)`

Default building block for network interface action upon IO driver start event. Creates network interface, if AUTOUP enabled turns the interface on, if DHCPS enabled starts dhcp server.

**Note:** This API can be directly used as event handler.

**Parameters**
- `esp_netif` — [in] Handle to esp-netif instance
- `base` —
- `event_id` —
- `data` —

`void esp_netif_action_stop (void* esp_netif, esp_event_base_t base, int32_t event_id, void* data)`

Default building block for network interface action upon IO driver stop event.

**Note:** This API can be directly used as event handler.

**Parameters**
- `esp_netif` — [in] Handle to esp-netif instance
- `base` —
- `event_id` —
- `data` —

`void esp_netif_action_connected (void* esp_netif, esp_event_base_t base, int32_t event_id, void* data)`

Default building block for network interface action upon IO driver connected event.

**Note:** This API can be directly used as event handler.

**Parameters**
- `esp_netif` — [in] Handle to esp-netif instance
- `base` —
- `event_id` —
- `data` —

`void esp_netif_action_disconnected (void* esp_netif, esp_event_base_t base, int32_t event_id, void* data)`

Default building block for network interface action upon IO driver disconnected event.

**Parameters**
- `esp_netif` — [in] Handle to esp-netif instance
- `base` —
- `event_id` —
- `data` —
Chapter 2. API Reference

Note: This API can be directly used as event handler

**Parameters**

- `esp_netif` - [in] Handle to esp-netif instance
- `base`
- `event_id`
- `data`

```c
void esp_netif_action_got_ip (void *esp_netif, esp_event_base_t base, int32_t event_id, void *data)
```

Default building block for network interface action upon network got IP event.

Note: This API can be directly used as event handler

**Parameters**

- `esp_netif` - [in] Handle to esp-netif instance
- `base`
- `event_id`
- `data`

```c
void esp_netif_action_join_ip6_multicast_group (void *esp_netif, esp_event_base_t base, int32_t event_id, void *data)
```

Default building block for network interface action upon IPv6 multicast group join.

Note: This API can be directly used as event handler

**Parameters**

- `esp_netif` - [in] Handle to esp-netif instance
- `base`
- `event_id`
- `data`

```c
void esp_netif_action_leave_ip6_multicast_group (void *esp_netif, esp_event_base_t base, int32_t event_id, void *data)
```

Default building block for network interface action upon IPv6 multicast group leave.

Note: This API can be directly used as event handler

**Parameters**

- `esp_netif` - [in] Handle to esp-netif instance
- `base`
- `event_id`
- `data`

```c
void esp_netif_action_add_ip6_address (void *esp_netif, esp_event_base_t base, int32_t event_id, void *data)
```

Default building block for network interface action upon IPv6 address added by the underlying stack.

Note: This API can be directly used as event handler
Parameters
  • `esp_netif` - [in] Handle to esp-netif instance
  • `base` -
  • `event_id` -
  • `data` -

```c
void esp_netif_action_remove_ip6_address (void *esp_netif, esp_event_base_t base, int32_t event_id, void *data)
```

Default building block for network interface action upon IPv6 address removed by the underlying stack.

**Note:** This API can be directly used as event handler

Parameters
  • `esp_netif` - [in] Handle to esp-netif instance
  • `base` -
  • `event_id` -
  • `data` -

```c
esp_err_t esp_netif_set_default_netif (esp_netif_t *esp_netif)
```

Manual configuration of the default netif.

This API overrides the automatic configuration of the default interface based on the route_prio If the selected netif is set default using this API, no other interface could be set-default disregarding its route_prio number (unless the selected netif gets destroyed)

**Parameters**
- `esp_netif` - [in] Handle to esp-netif instance

**Returns**
- ESP_OK on success

```c
esp_netif_t *esp_netif_get_default_netif (void)
```

Getter function of the default netif.

This API returns the selected default netif.

**Returns**
- Handle to esp-netif instance of the default netif.

```c
esp_err_t esp_netif_join_ip6_multicast_group (esp_netif_t *esp_netif, const esp_ip6_addr_t *addr)
```

Cause the TCP/IP stack to join a IPv6 multicast group.

**Parameters**
- `esp_netif` - [in] Handle to esp-netif instance
- `addr` - [in] The multicast group to join

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_MLD6_FAILED
- ESP_ERR_NO_MEM

```c
esp_err_t esp_netif_leave_ip6_multicast_group (esp_netif_t *esp_netif, const esp_ip6_addr_t *addr)
```

Cause the TCP/IP stack to leave a IPv6 multicast group.

**Parameters**
- `esp_netif` - [in] Handle to esp-netif instance
- `addr` - [in] The multicast group to leave

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_MLD6_FAILED
- ESP_ERR_NO_MEM
**esp_err_t esp_netif_set_mac** *(esp_netif_t *esp_netif, uint8_t mac[])*

Set the mac address for the interface instance.

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance
- `mac` [in] Desired mac address for the related network interface

**Returns**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_NOT_SUPPORTED - mac not supported on this interface

**esp_err_t esp_netif_get_mac** *(esp_netif_t *esp_netif, uint8_t mac[])*

Get the mac address for the interface instance.

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance
- `mac` [out] Resultant mac address for the related network interface

**Returns**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_NOT_SUPPORTED - mac not supported on this interface

**esp_err_t esp_netif_set_hostname** *(esp_netif_t *esp_netif, const char *hostname)*

Set the hostname of an interface.

The configured hostname overrides the default configuration value CONFIG_LWIP_LOCAL_HOSTNAME. Please note that when the hostname is altered after interface started/connected the changes would only be reflected once the interface restarts/reconnects

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance

**Returns**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_ESP_NETIF_INVALID_PARAMS - parameter error

**esp_err_t esp_netif_get_hostname** *(esp_netif_t *esp_netif, const char **hostname)*

Get interface hostname.

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance
- `hostname` [out] Returns a pointer to the hostname. May be NULL if no hostname is set. If set non-NULL, pointer remains valid (and string may change if the hostname changes).

**Returns**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_ESP_NETIF_INVALID_PARAMS - parameter error

**bool esp_netif_is_netif_up** *(esp_netif_t *esp_netif)*

Test if supplied interface is up or down.

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance

**Returns**
- true - Interface is up
- false - Interface is down

**esp_err_t esp_netif_get_ip_info** *(esp_netif_t *esp_netif, esp_netif_ip_info_t *ip_info)*

Get interface’s IP address information.

If the interface is up, IP information is read directly from the TCP/IP stack. If the interface is down, IP information is read from a copy kept in the ESP-NETIF instance.
Parameters
- `esp_netif` [in] Handle to esp-netif instance
- `ip_info` [out] If successful, IP information will be returned in this argument.

Returns
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

```c
esp_err_t esp_netif_get_old_ip_info (esp_netif_t *esp_netif, esp_netif_ip_info_t *ip_info)
```

Get interface’s old IP information.

Returns an “old” IP address previously stored for the interface when the valid IP changed.

If the IP lost timer has expired (meaning the interface was down for longer than the configured interval) then the old IP information will be zero.

Parameters
- `esp_netif` [in] Handle to esp-netif instance
- `ip_info` [out] If successful, IP information will be returned in this argument.

Returns
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

```c
esp_err_t esp_netif_set_ip_info (esp_netif_t *esp_netif, const esp_netif_ip_info_t *ip_info)
```

Set interface’s IP address information.

This function is mainly used to set a static IP on an interface.

If the interface is up, the new IP information is set directly in the TCP/IP stack.

The copy of IP information kept in the ESP-NETIF instance is also updated (this copy is returned if the IP is queried while the interface is still down.)

Note: DHCP client/server must be stopped (if enabled for this interface) before setting new IP information.

Note: Calling this interface for may generate a SYSTEM_EVENT_STA_GOT_IP or SYSTEM_EVENT_ETH_GOT_IP event.

Parameters
- `esp_netif` [in] Handle to esp-netif instance
- `ip_info` [in] IP information to set on the specified interface

Returns
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_NOT_STOPPED If DHCP server or client is still running

```c
esp_err_t esp_netif_set_old_ip_info (esp_netif_t *esp_netif, const esp_netif_ip_info_t *ip_info)
```

Set interface old IP information.

This function is called from the DHCP client (if enabled), before a new IP is set. It is also called from the default handlers for the SYSTEM_EVENT_STA_CONNECTED and SYSTEM_EVENT_ETH_CONNECTED events.

Calling this function stores the previously configured IP, which can be used to determine if the IP changes in the future.

If the interface is disconnected or down for too long, the “IP lost timer” will expire (after the configured interval) and set the old IP information to zero.

Parameters
Chapter 2. API Reference

- `esp_netif` [in] Handle to esp-netif instance
- `ip_info` [in] Store the old IP information for the specified interface

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

```c
int esp_netif_get_netif_impl_index (esp_netif_t *esp_netif)
```

Get net interface index from network stack implementation.

**Note:** This index could be used in `setsockopt()` to bind socket with multicast interface

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance

**Returns**
- implementation specific index of interface represented with supplied `esp_netif`

```c
esp_err_t esp_netif_get_netif_impl_name (esp_netif_t *esp_netif, char *name)
```

Get net interface name from network stack implementation.

**Note:** This name could be used in `setsockopt()` to bind socket with appropriate interface

**Parameters**

- `esp_netif` [in] Handle to esp-netif instance
- `name` [out] Interface name as specified in underlying TCP/IP stack. Note that the actual name will be copied to the specified buffer, which must be allocated to hold maximum interface name size (6 characters for lwIP)

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

```c
esp_err_t esp_netif_napt_enable (esp_netif_t *esp_netif)
```

Enable NAPT on an interface.

**Note:** Enable operation can be performed only on one interface at a time. NAPT cannot be enabled on multiple interfaces according to this implementation.

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance

**Returns**
- ESP_OK
- ESP_FAIL
- ESP_ERR_NOT_SUPPORTED

```c
esp_err_t esp_netif_napt_disable (esp_netif_t *esp_netif)
```

Disable NAPT on an interface.

**Parameters**
- `esp_netif` [in] Handle to esp-netif instance

**Returns**
- ESP_OK
- ESP_FAIL
- ESP_ERR_NOT_SUPPORTED

```c
esp_err_t esp_netif_dhcps_option (esp_netif_t *esp_netif, esp_netif_dhcp_option_mode_t opt_op, esp_netif_dhcp_option_id_t opt_id, void *opt_val, uint32_t opt_len)
```

Set or Get DHCP server option.

**Parameters**
Chapter 2. API Reference

- **esp_netif** – [in] Handle to esp-netif instance
- **opt_op** – [in] ESP_NETIF_OP_SET to set an option, ESP_NETIF_OP_GET to get an option.
- **opt_id** – [in] Option index to get or set, must be one of the supported enum values.
- **opt_val** – [inout] Pointer to the option parameter.
- **opt_len** – [in] Length of the option parameter.

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

```c
esp_err_t esp_netif_dhcpc_option(esp_netif_t *esp_netif, esp_netif_dhcp_option_mode_t opt_op,
                                 esp_netif_dhcp_option_id_t opt_id, void *opt_val, uint32_t opt_len)
```

Set or Get DHCP client option.

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance
- **opt_op** – [in] ESP_NETIF_OP_SET to set an option, ESP_NETIF_OP_GET to get an option.
- **opt_id** – [in] Option index to get or set, must be one of the supported enum values.
- **opt_val** – [inout] Pointer to the option parameter.
- **opt_len** – [in] Length of the option parameter.

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

```c
esp_err_t esp_netif_dhcpc_start(esp_netif_t *esp_netif)
```

Start DHCP client (only if enabled in interface object)

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED
- ESP_ERR_ESP_NETIF_DHCPC_START_FAILED

```c
esp_err_t esp_netif_dhcpc_stop(esp_netif_t *esp_netif)
```

Stop DHCP client (only if enabled in interface object)

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_IF_NOT_READY

```c
esp_err_t esp_netif_dhcpc_get_status(esp_netif_t *esp_netif, esp_netif_dhcp_status_t *status)
```

Get DHCP client status.

**Note:** The default event handlers for the SYSTEM_EVENT_STA_CONNECTED and SYSTEM_EVENT_ETH_CONNECTED events call this function.

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED
- ESP_ERR_ESP_NETIF_DHCPC_START_FAILED

**Note:** Calling action_netif_stop() will also stop the DHCP Client if it is running.

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance

**Returns**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_IF_NOT_READY

**Note:**
Chapter 2. API Reference

Parameters
- `esp_netif` - [in] Handle to esp-netif instance
- `status` - [out] If successful, the status of DHCP client will be returned in this argument.

Returns
- ESP_OK

`esp_err_t esp_netif_dhcps_get_status(esp_netif_t *esp_netif, esp_netif_dhcp_status_t *status)`
Get DHCP Server status.

Parameters
- `esp_netif` - [in] Handle to esp-netif instance
- `status` - [out] If successful, the status of the DHCP server will be returned in this argument.

Returns
- ESP_OK

`esp_err_t esp_netif_dhcps_start(esp_netif_t *esp_netif)`
Start DHCP server (only if enabled in interface object)

Parameters `esp_netif` - [in] Handle to esp-netif instance

Returns
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

`esp_err_t esp_netif_dhcps_stop(esp_netif_t *esp_netif)`
Stop DHCP server (only if enabled in interface object)

Parameters `esp_netif` - [in] Handle to esp-netif instance

Returns
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_IF_NOT_READY

`esp_err_t esp_netif_dhcps_get_clients_by_mac(esp_netif_t *esp_netif, int num, esp_netif_pair_mac_ip_t *mac_ip_pair)`
Populate IP addresses of clients connected to DHCP server listed by their MAC addresses.

Parameters
- `esp_netif` - [in] Handle to esp-netif instance
- `num` - [in] Number of clients with specified MAC addresses in the array of pairs
- `mac_ip_pair` - [inout] Array of pairs of MAC and IP addresses (MAC are inputs, IP outputs)

Returns
- ESP_OK on success
- ESP_ERR_ESP_NETIF_INVALID_PARAMS on invalid params
- ESP_ERR_NOT_SUPPORTED if DHCP server not enabled

`esp_err_t esp_netif_set_dns_info(esp_netif_t *esp_netif, esp_netif_dns_type_t type, esp_netif_dns_info_t *dns)`
Set DNS Server information.

This function behaves differently if DHCP server or client is enabled

If DHCP client is enabled, main and backup DNS servers will be updated automatically from the DHCP lease if the relevant DHCP options are set. Fallback DNS Server is never updated from the DHCP lease and is designed to be set via this API. If DHCP client is disabled, all DNS server types can be set via this API only.

If DHCP server is enabled, the Main DNS Server setting is used by the DHCP server to provide a DNS Server option to DHCP clients (Wi-Fi stations).

- The default Main DNS server is typically the IP of the DHCP server itself.
This function can override it by setting server type ESP_NETIF_DNS_MAIN. Other DNS Server types are not supported for the DHCP server. To propagate the DNS info to client, please stop the DHCP server before using this API.

Parameters
- `esp_netif` - [in] Handle to esp-netif instance
- `type` - [in] Type of DNS Server to set: ESP_NETIF_DNS_MAIN, ESP_NETIF_DNS_BACKUP, ESP_NETIF_DNS_FALLBACK
- `dns` - [in] DNS Server address to set

Returns
- ESP_OK on success
- ESP_ERR_ESP_NETIF_INVALID_PARAMS invalid params

\[ \text{esp_err_t} \text{ esp_netif_get_dns_info} (\text{esp_netif_t} *\text{esp_netif}, \text{esp_netif_dns_type_t} \text{type}, \text{esp_netif_dns_info_t} *\text{dns}) \]

Get DNS Server information.

Return the currently configured DNS Server address for the specified interface and Server type.

This may be result of a previous call to `esp_netif_set_dns_info()`. If the interface’s DHCP client is enabled, the Main or Backup DNS Server may be set by the current DHCP lease.

Parameters
- `esp_netif` - [in] Handle to esp-netif instance
- `type` - [in] Type of DNS Server to get: ESP_NETIF_DNS_MAIN, ESP_NETIF_DNS_BACKUP, ESP_NETIF_DNS_FALLBACK
- `dns` - [out] DNS Server result is written here on success

Returns
- ESP_OK on success
- ESP_ERR_ESP_NETIF_INVALID_PARAMS invalid params

\[ \text{esp_err_t} \text{ esp_netif_create_ip6_linklocal} (\text{esp_netif_t} *\text{esp_netif}) \]

Create interface link-local IPv6 address.

Cause the TCP/IP stack to create a link-local IPv6 address for the specified interface.

This function also registers a callback for the specified interface, so that if the link-local address becomes verified as the preferred address then a SYSTEM_EVENT_GOT_IP6 event will be sent.

Parameters `esp_netif` - [in] Handle to esp-netif instance

Returns
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

\[ \text{esp_err_t} \text{ esp_netif_get_ip6_linklocal} (\text{esp_netif_t} *\text{esp_netif}, \text{esp_ip6_addr_t} *\text{if_ip6}) \]

Get interface link-local IPv6 address.

If the specified interface is up and a preferred link-local IPv6 address has been created for the interface, return a copy of it.

Parameters
- `esp_netif` - [in] Handle to esp-netif instance
- `if_ip6` - [out] IPv6 information will be returned in this argument if successful.

Returns
- ESP_OK
- ESP_FAIL If interface is down, does not have a link-local IPv6 address, or the link-local IPv6 address is not a preferred address.

\[ \text{esp_err_t} \text{ esp_netif_get_ip6_global} (\text{esp_netif_t} *\text{esp_netif}, \text{esp_ip6_addr_t} *\text{if_ip6}) \]

Get interface global IPv6 address.

If the specified interface is up and a preferred global IPv6 address has been created for the interface, return a copy of it.
Parameters
- **esp_netif** - [in] Handle to esp-netif instance
- **if_ip6** - [out] IPv6 information will be returned in this argument if successful.

Returns
- ESP_OK
- ESP_FAIL If interface is down, does not have a global IPv6 address, or the global IPv6 address is not a preferred address.

```c
int esp_netif_get_all_ip6 (esp_netif_t *esp_netif, esp_ip6_addr_t if_ip6[])
```
Get all IPv6 addresses of the specified interface.

Parameters
- **esp_netif** - [in] Handle to esp-netif instance
- **if_ip6** - [out] Array of IPv6 addresses will be copied to the argument

Returns number of returned IPv6 addresses

```c
void esp_netif_set_ip4_addr (esp_ip4_addr_t *addr, uint8_t a, uint8_t b, uint8_t c, uint8_t d)
```
Sets IPv4 address to the specified octets.

Parameters
- **addr** - [out] IP address to be set
- **a** - the first octet (127 for IP 127.0.0.1)
- **b** -
- **c** -
- **d** -

```c
char *esp_ip4addr_ntoa (const esp_ip4_addr_t *addr, char *buf, int buflen)
```
Converts numeric IP address into decimal dotted ASCII representation.

Parameters
- **addr** - ip address in network order to convert
- **buf** - target buffer where the string is stored
- **buflen** - length of buf

Returns either pointer to buf which now holds the ASCII representation of addr or NULL if buf was too small

```c
uint32_t esp_ip4addr_aton (const char *addr)
```
Ascii internet address interpretation routine The value returned is in network order.

Parameters **addr** - IP address in ascii representation (e.g. “127.0.0.1”)

Returns ip address in network order

```c
esp_err_t esp_netif_str_to_ip4 (const char *src, esp_ip4_addr_t *dst)
```
Converts Ascii internet IPv4 address into esp_ip4_addr_t.

Parameters
- **src** - [in] IPv4 address in ascii representation (e.g. “127.0.0.1”)
- **dst** - [out] Address of the target esp_ip4_addr_t structure to receive converted address

Returns
- ESP_OK on success
- ESP_FAIL if conversion failed
- ESP_ERR_INVALID_ARG if invalid parameter is passed into

```c
esp_err_t esp_netif_str_to_ip6 (const char *src, esp_ip6_addr_t *dst)
```
Converts Ascii internet IPv6 address into esp_ip6_addr_t Zeros in the IP address can be stripped or completely omitted: “2001:db8:85a3:0:0:0:2:1” or “2001:db8::2:1”

Parameters
- **src** - [in] IPv6 address in ascii representation (e.g. “” 2001:0db8:85a3:0:0000:0000:0002:0001”)
- **dst** - [out] Address of the target esp_ip6_addr_t structure to receive converted address

Returns
- ESP_OK on success
• ESP_FAIL if conversion failed
• ESP_ERR_INVALID_ARG if invalid parameter is passed into

`esp_netif_iodriver_handle esp_netif_get_io_driver (esp_netif_t *esp_netif)`
Get media driver handle for this esp-netif instance.
Parameters `esp_netif` - [in] Handle to esp-netif instance
Returns opaque pointer of related IO driver

`esp_netif_t *esp_netif_get_handle_from_ifkey (const char *if_key)`
Searches over a list of created objects to find an instance with supplied if key.
Parameters `if_key` - Textual description of network interface
Returns Handle to esp-netif instance

`esp_netif_flags_t esp_netif_get_flags (esp_netif_t *esp_netif)`
Returns configured flags for this interface.
Parameters `esp_netif` - [in] Handle to esp-netif instance
Returns Configuration flags

`const char *esp_netif_get_ifkey (esp_netif_t *esp_netif)`
Returns configured interface key for this esp-netif instance.
Parameters `esp_netif` - [in] Handle to esp-netif instance
Returns Textual description of related interface

`const char *esp_netif_get_desc (esp_netif_t *esp_netif)`
Returns configured interface type for this esp-netif instance.
Parameters `esp_netif` - [in] Handle to esp-netif instance
Returns Enumerated type of this interface, such as station, AP, ethernet

`int esp_netif_get_route_prio (esp_netif_t *esp_netif)`
Returns configured routing priority number.
Parameters `esp_netif` - [in] Handle to esp-netif instance
Returns Integer representing the instance’s route-prio, or -1 if invalid paramters

`int32_t esp_netif_get_event_id (esp_netif_t *esp_netif, esp_netif_ip_event_type_t event_type)`
Returns configured event for this esp-netif instance and supplied event type.
Parameters
• `esp_netif` - [in] Handle to esp-netif instance
• `event_type` - (either get or lost IP)
Returns specific event id which is configured to be raised if the interface lost or acquired IP address
-1 if supplied event_type is not known

`esp_netif_t *esp_netif_next (esp_netif_t *esp_netif)`
Iterates over list of interfaces. Returns first netif if NULL given as parameter.
Parameters `esp_netif` - [in] Handle to esp-netif instance
Returns First netif from the list if supplied parameter is NULL, next one otherwise

`size_t esp_netif_get_nr_of_ifs (void)`
Returns number of registered esp_netif objects.
Returns Number of esp_netifs

`void esp_netif_netstack_buf_ref (void *netstack_buf)`
Increase the reference counter of net stack buffer
Parameters `netstack_buf` - [in] the net stack buffer
void esp_netif_netstack_buf_free (void *netstack_buf)
   free the net stack buffer

   Parameters netstack_buf - [in] the net stack buffer

esp_err_t esp_netif_tcpip_exec (esp_netif_callback_fn fn, void *ctx)
   Utility to execute the supplied callback in TCP/IP context.

   Parameters
   • fn - Pointer to the callback
   • ctx - Parameter to the callback
   Returns The error code (esp_err_t) returned by the callback

Type Definitions

typedef esp_err_t (*esp_netif_callback_fn)(void *ctx)
   TCPIP threadsafe callback used with esp_netif_tcpip_exec()

Header File

• components/esp_netif/include/esp_netif_sntp.h

Functions

esp_err_t esp_netif_sntp_init (const esp_sntp_config_t *config)
   Initialize SNTP with supplied config struct.

   Parameters config - Config struct
   Returns ESP_OK on success

esp_err_t esp_netif_sntp_start (void)
   Start SNTP service if it wasn’t started during init (config.start = false) or restart it if already started.

   Returns ESP_OK on success

void esp_netif_sntp_deinit (void)
   Deinitialize esp_netif SNTP module.

esp_err_t esp_netif_sntp_sync_wait (TickType_t tout)
   Wait for time sync event.

   Parameters tout - Specified timeout in RTOS ticks
   Returns ESP_TIMEOUT if sync event didn’t came withing the timeout
   ESP_ERR_NOT_FINISHED if the sync event came, but we’re in smooth update
   mode and still in progress (SNTP_SYNC_STATUS_IN_PROGRESS) ESP_OK if time sync’ed

Structures

struct esp_sntp_config
   SNTP configuration struct.

Public Members

bool smooth_sync
   set to true if smooth sync required
bool \texttt{server\_from\_dhcp}
  set to true to request NTP server config from DHCP

bool \texttt{wait\_for\_sync}
  if true, we create a semaphore to signal time sync event

bool \texttt{start}
  set to true to automatically start the SNTP service

\texttt{esp\_sntp\_time\_cb\_t} \texttt{sync\_cb}
  optionally sets callback function on time sync event

bool \texttt{renew\_servers\_after\_new\_IP}
  this is used to refresh server list if NTP provided by DHCP (which cleans other pre-configured servers)

\texttt{ip\_event\_t} \texttt{ip\_event\_to\_renew}
  set the IP event id on which we refresh server list (if renew\_servers\_after\_new\_IP=true)

size\_t \texttt{index\_of\_first\_server}
  refresh server list after this server (if renew\_servers\_after\_new\_IP=true)

size\_t \texttt{num\_of\_servers}
  number of preconfigured NTP servers

const char *\texttt{servers}[1]
  list of servers

**Macros**

\texttt{ESP\_SNTP\_SERVER\_LIST}(...)
  Utility macro for providing multiple servers in parentheses.

\texttt{ESP\_NETIF\_SNTP\_DEFAULT\_CONFIG\_MULTIPLE}(\texttt{servers\_in\_list}, \texttt{list\_of\_servers})
  Default configuration to init SNTP with multiple servers.

  \textbf{Parameters}
  \begin{itemize}
    \item \texttt{servers\_in\_list} – Number of servers in the list
    \item \texttt{list\_of\_servers} – List of servers (use \texttt{ESP\_SNTP\_SERVER\_LIST}(\ldots))
  \end{itemize}

\texttt{ESP\_NETIF\_SNTP\_DEFAULT\_CONFIG}(\texttt{server})
  Default configuration with a single server.

**Type Definitions**

typedef void (*\texttt{esp\_sntp\_time\_cb\_t})(\texttt{struct timeval *}tv)
  Time sync notification function.

typedef struct \texttt{esp\_sntp\_config} \texttt{esp\_sntp\_config\_t}
  SNTP configuration struct.

**Header File**

\begin{itemize}
  \item components/esp\_netif/include/esp\_netif\_types.h
\end{itemize}
Structures

struct esp_netif_dns_info_t
    DNS server info.

Public Members

    esp_ip_addr_t ip
        IPV4 address of DNS server

struct esp_netif_ip_info_t
    Event structure for IP_EVENT_STA_GOT_IP, IP_EVENT_ETH_GOT_IP events

Public Members

    esp_ip4_addr_t ip
        Interface IPV4 address

    esp_ip4_addr_t netmask
        Interface IPV4 netmask

    esp_ip4_addr_t gw
        Interface IPV4 gateway address

struct esp_netif_ip6_info_t
    IPV6 IP address information.

Public Members

    esp_ip6_addr_t ip
        Interface IPV6 address

struct ip_event_got_ip_t
    Event structure for IP_EVENT_GOT_IP event.

Public Members

    esp_netif_t *esp_netif
        Pointer to corresponding esp-netif object

    esp_netif_ip_info_t ip_info
        IP address, netmask, gateway IP address

    bool ip_changed
        Whether the assigned IP has changed or not

struct ip_event_got_ip6_t
    Event structure for IP_EVENT_GOT_IP6 event
Public Members

`esp_netif_t *esp_netif`
Pointer to corresponding esp-netif object

`esp_netif_ip6_info_t ip6_info`
IPv6 address of the interface

`int ip_index`
IPv6 address index

`struct ip_event_add_ip6_t`
Event structure for ADD_IP6 event

Public Members

`esp_ip6_addr_t addr`
The address to be added to the interface

`bool preferred`
The default preference of the address

`struct ip_event_ap_staipassigned_t`
Event structure for IP_EVENT_AP_STAIPASSIGNED event

Public Members

`esp_netif_t *esp_netif`
Pointer to the associated netif handle

`esp_ip4_addr_t ip`
IP address which was assigned to the station

`uint8_t mac[6]`
MAC address of the connected client

`struct bridgeif_config`
LwIP bridge configuration

Public Members

`uint16_t max_fdb_dyn_entries`
maximum number of entries in dynamic forwarding database

`uint16_t max_fdb_sta_entries`
maximum number of entries in static forwarding database
Chapter 2. API Reference

```
uint8_t max_ports
    maximum number of ports the bridge can consist of

struct esp_netif_inherent_config
    ESP-netif inherent config parameters.

Public Members

    esp_netif_flags_t flags
        flags that define esp-netif behavior

uint8_t mac[6]
    initial mac address for this interface

const esp_netif_ip_info_t *ip_info
    initial ip address for this interface

uint32_t get_ip_event
    event id to be raised when interface gets an IP

uint32_t lost_ip_event
    event id to be raised when interface lost its IP

const char *if_key
    string identifier of the interface

const char *if_desc
    textual description of the interface

int route_prio
    numeric priority of this interface to become a default routing if (if other netifs are up). A higher value of route_prio indicates a higher priority

bridgeif_config_t *bridge_info
    LwIP bridge configuration

struct esp_netif_driver_base_s
    ESP-netif driver base handle.

Public Members

    esp_err_t (*post_attach)(esp_netif_t *netif, esp_netif_i2odriver_handle h)
        post attach function pointer

    esp_netif_t *netif
        netif handle
```
**struct esp_netif_driver_ifconfig**

Specific IO driver configuration.

**Public Members**

*esp_netif_iiodriver_handle handle*

io-driver handle

*esp_err_t (**transmit**)(void *h, void *buffer, size_t len)*

transmit function pointer

*esp_err_t (**transmit_wrap**)(void *h, void *buffer, size_t len, void *netstack_buffer)*

transmit wrap function pointer

void (**driver_free_rx_buffer**)(void *h, void *buffer)

free rx buffer function pointer

**struct esp_netif_config**

Generic esp_netif configuration.

**Public Members**

const *esp_netif_inherent_config_t *base*

base config

const *esp_netif_driver_ifconfig_t *driver*

driver config

const *esp_netif_netstack_config_t *stack*

stack config

**struct esp_netif_pair_mac_ip_t**

DHCP client’s addr info (pair of MAC and IP address)

**Public Members**

uint8_t mac[6]

Clients MAC address

*esp_ip4_addr_t ip*

Clients IP address

**Macros**

**ESP_ERR_ESP_NETIF_BASE**

Definition of ESP-NETIF based errors.
ESP_ERR_ESP_NETIF_INVALID_PARAMS
ESP_ERR_ESP_NETIF_IF_NOT_READY
ESP_ERR_ESP_NETIF_DHCPC_START_FAILED
ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED
ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
ESP_ERR_ESP_NETIF_NO_MEM
ESP_ERR_ESP_NETIF_DHCP_NOT_STOPPED
ESP_ERR_ESP_NETIF_DRIVER.Attach_FAILED
ESP_ERR_ESP_NETIF_INIT_FAILED
ESP_ERR_ESP_NETIF_DNS_NOT_CONFIGURED
ESP_ERR_ESP_NETIF_MLD6_FAILED
ESP_ERR_ESP_NETIF_IP6_ADDR_FAILED
ESP_ERR_ESP_NETIF_DHCPS_START_FAILED
ESP_NETIF_BR_FLOOD
    Definition of ESP-NETIF bridge controll.
ESP_NETIF_BR_DROP
ESP_NETIF_BR_FDW_CPU

Type Definitions

typedef struct esp_netif_obj esp_netif_t

typedef enum esp_netif_flags esp_netif_flags_t

typedef enum esp_netif_ip_event_type esp_netif_ip_event_type_t

typedef struct bridgeif_config bridgeif_config_t
    LwIP bridge configuration

typedef struct esp_netif_inherent_config esp_netif_inherent_config_t
    ESP-netif inherent config parameters.
typedef struct esp_netif_config esp_netif_config_t

typedef void *esp_netif_iodriver_handle
    IO driver handle type.

typedef struct esp_netif_driver_base_s esp_netif_driver_base_t
    ESP-netif driver base handle.

typedef struct esp_netif_driver_ifconfig esp_netif_driver_ifconfig_t

typedef struct esp_netif_netstack_config esp_netif_netstack_config_t
    Specific L3 network stack configuration.

typedef esp_err_t (*esp_netif_receive_t)(esp_netif_t *esp_netif, void *buffer, size_t len, void *eb)
    ESP-NETIF Receive function type.

Enumerations

enum esp_netif_dns_type_t
    Type of DNS server.
    Values:

    enumerator ESP_NETIF_DNS_MAIN
        DNS main server address

    enumerator ESP_NETIF_DNS_BACKUP
        DNS backup server address (Wi-Fi STA and Ethernet only)

    enumerator ESP_NETIF_DNS_FALLBACK
        DNS fallback server address (Wi-Fi STA and Ethernet only)

    enumerator ESP_NETIF_DNS_MAX

enum esp_netif_dhcp_status_t
    Status of DHCP client or DHCP server.
    Values:

    enumerator ESP_NETIF_DHCP_INIT
        DHCP client/server is in initial state (not yet started)

    enumerator ESP_NETIF_DHCP_STARTED
        DHCP client/server has been started

    enumerator ESP_NETIF_DHCP_STOPPED
        DHCP client/server has been stopped

    enumerator ESP_NETIF_DHCP_STATUS_MAX
enum esp_netif_dhcp_option_mode_t
    Mode for DHCP client or DHCP server option functions.
    Values:
    
    enumerator ESP_NETIF_OP_START
    enumerator ESP_NETIF_OP_SET
       Set option
    enumerator ESP_NETIF_OP_GET
       Get option
    enumerator ESP_NETIF_OP_MAX

enum esp_netif_dhcp_option_id_t
    Supported options for DHCP client or DHCP server.
    Values:
    
    enumerator ESP_NETIF_SUBNET_MASK
       Network mask
    enumerator ESP_NETIF_DOMAIN_NAME_SERVER
       Domain name server
    enumerator ESP_NETIF_ROUTER_SOLICITATION_ADDRESS
       Solicitation router address
    enumerator ESP_NETIF_REQUESTED_IP_ADDRESS
       Request specific IP address
    enumerator ESP_NETIF_IP_ADDRESSLEASE_TIME
       Request IP address lease time
    enumerator ESP_NETIF_IP_REQUEST_RETRY_TIME
       Request IP address retry counter
    enumerator ESP_NETIF_VENDOR_CLASSIDENTIFIER
       Vendor Class Identifier of a DHCP client
    enumerator ESP_NETIF_VENDOR_SPECIFIC_INFO
       Vendor Specific Information of a DHCP server

enum ip_event_t
    IP event declarations
    Values:
    
    enumerator IP_EVENT_STA_GOT_IP
       station got IP from connected AP
enumerator **IP_EVENT_STA_LOST_IP**
    station lost IP and the IP is reset to 0

enumerator **IP_EVENT_AP_STAIPASSIGNED**
    soft-AP assign an IP to a connected station

enumerator **IP_EVENT_GOT_IP6**
    station or ap or ethernet interface v6IP addr is preferred

enumerator **IP_EVENT_ETH_GOT_IP**
    ethernet got IP from connected AP

enumerator **IP_EVENT_ETH_LOST_IP**
    ethernet lost IP and the IP is reset to 0

enumerator **IP_EVENT_PPP_GOT_IP**
    PPP interface got IP

enumerator **IP_EVENT_PPP_LOST_IP**
    PPP interface lost IP

enum **esp_netif_flags**

    Values:

enumerator **ESP_NETIF_DHCP_CLIENT**

enumerator **ESP_NETIF_DHCP_SERVER**

enumerator **ESP_NETIF_FLAG_AUTOUP**

enumerator **ESP_NETIF_FLAG_GARP**

enumerator **ESP_NETIF_FLAG_EVENT_IP_MODIFIED**

enumerator **ESP_NETIF_FLAG_IS_PPP**

enumerator **ESP_NETIF_FLAG_IS_BRIDGE**

enumerator **ESP_NETIF_FLAG_MLDV6_REPORT**

enum **esp_netif_ip_event_type**

    Values:

enumerator **ESP_NETIF_IP_EVENT_GOT_IP**

enumerator **ESP_NETIF_IP_EVENT_LOST_IP**
Header File

- components/esp_netif/include/esp_netif_ip_addr.h

Functions

`esp_ip6_addr_type_t esp_netif_ip6_get_addr_type(esp_ip6_addr_t *ip6_addr)`
Get the IPv6 address type.

Parameters

- `ip6_addr` - [in] IPv6 type

Returns

IPv6 type in form of enum `esp_ip6_addr_type_t`

static inline void `esp_netif_ip_addr_copy(esp_ip_addr_t *dest, const esp_ip_addr_t *src)`
Copy IP addresses.

Parameters

- `dest` - [out] destination IP
- `src` - [in] source IP

Structures

struct `esp_ip6_addr`
IPv6 address.

Public Members

- `uint32_t addr[4]`
  IPv6 address

- `uint8_t zone`
  zone ID

struct `esp_ip4_addr`
IPv4 address.

Public Members

- `uint32_t addr`
  IPv4 address

struct `_ip_addr`
IP address.

Public Members

- `esp_ip6_addr_t ip6`
  IPv6 address type

- `esp_ip4_addr_t ip4`
  IPv4 address type
union _ip_addr:[anonymous] u_addr
    IP address union

uint8_t t_type
    ipaddress type

Macros
esp_netif_htonl (x)
esp_netif_ip4_makeu32 (a, b, c, d)
ESP_IP6_ADDR_BLOCK1 (ip6addr)
ESP_IP6_ADDR_BLOCK2 (ip6addr)
ESP_IP6_ADDR_BLOCK3 (ip6addr)
ESP_IP6_ADDR_BLOCK4 (ip6addr)
ESP_IP6_ADDR_BLOCK5 (ip6addr)
ESP_IP6_ADDR_BLOCK6 (ip6addr)
ESP_IP6_ADDR_BLOCK7 (ip6addr)
ESP_IP6_ADDR_BLOCK8 (ip6addr)

IPSTR
esp_ip4_addr_get_byte (ipaddr, idx)
esp_ip4_addr1 (ipaddr)
esp_ip4_addr2 (ipaddr)
esp_ip4_addr3 (ipaddr)
esp_ip4_addr4 (ipaddr)
esp_ip4_addr1_16 (ipaddr)
esp_ip4_addr2_16 (ipaddr)
esp_ip4_addr3_16 (ipaddr)
esp_ip4_addr4_16 (ipaddr)
IP2STR (ipaddr)

IPV6STR
IPV62STR (ipaddr)

ESP_IPADDR_TYPE_V4
ESP_IPADDR_TYPE_V6
ESP_IPADDR_TYPE_ANY
Chapter 2. API Reference

ESP_IP4TOUINT32 (a, b, c, d)
ESP_IP4TOADDR (a, b, c, d)
ESP_IP4ADDR_INIT (a, b, c, d)
ESP_IP6ADDR_INIT (a, b, c, d)

IPADDR_STRLEN_MAX
ESP_IP_IS_ANY (addr)

Type Definitions
typedef struct esp_ip4_addr esp_ip4_addr_t
typedef struct esp_ip6_addr esp_ip6_addr_t
typedef struct _ip_addr esp_ip_addr_t
IP address.

Enumerations
enum esp_ip6_addr_type_t
    Values:
enumerator ESP_IP6_ADDR_IS_UNKNOWN
enumerator ESP_IP6_ADDR_IS_GLOBAL
enumerator ESP_IP6_ADDR_IS_LINK_LOCAL
enumerator ESP_IP6_ADDR_IS_SITE_LOCAL
enumerator ESP_IP6_ADDR_IS_UNIQUE_LOCAL
enumerator ESP_IP6_ADDR_IS_IPV4_MAPPED_IPV6

Header File
• components/esp_netif/include/esp_vfs_l2tap.h

Functions
esp_err_t esp_vfs_l2tap_intf_register (l2tap_vfs_config_t *config)
Add L2 TAP virtual filesystem driver.
This function must be called prior usage of ESP-NETIF L2 TAP Interface
Parameters config - L2 TAP virtual filesystem driver configuration. Default base path
/dev/net/tap is used when this parameter is NULL.
Returns esp_err_t
• ESP_OK on success
Chapter 2. API Reference

```c
esp_err_t esp_vfs_l2tap_intf_unregister (const char *base_path)

Removes L2 TAP virtual filesystem driver.

Parameters base_path – Base path to the L2 TAP virtual filesystem driver. Default path /dev/net/tap is used when this parameter is NULL.

Returns esp_err_t
  • ESP_OK on success
```

```c
esp_err_t esp_vfs_l2tap_eth_filter (l2tap_iodriver_handle driver_handle, void *buff, size_t *size)

Filters received Ethernet L2 frames into L2 TAP infrastructure.

Parameters
  • driver_handle – handle of driver at which the frame was received
  • buff – received L2 frame
  • size – input length of the L2 frame which is set to 0 when frame is filtered into L2 TAP

Returns esp_err_t
  • ESP_OK is always returned
```

Structures

```c
struct l2tap_vfs_config_t

L2Tap VFS config parameters.
```

Public Members

```c
const char *base_path

vfs base path
```

Macros

```
L2TAP_VFS_DEFAULT_PATH
L2TAP_VFS_CONFIG_DEFAULT ()
```

Type Definitions

```c
typedef void *l2tap_iodriver_handle
```

Enumerations

```c
enum l2tap_ioctl_opt_t

Values:

enumerator L2TAP_S_RCV_FILTER
enumerator L2TAP_G_RCV_FILTER
enumerator L2TAP_S_INTF_DEVICE
enumerator L2TAP_G_INTF_DEVICE
enumerator L2TAP_S_DEVICE_DRV_HNDL
```
Chapter 2. API Reference

enumerator L2TAP_G_DEVICE_DRV_HNDL

WiFi default API reference

Header File
- components/esp_wifi/include/esp_wifi_default.h

Functions

*esp_err_t* esp_netif_attach_wifi_station(esp_netif_t *esp_netif)

Attaches wifi station interface to supplied netif.

Parameters esp_netif – instance to attach the wifi station to

Returns
- ESP_OK on success
- ESP_FAIL if attach failed

*esp_err_t* esp_netif_attach_wifi_ap(esp_netif_t *esp_netif)

Attaches wifi soft AP interface to supplied netif.

Parameters esp_netif – instance to attach the wifi AP to

Returns
- ESP_OK on success
- ESP_FAIL if attach failed

*esp_err_t* esp_wifi_set_default_wifi_sta_handlers(void)

Sets default wifi event handlers for STA interface.

Returns
- ESP_OK on success, error returned from esp_event_handler_register if failed

*esp_err_t* esp_wifi_set_default_wifi_ap_handlers(void)

Sets default wifi event handlers for AP interface.

Returns
- ESP_OK on success, error returned from esp_event_handler_register if failed

*esp_err_t* esp_wifi_set_default_wifi_nan_handlers(void)

Sets default wifi event handlers for NAN interface.

Returns
- ESP_OK on success, error returned from esp_event_handler_register if failed

*esp_err_t* esp_wifi_clear_default_wifi_driver_and_handlers(void)

Clears default wifi event handlers for supplied network interface.

Parameters esp_netif – instance of corresponding if object

Returns
- ESP_OK on success, error returned from esp_event_handler_register if failed

*esp_netif_t* esp_netif_create_default_wifi_ap(void)

Creates default WIFI AP. In case of any init error this API aborts.

Note: The API creates esp_netif object with default WiFi access point config, attaches the netif to wifi and registers wifi handlers to the default event loop. This API uses assert() to check for potential errors, so it could abort the program. (Note that the default event loop needs to be created prior to calling this API)

Returns pointer to esp-netif instance
Chapter 2. API Reference

**esp_netif_t**

*esp_netif_create_default_wifi_sta* (void)

Creates default WIFI STA. In case of any init error this API aborts.

**Note:** The API creates esp_netif object with default WiFi station config, attaches the netif to wifi and registers wifi handlers to the default event loop. This API uses assert() to check for potential errors, so it could abort the program. (Note that the default event loop needs to be created prior to calling this API)

Returns pointer to esp-netif instance

*esp_netif_create_default_wifi_nan* (void)

Creates default WIFI NAN. In case of any init error this API aborts.

**Note:** The API creates esp_netif object with default WiFi station config, attaches the netif to wifi and registers wifi handlers to the default event loop. (Note that the default event loop needs to be created prior to calling this API)

Returns pointer to esp-netif instance

void *esp_netif_destroy_default_wifi* (void *esp_netif)

Destroys default WIFI netif created with esp_netif_create_default_wifi_…() API.

**Note:** This API unregisters wifi handlers and detaches the created object from the wifi. (this function is a no-operation if esp_netif is NULL)

Parameters esp_netif –[in] object to detach from WiFi and destroy

*esp_netif_create_wifi* (wifi_interface_t wifi_if, const esp_netif_inherent_config_t *esp_netif_config)

Creates esp_netif WiFi object based on the custom configuration.

**Attention** This API DOES NOT register default handlers!

Parameters

- wifi_if –[in] type of wifi interface
- esp_netif_config – inherent esp-netif configuration pointer

Returns pointer to esp-netif instance

*[esp_err_t]*

*esp_netif_create_default_wifi_mesh_netifs* (esp_netif_t **p_netif_sta, esp_netif_t **p_netif_ap)

Creates default STA and AP network interfaces for esp-mesh.

Both netifs are almost identical to the default station and softAP, but with DHCP client and server disabled. Please note that the DHCP client is typically enabled only if the device is promoted to a root node.

Returns created interfaces which could be ignored setting parameters to NULL if an application code does not need to save the interface instances for further processing.

Parameters

- p_netif_sta –[out] pointer where the resultant STA interface is saved (if non NULL)
- p_netif_ap –[out] pointer where the resultant AP interface is saved (if non NULL)

Returns ESP_OK on success
2.5.5  IP Network Layer

ESP-NETIF Custom I/O Driver

This section outlines implementing a new I/O driver with esp-netif connection capabilities. By convention the I/O driver has to register itself as an esp-netif driver and thus holds a dependency on esp-netif component and is responsible for providing data path functions, post-attach callback and in most cases also default event handlers to define network interface actions based on driver’s lifecycle transitions.

Packet input/output  As shown in the diagram, the following three API functions for the packet data path must be defined for connecting with esp-netif:

- esp_netif_transmit()
- esp_netif_free_rx_buffer()
- esp_netif_receive()

The first two functions for transmitting and freeing the rx buffer are provided as callbacks, i.e. they get called from esp-netif (and its underlying TCP/IP stack) and I/O driver provides their implementation.

The receiving function on the other hand gets called from the I/O driver, so that the driver’s code simply calls esp_netif_receive() on a new data received event.

Post attach callback  A final part of the network interface initialization consists of attaching the esp-netif instance to the I/O driver, by means of calling the following API:

```c
esp_err_t esp_netif_attach(esp_netif_t *esp_netif, esp_netif_iodriver_handle -->driver_handle);
```

It is assumed that the esp_netif_iodriver_handle is a pointer to driver’s object, a struct derived from struct esp_netif_driver_base_s, so that the first member of I/O driver structure must be this base structure with pointers to

- post-attach function callback
- related esp-netif instance

As a consequence the I/O driver has to create an instance of the struct per below:

```c
typedef struct my_netif_driver_s {
    esp_netif_driver_base_t base; /*! base structure reserved as_
    esp-netif driver */
    driver_impl */
    *h; /*! handle of driver_
    implementation */
} my_netif_driver_t;
```

with actual values of my_netif_driver_t::base.post_attach and the actual drivers handle my_netif_driver_t::h. So when the esp_netif_attach() gets called from the initialization code, the post-attach callback from I/O driver’s code gets executed to mutually register callbacks between esp-netif and I/O driver instances. Typically the driver is started as well in the post-attach callback. An example of a simple post-attach callback is outlined below:

```c
static esp_err_t my_post_attach_start(esp_netif_t * esp_netif, void * args)
{
    my_netif_driver_t *driver = args;
    const esp_netif_driver_ifconfig_t driver_ifconfig = {
        .driver_free_rx_buffer = my_free_rx_buf,
        .transmit = my_transmit,
        .handle = driver->driver_impl
    };
    driver->base.netif = esp_netif;
    ESP_ERROR_CHECK(esp_netif_set_driver_config(esp_netif, &driver_ifconfig));
}
```
(continues on next page)
Default handlers  I/O drivers also typically provide default definitions of lifecycle behaviour of related network interfaces based on state transitions of I/O drivers. For example driver start $\rightarrow$ network start, etc. An example of such a default handler is provided below:

```c
esp_err_t my_driver_netif_set_default_handlers(my_netif_driver_t *driver, esp_netif_t * esp_netif)
{
    driver_set_event_handler(driver->driver_impl, esp_netif_action_start, MY_DRV(EVENT_START, esp_netif);
    driver_set_event_handler(driver->driver_impl, esp_netif_action_stop, MY_DRV(EVENT_STOP, esp_netif);
    return ESP_OK;
}
```

Network stack connection  The packet data path functions for transmitting and freeing the rx buffer (defined in the I/O driver) are called from the esp-netif, specifically from its TCP/IP stack connecting layer.

Note, that IDF provides several network stack configurations for the most common network interfaces, such as for the WiFi station or Ethernet. These configurations are defined in esp_netif/include/esp_netif_defaults.h and should be sufficient for most network drivers. (In rare cases, expert users might want to define custom lwIP based interface layers; it is possible, but an explicit dependency to lwIP needs to be set)

The following API reference outlines these network stack interaction with the esp-netif:

**Header File**

- components/esp_netif/include/esp_netif_net_stack.h

**Functions**

- `esp_netif_t * esp_netif_get_handle_from_netif_impl (void *dev)`
  Returns esp-netif handle.

  Parameters

  `dev` - [in] opaque ptr to network interface of specific TCP/IP stack

  Returns

  handle to related esp-netif instance

- `void * esp_netif_get_netif_impl (esp_netif_t *esp_netif)`
  Returns network stack specific implementation handle (if supported)

  Note that it is not supported to acquire PPP netif impl pointer and this function will return NULL for esp_netif instances configured to PPP mode

  Parameters

  `esp_netif` - [in] Handle to esp-netif instance

  Returns

  handle to related network stack netif handle

- `esp_err_t esp_netif_set_link_speed (esp_netif_t *esp_netif, uint32_t speed)`
  Set link-speed for the specified network interface.

  Parameters

  - `esp_netif` - [in] Handle to esp-netif instance
  - `speed` - [in] Link speed in bit/s

  Returns

  ESP_OK on success
**Chapter 2. API Reference**

**esp_err_t esp_netif_transmit** *(esp_netif_t *esp_netif, void *data, size_t len)*

Outputs packets from the TCP/IP stack to the media to be transmitted.

This function gets called from network stack to output packets to IO driver.

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance
- **data** – [in] Data to be transmitted
- **len** – [in] Length of the data frame

**Returns** ESP_OK on success, an error passed from the I/O driver otherwise

**esp_err_t esp_netif_transmit_wrap** *(esp_netif_t *esp_netif, void *data, size_t len, void *netstack_buf)*

Outputs packets from the TCP/IP stack to the media to be transmitted.

This function gets called from network stack to output packets to IO driver.

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance
- **data** – [in] Data to be transmitted
- **len** – [in] Length of the data frame
- **netstack_buf** – [in] Net stack buffer

**Returns** ESP_OK on success, an error passed from the I/O driver otherwise

**void esp_netif_free_rx_buffer** *(void *esp_netif, void *buffer)*

Free the rx buffer allocated by the media driver.

This function gets called from network stack when the rx buffer to be freed in IO driver context, i.e. to deallocate a buffer owned by io driver (when data packets were passed to higher levels to avoid copying)

**Parameters**
- **esp_netif** – [in] Handle to esp-netif instance
- **buffer** – [in] Rx buffer pointer

Code examples for TCP/IP socket APIs are provided in the **protocols/sockets** directory of ESP-IDF examples.

### 2.5.6 Application Layer

Documentation for Application layer network protocols (above the IP Network layer) are provided in Application Protocols.

### 2.6 Peripherals API

#### 2.6.1 Analog to Digital Converter (ADC) Oneshot Mode Driver

**Introduction**

The Analog to Digital Converter is integrated on the chip and is capable of measuring analog signals from specific analog IO pins.

ESP32 has two ADC unit(s), which can be used in scenario(s) like:
- Generate one-shot ADC conversion result
- Generate continuous ADC conversion results

This guide introduces ADC oneshot mode conversion.
Functional Overview

The following sections of this document cover the typical steps to install and operate an ADC:

- **Resource Allocation** - covers which parameters should be set up to get an ADC handle and how to recycle the resources when ADC finishes working.
- **Unit Configuration** - covers the parameters that should be set up to configure the ADC unit, so as to get ADC conversion raw result.
- **Read Conversion Result** - covers how to get ADC conversion raw result.
- **Hardware Limitations** - describes the ADC-related hardware limitations.
- **Power Management** - covers power management-related information.
- **IRAM Safe** - describes tips on how to read ADC conversion raw results when the cache is disabled.
- **Thread Safety** - lists which APIs are guaranteed to be thread-safe by the driver.
- **Kconfig Options** - lists the supported Kconfig options that can be used to make a different effect on driver behavior.

**Resource Allocation**

The ADC oneshot mode driver is implemented based on ESP32 SAR ADC module. Different ESP chips might have different numbers of independent ADCs. From the oneshot mode driver’s point of view, an ADC instance is represented by `adc_oneshot_unit_handle_t`.

To install an ADC instance, set up the required initial configuration structure `adc_oneshot_unit_init_cfg_t`:

- `adc_oneshot_unit_init_cfg_t::unit_id` selects the ADC. Please refer to the datasheet to know dedicated analog IOs for this ADC.
- `adc_oneshot_unit_init_cfg_t::clk_src` selects the source clock of the ADC. If set to 0, the driver will fall back to using a default clock source, see `adc_oneshot_clk_src_t` to know the details.
- `adc_oneshot_unit_init_cfg_t::ulp_mode` sets if the ADC will be working under ULP mode.

After setting up the initial configurations for the ADC, call `adc_oneshot_new_unit()` with the prepared `adc_oneshot_unit_init_cfg_t`. This function will return an ADC unit handle if the allocation is successful.

This function may fail due to various errors such as invalid arguments, insufficient memory, etc. Specifically, when the to-be-allocated ADC instance is registered already, this function will return `ESP_ERR_NOT_FOUND` error. Number of available ADC(s) is recorded by `SOC_ADC_PERIPH_NUM`.

If a previously created ADC instance is no longer required, you should recycle the ADC instance by calling `adc_oneshot_del_unit()`, related hardware and software resources will be recycled as well.

**Create an ADC Unit Handle Under Normal Oneshot Mode**

```c
adc_oneshot_unit_handle_t acl1_handle;
adc_oneshot_unit_init_cfg_t init_config1 = {
    .unit_id = ADC_UNIT_1,
    .ulp_mode = ADC_ULP_MODE_DISABLE,
};
ESP_ERROR_CHECK(adc_oneshot_new_unit(&init_config1, &acl1_handle));
```

**Recycle the ADC Unit**

```c
ESP_ERROR_CHECK(adc_oneshot_del_unit(acl1_handle));
```

**Unit Configuration**

After an ADC instance is created, set up the `adc_oneshot_chan_cfg_t` to configure ADC IOs to measure analog signal:

- `adc_oneshot_chan_cfg_t::atten`, ADC attenuation. Refer to TRM > On-Chip Sensor and Analog Signal Processing.
- `adc_oneshot_chan_cfg_t::bitwidth`, the bitwidth of the raw conversion result.
Note: For the IO corresponding ADC channel number, check datasheet to know the ADC IOs.

Additionally, `adc_continuous_io_to_channel()` and `adc_continuous_channel_to_io()` can be used to know the ADC channels and ADC IOs.

To make these settings take effect, call `adc_oneshot_config_channel()` with the above configuration structure. You should specify an ADC channel to be configured as well. Function `adc_oneshot_config_channel()` can be called multiple times to configure different ADC channels. The Driver will save each of these channel configurations internally.

Configure Two ADC Channels

```c
adc_oneshot_chan_cfg_t config = {
    .bitwidth = ADC_BITWIDTH_DEFAULT,
    .atten = ADC_ATTEN_DB_11,
};
ESP_ERROR_CHECK(adc_oneshot_config_channel(adc1_handle, EXAMPLE_ADC1_CHAN0, &config));
ESP_ERROR_CHECK(adc_oneshot_config_channel(adc1_handle, EXAMPLE_ADC1_CHAN1, &config));
```

Read Conversion Result

After above configurations, the ADC is ready to measure the analog signal(s) from the configured ADC channel(s). Call `adc_oneshot_read()` to get the conversion raw result of an ADC channel.

- `adc_oneshot_read()` is safe to use. ADC(s) are shared by some other drivers/peripherals, see Hardware Limitations. This function uses mutexes to avoid concurrent hardware usage. Therefore, this function should not be used in an ISR context. This function may fail when the ADC is in use by other drivers/peripherals, and return ESP_ERR_TIMEOUT. Under this condition, the ADC raw result is invalid.

This function will fail due to invalid arguments.

The ADC conversion results read from this function are raw data. To calculate the voltage based on the ADC raw results, this formula can be used:

\[
V_{out} = D_{out} \times \frac{V_{max}}{D_{max}} \quad (1)
\]

where:

<p>| | | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Vout</td>
<td>Digital output result, standing for the voltage.</td>
<td></td>
</tr>
<tr>
<td>Dout</td>
<td>ADC raw digital reading result.</td>
<td></td>
</tr>
<tr>
<td>Vmax</td>
<td>Maximum measurable input analog voltage, this is related to the ADC attenuation, please refer to TRM &gt; On-Chip Sensor and Analog Signal Processing.</td>
<td></td>
</tr>
<tr>
<td>Dmax</td>
<td>Maximum of the output ADC raw digital reading result, which is (2^\text{bitwidth}), where bitwidth is the :cpp:member::adc_oneshot_chan_cfg_t::bitwidth configured before.</td>
<td></td>
</tr>
</tbody>
</table>

To do further calibration to convert the ADC raw result to voltage in mV, please refer to calibration doc Analog to Digital Converter (ADC) Calibration Driver.

Read Raw Result

```c
ESP_ERROR_CHECK(adc_oneshot_read(adc1_handle, EXAMPLE_ADC1_CHAN0, &adc_raw[0][0]));
ESP_LOGI(TAG, "ADC%d Channel[%d] Raw Data: %d", ADC_UNIT_1 + 1, EXAMPLE_ADC1_CHAN0, adc_raw[0][0]);
ESP_ERROR_CHECK(adc_oneshot_read(adc1_handle, EXAMPLE_ADC1_CHAN1, &adc_raw[0][1]));
ESP_LOGI(TAG, "ADC%d Channel[%d] Raw Data: %d", ADC_UNIT_1 + 1, EXAMPLE_ADC1_CHAN1, adc_raw[0][1]);
```
Hardware Limitations

- Random Number Generator (RNG) uses ADC as an input source. When ADC `adc_oneshot_read()` works, the random number generated from RNG will be less random.
- A specific ADC unit can only work under one operating mode at any one time, either continuous mode or oneshot mode. `adc_oneshot_read()` has provided the protection.
- ADC2 is also used by Wi-Fi. `adc_oneshot_read()` has provided protection between the Wi-Fi driver and ADC oneshot mode driver.
- ESP32-DevKitC: GPIO0 cannot be used in oneshot mode, because the DevKit has used it for auto-flash.
- ESP-WROVER-KIT: GPIO 0, 2, 4, and 15 cannot be used due to external connections for different purposes.

Power Management

When power management is enabled, i.e., `CONFIG_PM_ENABLE` is on, the system clock frequency may be adjusted when the system is in an idle state. However, the ADC oneshot mode driver works in a polling routine, the `adc_oneshot_read()` will poll the CPU until the function returns. During this period of time, the task in which ADC oneshot mode driver resides will not be blocked. Therefore the clock frequency is stable when reading.

IRAM Safe

By default, all the ADC oneshot mode driver APIs are not supposed to be run when the Cache is disabled. Cache may be disabled due to many reasons, such as Flash writing/erasing, OTA, etc. If these APIs execute when the Cache is disabled, you will probably see errors like `Illegal Instruction` or `Load/Store Prohibited`.

Thread Safety

- `adc_oneshot_new_unit()`
- `adc_oneshot_config_channel()`
- `adc_oneshot_read()`

Above functions are guaranteed to be thread-safe. Therefore, you can call them from different RTOS tasks without protection by extra locks.

- `adc_oneshot_del_unit()` is not thread-safe. Besides, concurrently calling this function may result in failures of the above thread-safe APIs.

Kconfig Options

- `CONFIG_ADC_ONESHOT_CTRL_FUNC_IN_IRAM` controls where to place the ADC fast read function (IRAM or Flash), see IRAM Safe for more details.

Application Examples

- ADC oneshot mode example: `peripherals/adc/oneshot_read`.

API Reference

Header File

- `components/hal/include/hal/adc_types.h`

Structures

```c
struct adc_digi_pattern_config_t
{
    ADC digital controller pattern configuration.
}```
Public Members

uint8_t atten
Attenuation of this ADC channel.

uint8_t channel
ADC channel.

uint8_t unit
ADC unit.

uint8_t bit_width
ADC output bit width.

struct adc_digi_output_data_t
ADC digital controller (DMA mode) output data format. Used to analyze the acquired ADC (DMA) data.

Note: ESP32: Only type1 is valid. ADC2 does not support DMA mode.

Note: ESP32-S2: Member channel can be used to judge the validity of the ADC data, because the role of the arbiter may get invalid ADC data.

Public Members

uint16_t data
ADC real output data info. Resolution: 12 bit.
ADC real output data info. Resolution: 11 bit.

uint16_t channel
ADC channel index info.
ADC channel index info. For ESP32-S2: If (channel < ADC_CHANNEL_MAX), The data is valid. If (channel > ADC_CHANNEL_MAX), The data is invalid.

struct adc_digi_output_data_t::[anonymous]::[anonymous] type1
ADC type1

uint16_t unit
ADC unit index info. 0: ADC1; 1: ADC2.

struct adc_digi_output_data_t::[anonymous]::[anonymous] type2
When the configured output format is 11bit.

uint16_t val
Raw data value
Type Definitions

typedef `soc_periph_adc_digi_clk_src_t` **adc_oneshot_clk_src_t**
   Clock source type of oneshot mode which uses digital controller.

typedef `soc_periph_adc_digi_clk_src_t` **adc_continuous_clk_src_t**
   Clock source type of continuous mode which uses digital controller.

Enumerations

enum **adc_unit_t**
   ADC unit.

   *Values:*
   
   - enumerator **ADC_UNIT_1**
     SAR ADC 1.
   
   - enumerator **ADC_UNIT_2**
     SAR ADC 2.

enum **adc_channel_t**
   ADC channels.

   *Values:*
   
   - enumerator **ADC_CHANNEL_0**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_1**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_2**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_3**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_4**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_5**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_6**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_7**
     ADC channel.
   
   - enumerator **ADC_CHANNEL_8**
     ADC channel.
enumerator **ADC_CHANNEL_9**
    ADC channel.

enum **adc_atten_t**
ADC attenuation parameter. Different parameters determine the range of the ADC.

*Values:*

enumerator **ADC_ATTEN_DB_0**
    No input attenuation, ADC can measure up to approx.

counterenumerator **ADC_ATTEN_DB_2_5**
    The input voltage of ADC will be attenuated extending the range of measurement by about 2.5 dB (1.33 \time)

counterenumerator **ADC_ATTEN_DB_6**
    The input voltage of ADC will be attenuated extending the range of measurement by about 6 dB (2 \time)

counterenumerator **ADC_ATTEN_DB_11**
    The input voltage of ADC will be attenuated extending the range of measurement by about 11 dB (3.55 \time)

enum **adc_bitwidth_t**

*Values:*

enumerator **ADC_BITWIDTH_DEFAULT**
    Default ADC output bits, max supported width will be selected.

counterenumerator **ADC_BITWIDTH_9**
    ADC output width is 9Bit.

counterenumerator **ADC_BITWIDTH_10**
    ADC output width is 10Bit.

counterenumerator **ADC_BITWIDTH_11**
    ADC output width is 11Bit.

counterenumerator **ADC_BITWIDTH_12**
    ADC output width is 12Bit.

counterenumerator **ADC_BITWIDTH_13**
    ADC output width is 13Bit.

enum **adc_ulp_mode_t**

*Values:*

enumerator **ADC_ULP_MODE_DISABLE**
    ADC ULP mode is disabled.
Chapter 2. API Reference

enumerator **ADC_ULP_MODE_FSM**
ADC is controlled by ULP FSM.

enumerator **ADC_ULP_MODE_RISCV**
ADC is controlled by ULP RISCV.

enum **adc_digi_convert_mode_t**
ADC digital controller (DMA mode) work mode.
*Values:*

enumerator **ADC_CONV_SINGLE_UNIT_1**
Only use ADC1 for conversion.

enumerator **ADC_CONV_SINGLE_UNIT_2**
Only use ADC2 for conversion.

enumerator **ADC_CONV_BOTH_UNIT**
Use Both ADC1 and ADC2 for conversion simultaneously.

enumerator **ADC_CONV_ALTER_UNIT**
Use both ADC1 and ADC2 for conversion by turn. e.g. ADC1 -> ADC2 -> ADC1 -> ADC2 …..

enum **adc_digi_output_format_t**
ADC digital controller (DMA mode) output data format option.
*Values:*

enumerator **ADC_DIGI_OUTPUT_FORMAT_TYPE1**
See `adc_digi_output_data_t.type1`

enumerator **ADC_DIGI_OUTPUT_FORMAT_TYPE2**
See `adc_digi_output_data_t.type2`

enum **adc_digi_iir_filter_t**
ADC IIR Filter ID.
*Values:*

enumerator **ADC_DIGI_IIR_FILTER_0**
Filter 0.

enumerator **ADC_DIGI_IIR_FILTER_1**
Filter 1.

enum **adc_digi_iir_filter_coeff_t**
IIR Filter Coefficient.
*Values:*

enumerator **ADC_DIGI_IIR_FILTER_COEFF_2**
The filter coefficient is 2.
enumerator **ADC_DIGI_IIR_FILTER_COEFF_4**
The filter coefficient is 4.

enumerator **ADC_DIGI_IIR_FILTER_COEFF_8**
The filter coefficient is 8.

enumerator **ADC_DIGI_IIR_FILTER_COEFF_16**
The filter coefficient is 16.

enumerator **ADC_DIGI_IIR_FILTER_COEFF_64**
The filter coefficient is 64.

**Header File**
- components/esp_adc/include/esp_adc/adc_oneshot.h

**Functions**

- **esp_err_t adc_oneshot_new_unit** (const *init_config*, *ret_unit*)
  
  Create a handle to a specific ADC unit.

**Note:** This API is thread-safe. For more details, see ADC programming guide

**Parameters**
- **init_config** – [in] Driver initial configurations
- **ret_unit** – [out] ADC unit handle

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid arguments
- ESP_ERR_NO_MEM: No memory
- ESP_ERR_NOT_FOUND: The ADC peripheral to be claimed is already in use
- ESP_FAIL: Clock source isn’t initialised correctly

- **esp_err_t adc_oneshot_config_channel** (*handle*, *channel*, *config*)

  Set ADC oneshot mode required configurations.

**Note:** This API is thread-safe. For more details, see ADC programming guide

**Parameters**
- **handle** – [in] ADC handle
- **channel** – [in] ADC channel to be configured
- **config** – [in] ADC configurations

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid arguments

- **esp_err_t adc_oneshot_read** (*handle*, *channel*, int *out_raw*)
  
  Get one ADC conversion raw result.
Chapter 2. API Reference

Note: This API is thread-safe. For more details, see ADC programming guide

Note: This API should NOT be called in an ISR context

Parameters
- **handle** - [in] ADC handle
- **chan** - [in] ADC channel
- **out_raw** - [out] ADC conversion raw result

Returns
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid arguments
- ESP_ERR_TIMEOUT: Timeout, the ADC result is invalid

```c
esp_err_t adc_oneshot_del_unit(adc_oneshot_unit_handle_t handle)
```
Delete the ADC unit handle.

Note: This API is thread-safe. For more details, see ADC programming guide

Parameters **handle** - [in] ADC handle

Returns
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid arguments
- ESP_ERR_NOT_FOUND: The ADC peripheral to be disclaimed isn’t in use

```c
esp_err_t adc_oneshot_io_to_channel(int io_num, adc_unit_t *unit_id, adc_channel_t *channel)
```
Get ADC channel from the given GPIO number.

Parameters
- **io_num** - [in] GPIO number
- **unit_id** - [out] ADC unit
- **channel** - [out] ADC channel

Returns
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_ERR_NOT_FOUND: The IO is not a valid ADC pad

```c
esp_err_t adc_oneshot_channel_to_io(adc_unit_t unit_id, adc_channel_t channel, int *io_num)
```
Get GPIO number from the given ADC channel.

Parameters
- **unit_id** - [in] ADC unit
- **channel** - [in] ADC channel
- **io_num** - [out] GPIO number

Returns
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid argument

```c
esp_err_t adc_oneshot_get_calibrated_result(adc_oneshot_unit_handle_t handle,
                                           adc_cali_handle_t cali_handle, adc_channel_t chan,
                                           int *cali_result)
```
Convenience function to get ADC calibrated result.

This is an all-in-one function which does:
- oneshot read ADC raw result
- calibrate the raw result and convert it into calibrated result (in mV)
**Chapter 2. API Reference**

### Parameters

- **handle** - [in] ADC oneshot handle, you should call `adc_oneshot_new_unit()` to get this handle.
- **cali_handle** - [in] ADC calibration handle, you should call `adc_cali_create_scheme_x()` in `adc_cali_scheme.h` to create a handle.
- **chan** - [in] ADC channel.
- **cali_result** - [out] Calibrated ADC result (in mV).

### Returns

- ESP_OK Other return errors from `adc_oneshot_read()` and `adc_cali_raw_to_voltage()`.

### Structures

**structadc_oneshot_unit_init_cfg_t**

ADC oneshot driver initial configurations.

**Public Members**

```c
adc_unit_t unit_id
```

ADC unit.

```c
adc_oneshot_clk_src_t clk_src
```

Clock source.

```c
adc_ulp_mode_t ulp_mode
```

ADC controlled by ULP, see `adc_ulp_mode_t`.

**structadc_oneshot_chan_cfg_t**

ADC channel configurations.

**Public Members**

```c
adc_atten_t atten
```

ADC attenuation.

```c
adc_bitwidth_t bitwidth
```

ADC conversion result bits.

### Type Definitions

```c
typedef struct adc_oneshot_unit_ctx_t* adc_oneshot_unit_handle_t
```

Type of ADC unit handle for oneshot mode.

### 2.6.2 Analog to Digital Converter (ADC) Continuous Mode Driver

#### Introduction

The Analog to Digital Converter is an on-chip sensor which is able to measure analog signals from specific analog IO pads.

ESP32 has two ADC unit(s), which can be used in scenario(s) like:

- Generate one-shot ADC conversion result
Chapter 2. API Reference

- Generate continuous ADC conversion results
This guide will introduce ADC continuous mode conversion.

**Driver Concepts**  ADC continuous mode conversion is made up with multiple Conversion Frames.
- Conversion Frame: One Conversion Frame contains multiple Conversion Results. Conversion Frame size is configured in `adc_continuous_new_handle()`, in bytes.
- Conversion Result: One Conversion Result contains multiple bytes (see `SOC_ADC_DIGI_RESULT_BYTES`). Its structure is `adc_digi_output_data_t`, including ADC unit, ADC channel and raw data.

![One Conversion Frame Diagram](image)

**Functional Overview**

The following sections of this document cover the typical steps to install the ADC continuous mode driver, and read ADC conversion results from group of ADC channels continuously:
- **Resource Allocation** - covers which parameters should be set up to initialize the ADC continuous mode driver and how to deinitialize it.
- **ADC Configurations** - describes how to configure the ADC(s) to make it work under continuous mode.
- **ADC Control** - describes ADC control functions.
- **Register Event Callbacks** - describes how to hook user specific code to an ADC continuous mode event callback function.
- **Read Conversion Result** - covers how to get ADC conversion result.
- **Hardware Limitations** - describes the ADC related hardware limitations.
- **Power Management** - covers power management related.
- **IRAM Safe** - covers the IRAM safe functions.
- **Thread Safety** - lists which APIs are guaranteed to be thread safe by the driver.

**Resource Allocation** The ADC continuous mode driver is implemented based on ESP32 SAR ADC module. Different ESP targets might have different number of independent ADCs.

To create an ADC continuous mode driver handle, set up the required configuration structure `adc_continuous_handle_cfg_t`:
- `adc_continuous_handle_cfg_t::max_store_buf_size` set the maximum size (in bytes) of the pool that the driver saves ADC conversion result into. If this pool is full, new conversion results will be lost.
- `adc_continuous_handle_cfg_t::conv_frame_size` set the size of the ADC conversion frame, in bytes.

After setting up above configurations for the ADC, call `adc_continuous_new_handle()` with the prepared `adc_continuous_handle_cfg_t`. This function may fail due to various errors such as invalid arguments, insufficient memory, etc.

Especially, when this function returns `ESP_ERR_NOT_FOUND`, this means the I2S0 peripheral is in use. See Hardware Limitations for more information.

If the ADC continuous mode driver is no longer used, you should deinitialize the driver by calling `adc_continuous_deinit()`.
Initialize the ADC Continuous Mode Driver

```c
adc_continuous_handle_cfg_t adc_config = {
    .max_store_buf_size = 1024,
    .conv_frame_size = 100,
};
ESP_ERROR_CHECK(adc_continuous_new_handle(&adc_config));
```

Recycle the ADC Unit

```c
ESP_ERROR_CHECK(adc_continuous_deinit());
```

ADC Configurations After the ADC continuous mode driver is initialized, set up the `adc_continuous_config_t` to configure ADC IOs to measure analog signal:

- `adc_continuous_config_t::pattern_num`, number of ADC channels that will be used.
- `adc_continuous_config_t::adc_pattern`, list of configs for each ADC channel that will be used, see below description.
- `adc_continuous_config_t::sample_freg_hz`, expected ADC sampling frequency in Hz.
- `adc_continuous_config_t::conv_mode`, continuous conversion mode.
- `adc_continuous_config_t::format`, conversion output format.

For `adc_digi_pattern_config_t`:

- `adc_digi_pattern_config_t::atten`, ADC attenuation. Refer to the On-Chip Sensor chapter in TRM.
- `adc_digi_pattern_config_t::channel`, the IO corresponding ADC channel number. See below note.
- `adc_digi_pattern_config_t::unit`, the ADC that the IO is subordinate to.
- `adc_digi_pattern_config_t::bit_width`, the bitwidth of the raw conversion result.

**Note:** For the IO corresponding ADC channel number. Check datasheet to acquire the ADC IOs. On the other hand, `adc_continuous_io_to_channel()` and `adc_continuous_channel_to_io()` can be used to acquire the ADC channels and ADC IOs.

To make these settings take effect, call `adc_continuous_config()` with the configuration structure above. This API may fail due to reasons like `ESP_ERR_INVALID_ARG`. When it returns `ESP_ERR_INVALID_STATE`, this means the ADC continuous mode driver is started, you shouldn’t call this API at this moment.

See ADC continuous mode example `peripherals/adc/continuous_read` to see configuration codes.

ADC Control

**Start and Stop** Calling `adc_continuous_start()` will make the ADC start to measure analog signals from the configured ADC channels, and generate the conversion results. On the contrary, calling `adc_continuous_stop()` will stop the ADC conversion.

```c
ESP_ERROR_CHECK(adc_continuous_stop());
```

**Register Event Callbacks** By calling `adc_continuous_register_event_callbacks()`, you can hook your own function to the driver ISR. Supported event callbacks are listed in `adc_continuous_evt_cbs_t`

- `adc_continuous_evt_cbs_t::on_conv_done`, this is invoked when one conversion frame finishes.
- `adc_continuous_evt_cbs_t::on_pool_ovf`, this is invoked when internal pool is full. Newer conversion results will be discarded.
As above callbacks are called in an ISR context, you should always ensure the callback function is suitable for an ISR context. Blocking logics should not appear in these callbacks. Callback function prototype is declared in `adc_continuous_callback_t`.

You can also register your own context when calling `adc_continuous_register_event_callbacks()`, by the parameter `user_data`. This user data will be passed to the callback functions directly.

This function may fail due to reasons like `ESP_ERR_INVALID_ARG`. Specially, when `CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE` is enabled, this error may indicate that the callback functions aren’t in internal RAM. Check error log to know this. Besides, when it fails due to `ESP_ERR_INVALID_STATE`, this means the ADC continuous mode driver is started, you shouldn’t add callback at this moment.

**Conversion Done Event** The driver will fill in the event data of a `adc_continuous_evt_cbs_t::on_conv_done` event. Event data contains a buffer pointer to a conversion frame buffer, together with the size. Refer to `adc_continuous_evt_data_t` to know the event data structure.

**Note:** It is worth noting that, the data buffer `adc_continuous_evt_data_t::conv_frame_buffer` is maintained by the driver itself. Therefore, never free this piece of memory.

**Note:** When the Kconfig option `CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE` is enabled, the registered callbacks and the functions called by the callbacks should be placed in IRAM. The involved variables should be placed in internal RAM as well.

**Pool Overflow Event** The ADC continuous mode driver has an internal pool to save the conversion results. When the pool is full, a pool overflow event will emerge. Under this condition, the driver won’t fill in the event data. This usually happens the speed to read data from the pool (by calling `adc_continuous_read()`) is much slower than the ADC conversion speed.

**Read Conversion Result** After calling `adc_continuous_start()`, the ADC continuous conversion starts. Call `adc_continuous_read()` to get the conversion results of the ADC channels. You need to provide a buffer to get the raw results.

This function will try to read the expected length of conversion results each time.

- If the requested length isn’t reached, the function will still move the data from the internal pool to the buffer you prepared. Therefore, check the `out_length` to know the actual size of conversion results.
- If there is no conversion result generated in the internal pool, the function will block for `timeout_ms` until the conversion results are generated. If there is still no generated results, the function will return `ESP_ERR_TIMEOUT`.
- If the generated results fill up the internal pool, new generated results will be lost. Next time when the `adc_continuous_read()` is called, this function will return `ESP_ERR_INVALID_STATE` indicating this situation.

This API aims to give you a chance to read all the ADC continuous conversion results.

The ADC conversion results read from above function are raw data. To calculate the voltage based on the ADC raw results, this formula can be used:

\[
V_{out} = D_{out} \times V_{max} / D_{max} \quad (1)
\]

where:
Vout  Digital output result, standing for the voltage.

Dout  ADC raw digital reading result.

Vmax  Maximum measurable input analog voltage, this is related to the ADC attenuation, please refer to the On-Chip Sensor chapter in TRM.

Dmax  Maximum of the output ADC raw digital reading result, which is 2^bitwidth, where bitwidth is the :cpp:member::adc_digi_pattern_config_t:bit_width configured before.

To do further calibration to convert the ADC raw result to voltage in mV, please refer to calibration doc Analog to Digital Converter (ADC) Calibration Driver.

**Hardware Limitations**

- A specific ADC unit can only work under one operating mode at any one time, either continuous mode or oneshot mode. `adc_continuous_start()` has provided the protection.
- Random Number Generator uses ADC as an input source. When ADC continuous mode driver works, the random number generated from RNG will be less random.
- ADC2 is also used by the Wi-Fi. `adc_continuous_start()` has provided the protection between Wi-Fi driver and ADC continuous mode driver.
- ADC continuous mode driver uses I2S0 peripheral as hardware DMA fifo. Therefore, if I2S0 is in use already, the `adc_continuous_new_handle()` will return ESP_ERR_NOT_FOUND.
- ESP32 DevKitC: GPIO 0 cannot be used due to external auto program circuits.
- ESP-WROVER-KIT: GPIO 0, 2, 4 and 15 cannot be used due to external connections for different purposes.

**Power Management**  When power management is enabled (i.e. `CONFIG_PM_ENABLE` is on), the APB clock frequency may be adjusted when the system is in an idle state, thus potentially changing the behavior of ADC continuous conversion.

However, the continuous mode driver can prevent this change by acquiring a power management lock of type `ESP_PM_APB_FREQ_MAX`. The lock is acquired after the continuous conversion is started by `adc_continuous_start()`. Similarly, the lock will be released after `adc_continuous_stop()`. Therefore, `adc_continuous_start()` and `adc_continuous_stop()` should appear in pairs, otherwise the power management will be out of action.

**IRAM Safe**  All the ADC continuous mode driver APIs are not IRAM-safe. They are not supposed to be run when the Cache is disabled. By enabling the Kconfig option `CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE`, driver internal ISR handler is IRAM-safe, which means even when the Cache is disabled, the driver will still save the conversion results into its internal pool.

**Thread Safety**  ADC continuous mode driver APIs are not guaranteed to be thread safe. However, the share hardware mutual exclusion is provided by the driver. See Hardware Limitations for more details.

**Application Examples**

- ADC continuous mode example: peripherals/adc/continuous_read.

**API Reference**

**Header File**

- components/esp_adc/include/esp_adc/adc_continuous.h
Chapter 2. API Reference

Functions

**esp_err_t adc_continuous_new_handle** (const "adc_continuous_handle_cfg_t" *hdl_config, "adc_continuous_handle_t" *ret_handle)

Initialize ADC continuous driver and get a handle to it.

**Parameters**

- hdl_config [in] Pointer to ADC initialization config. Refer to "adc_continuous_handle_cfg_t".
- ret_handle [out] ADC continuous mode driver handle

**Returns**

- ESP_ERR_INVALID_ARG If the combination of arguments is invalid.
- ESP_ERR_NOT_FOUND No free interrupt found with the specified flags
- ESP_ERR_NO_MEM If out of memory
- ESP_OK On success

**esp_err_t adc_continuous_config** ("adc_continuous_handle_t" handle, const "adc_continuous_config_t" *config)

Set ADC continuous mode required configurations.

**Parameters**

- handle [in] ADC continuous mode driver handle
- config [in] Refer to "adc_digi_config_t".

**Returns**

- ESP_ERR_INVALID_STATE: Driver state is invalid, you shouldn’t call this API at this moment
- ESP_ERR_INVALID_ARG: If the combination of arguments is invalid.
- ESP_OK: On success

**esp_err_t adc_continuous_register_event_callbacks** ("adc_continuous_handle_t" handle, const "adc_continuous_evt_cbs_t" *cbs, void *user_data)

Register callbacks.

**Note:** User can deregister a previously registered callback by calling this function and setting the to-be-deregistered callback member in the cbs structure to NULL.

**Note:** When CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. Involved variables (including user_data) should be in internal RAM as well.

**Note:** You should only call this API when the ADC continuous mode driver isn’t started. Check return value to know this.

**Parameters**

- handle [in] ADC continuous mode driver handle
- cbs [in] Group of callback functions
- user_data [in] User data, which will be delivered to the callback functions directly

**Returns**

- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid arguments
- ESP_ERR_INVALID_STATE: Driver state is invalid, you shouldn’t call this API at this moment

**esp_err_t adc_continuous_start** ("adc_continuous_handle_t" handle)

Start the ADC under continuous mode. After this, the hardware starts working.
Chapter 2. API Reference

Parameters handle  
  - [in] ADC continuous mode driver handle

Returns
  • ESP_ERR_INVALID_STATE Driver state is invalid.
  • ESP_OK On success

**esp_err_t adc_continuous_read** (adc_continuous_handle_t handle, uint8_t *buf, uint32_t length_max, uint32_t *out_length, uint32_t timeout_ms)

Read bytes from ADC under continuous mode.

Parameters
  • handle  
    - [in] ADC continuous mode driver handle
  • buf  
    - [out] Conversion result buffer to read from ADC. Suggest convert to adc_digi_output_data_t for ADC Conversion Results. See @brief Driver Backgrounds to know this concept.
  • length_max  
    - [in] Expected length of the Conversion Results read from the ADC, in bytes.
  • out_length  
    - [out] Real length of the Conversion Results read from the ADC via this API, in bytes.
  • timeout_ms  
    - [in] Time to wait for data via this API, in millisecond.

Returns
  • ESP_ERR_INVALID_STATE Driver state is invalid. Usually it means the ADC sampling rate is faster than the task processing rate.
  • ESP_ERR_TIMEOUT Operation timed out
  • ESP_OK On success

**esp_err_t adc_continuous_stop** (adc_continuous_handle_t handle)

Stop the ADC. After this, the hardware stops working.

Parameters handle  
  - [in] ADC continuous mode driver handle

Returns
  • ESP_ERR_INVALID_STATE Driver state is invalid.
  • ESP_OK On success

**esp_err_t adc_continuous_deinit** (adc_continuous_handle_t handle)

Deinitialize the ADC continuous driver.

Parameters handle  
  - [in] ADC continuous mode driver handle

Returns
  • ESP_ERR_INVALID_STATE Driver state is invalid.
  • ESP_OK On success

**esp_err_t adc_continuous_io_to_channel** (int io_num, adc_unit_t *unit_id, adc_channel_t *channel)

Get ADC channel from the given GPIO number.

Parameters
  • io_num  
    - [in] GPIO number
  • unit_id  
    - [out] ADC unit
  • channel  
    - [out] ADC channel

Returns
  • ESP_OK: On success
  • ESP_ERR_INVALID_ARG: Invalid argument
  • ESP_ERR_NOT_FOUND: The IO is not a valid ADC pad

**esp_err_t adc_continuous_channel_to_io** (adc_unit_t unit_id, adc_channel_t channel, int *io_num)

Get GPIO number from the given ADC channel.

Parameters
  • unit_id  
    - [in] ADC unit
  • channel  
    - [in] ADC channel
  • io_num  
    - [out] GPIO number

Results
  • ESP_OK: On success
  • ESP_ERR_INVALID_ARG: Invalid argument
Chapter 2. API Reference

Structures

struct `adc_continuous_handle_cfg_t`
ADC continuous mode driver initial configurations.

Public Members

`uint32_t max_store_buf_size`
Max length of the conversion Results that driver can store, in bytes.

`uint32_t conv_frame_size`
Conversion frame size, in bytes. This should be in multiples of `SOC_ADC_DIGI_DATA_BYTES_PER_CONV`.

struct `adc_continuous_config_t`
ADC continuous mode driver configurations.

Public Members

`uint32_t pattern_num`
Number of ADC channels that will be used.

`adc_digi_pattern_config_t *adc_pattern`
List of configs for each ADC channel that will be used.

`uint32_t sample_freq_hz`
The expected ADC sampling frequency in Hz. Please refer to `soc/soc_caps.h` to know available sampling frequency range.

`adc_digi_convert_mode_t conv_mode`
ADC DMA conversion mode, see `adc_digi_convert_mode_t`.

`adc_digi_output_format_t format`
ADC DMA conversion output format, see `adc_digi_output_format_t`.

struct `adc_continuous_evt_data_t`
Event data structure.

Note: The `conv_frame_buffer` is maintained by the driver itself, so never free this piece of memory.

Public Members

`uint8_t *conv_frame_buffer`
Pointer to conversion result buffer for one conversion frame.

`uint32_t size`
Conversion frame size.
Chapter 2. API Reference

struct adc_continuous_evt_cbs_t

Group of ADC continuous mode callbacks.

Note: These callbacks are all running in an ISR environment.

Note: When CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. Involved variables should be in internal RAM as well.

Public Members

adc_continuous_callback_t on_conv_done

Event callback, invoked when one conversion frame is done. See @brief Driver Backgrounds to know conversion frame concept.

adc_continuous_callback_t on_pool_ovf

Event callback, invoked when the internal pool is full.

Macros

ADC_MAX_DELAY

Driver Backgrounds.

Type Definitions

typedef struct adc_continuous_ctx_t *adc_continuous_handle_t

Type of adc continuous mode driver handle.

typedef bool (*adc_continuous_callback_t)(adc_continuous_handle_t handle, const adc_continuous_evt_data_t *edata, void *user_data)

Prototype of ADC continuous mode event callback.

Param handle [in] ADC continuous mode driver handle
Param edata  [in] Pointer to ADC continuous mode event data
Param user_data [in] User registered context, registered when in adc_continuous_register_event_callbacks()

Return Whether a high priority task is woken up by this function

2.6.3 Analog to Digital Converter (ADC) Calibration Driver

Introduction

In ESP32, the digital-to-analog converter (ADC) compares the input analog voltage to the reference, and determines each bit of the output digital result. By design, the ADC reference voltage for ESP32 is 1100 mV. However, the true reference voltage can range from 1000 mV to 1200 mV among different chips. This guide introduces the ADC calibration driver to minimize the effect of different reference voltages, and get more accurate output results.
Functional Overview

The following sections of this document cover the typical steps to install and use the ADC calibration driver:

- **Calibration Scheme Creation** - covers how to create a calibration scheme handle and delete the calibration scheme handle.
- **Result Conversion** - covers how to convert ADC raw result to calibrated result.
- **Thread Safety** - lists which APIs are guaranteed to be thread-safe by the driver.
- **Minimize Noise** - describes a general way to minimize the noise.
- **Kconfig Options** - lists the supported Kconfig options that can be used to make a different effect on driver behavior.

### Calibration Scheme Creation

The ADC calibration driver provides ADC calibration scheme(s). From the calibration driver’s point of view, an ADC calibration scheme is created for an ADC calibration handle `adc_cali_handle_t`.

The function `adc_cali_check_scheme()` can be used to know which calibration scheme is supported on the chip. If you already know the supported schemes, this step can be skipped. Just call the corresponding function to create the scheme handle.

If you use your custom ADC calibration schemes, you could either modify this function `adc_cali_check_scheme()`, or just skip this step and call your custom creation function.

### ADC Calibration Line Fitting Scheme

ESP32 supports `ADC_CALI_SCHEME_VER_LINE_FITTING` scheme. To create this scheme, set up `adc_cali_line_fitting_config_t` first.

- `adc_cali_line_fitting_config_t::unit_id`, the ADC that your ADC raw results are from.
- `adc_cali_line_fitting_config_t::atten`, ADC attenuation that your ADC raw results use.
- `adc_cali_line_fitting_config_t::bitwidth`, bit width of ADC raw result.

There is also a configuration `adc_cali_line_fitting_config_t::default_vref`. Normally this can be simply set to 0. Line Fitting scheme does not rely on this value. However, if the Line Fitting scheme required eFuse bits are not burnt on your board, the driver will rely on this value to do the calibration.

You can use `adc_cali_scheme_line_fitting_check_efuse()` to check the eFuse bits. Normally the Line Fitting scheme eFuse value is `ADC_CALI_LINE_FITTING_EFUSE_VAL_EFUSE_TP` or `ADC_CALI_LINE_FITTING_EFUSE_VAL_EFUSE_VREF`. This means the Line Fitting scheme uses calibration parameters burnt in the eFuse to do the calibration.

When the Line Fitting scheme eFuse value is `ADC_CALI_LINE_FITTING_EFUSE_VAL_DEFAULT_VREF`, you need to set the `esp_adc_cali_line_fitting_init::default_vref`. Default vref is an estimate of the ADC reference voltage provided as a parameter during calibration.

After setting up the configuration structure, call `adc_cali_create_scheme_line_fitting()` to create a Line Fitting calibration scheme handle.

```c
ESP_LOGI(TAG, "calibration scheme version is \%s", "Line Fitting");
adc_cali_line_fitting_config_t cali_config = {
    .unit_id = unit,
    .atten = atten,
    .bitwidth = ADC_BITWIDTH_DEFAULT,
};
ESP_ERROR_CHECK(adc_cali_create_scheme_line_fitting(&cali_config, &handle));
```

When the ADC calibration is no longer used, please delete the calibration scheme handle by calling `adc_cali_delete_scheme_line_fitting()`.

### Delete Line Fitting Scheme
**Chapter 2. API Reference**

```c
ESP_LOGI(TAG, "delete %s calibration scheme", "Line Fitting");
ESP_ERROR_CHECK(adc_cali_delete_scheme_line_fitting(handle));
```

**Note:** If you want to use your custom calibration schemes, you could provide a creation function to create your calibration scheme handle. Check the function table `adc_cali_scheme_t` in `components/esp_adc/\interface/adc_cali_interface.h` to know the ESP ADC calibration interface.

**Result Conversion** After setting up the calibration characteristics, you can call `adc_cali_raw_to_voltage()` to convert the ADC raw result into calibrated result. The calibrated result is in the unit of mV. This function may fail due to an invalid argument. Especially, if this function returns `ESP_ERR_INVALID_STATE`, this means the calibration scheme is not created. You need to create a calibration scheme handle, use `adc_cali_check_scheme()` to know the supported calibration scheme. On the other hand, you could also provide a custom calibration scheme and create the handle.

**Get Voltage**

```c
ESP_ERROR_CHECK(adc_cali_raw_to_voltage(adc_cali_handle, adc_raw[0][0], &voltage[0][0]));
ESP_LOGI(TAG, "ADC%d Channel[%d] Cali Voltage: %d mV", ADC_UNIT_1 + 1, EXAMPLE_---ADC1_CHAN0, voltage[0][0]);
```

**Thread Safety** The factory function `esp_adc_cali_new_scheme()` is guaranteed to be thread-safe by the driver. Therefore, you can call them from different RTOS tasks without protection by extra locks.

Other functions that take the `adc_cali_handle_t` as the first positional parameter are not thread-safe, you should avoid calling them from multiple tasks.

**Kconfig Options**

- `CONFIG_ADC_CAL_EFUSE_TP_ENABLE` - disable this to decrease the code size, if the calibration eFuse value is not set to `ADC_CALI_LINE_FITTING_EFUSE_VAL_EFUSE_TP`.
- `CONFIG_ADC_CAL_EFUSE_VREF_ENABLE` - disable this to decrease the code size, if the calibration eFuse value is not set to `ADC_CALI_LINE_FITTING_EFUSE_VAL_EFUSE_VREF`.
- `CONFIG_ADC_CAL_LUT_ENABLE` - disable this to decrease the code size, if you do not calibrate the ADC raw results under `ADC_ATTEN_DB_11`.

**Minimize Noise** The ESP32 ADC is sensitive to noise, leading to large discrepancies in ADC readings. Depending on the usage scenario, you may need to connect a bypass capacitor (e.g., a 100 nF ceramic capacitor) to the ADC input pad in use, to minimize noise. Besides, multisampling may also be used to further mitigate the effects of noise.

**API Reference**

**Header File**

- `components/esp_adc/include/esp_adc/adc_cali.h`

**Functions**

```c
esp_err_t adc_cali_check_scheme(adc_cali_scheme_ver_t *scheme_mask)
```

Check the supported ADC calibration scheme.

**Parameters**

- `scheme_mask` - [out] Supported ADC calibration scheme(s)

**Returns**

- `ESP_OK`: On success
Fig. 6: Graph illustrating noise mitigation using capacitor and multisampling of 64 samples.

- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_ERR_NOT_SUPPORTED: No supported calibration scheme

```c
esp_err_t adc_cali_raw_to_voltage(adc_cali_handle_t handle, int raw, int *voltage)
```

Convert ADC raw data to calibrated voltage.

**Parameters**
- `handle` - [in] ADC calibration handle
- `raw` - [in] ADC raw data
- `voltage` - [out] Calibrated ADC voltage (in mV)

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_ERR_INVALID_STATE: Invalid state, scheme didn’t registered

**Type Definitions**

```c
typedef struct adc_cali_scheme_t *adc_cali_handle_t
```

ADC calibration handle.

**Enumerations**

```c
enum adc_cali_scheme_ver_t
```

ADC calibration scheme.

**Values:**

- `ADC_CALI_SCHEME_VER_LINE_FITTING`
  Line fitting scheme.

- `ADC_CALI_SCHEME_VER_CURVE_FITTING`
2.6.4 Clock Tree

The clock subsystem of ESP32 is used to source and distribute system/module clocks from a range of root clocks. The clock tree driver maintains the basic functionality of the system clock and the intricate relationship among module clocks.

This document starts with the introduction to root and module clocks. Then it covers the clock tree APIs that can be called to monitor the status of the module clocks at runtime.

Introduction

This section lists definitions of ESP32’s supported root clocks and module clocks. These definitions are commonly used in the driver configuration, to help select a proper source clock for the peripheral.

Root Clocks Root clocks generate reliable clock signals. These clock signals then pass through various gates, muxes, dividers, or multipliers to become the clock sources for every functional module: the CPU core(s), Wi-Fi, Bluetooth, the RTC, and the peripherals.

ESP32’s root clocks are listed in `soc_root_clk_t`:

- Internal 8 MHz RC Oscillator (RC_FAST)
  This RC oscillator generates a about 8.5 MHz clock signal output as the `RC_FAST_CLK`. The about 8.5 MHz signal output is also passed into a configurable divider, which by default divides the input clock frequency by 256, to generate a `RC_FAST_D256_CLK`. The exact frequency of `RC_FAST_CLK` can be computed in runtime through calibration on the `RC_FAST_D256_CLK`.

- External 2~40 MHz Crystal (XTAL)

- Internal 150 kHz RC Oscillator (RC_SLOW)
  This RC oscillator generates a about 150kHz clock signal output as the `RC_SLOW_CLK`. The exact frequency of this clock can be computed in runtime through calibration.

- External 32 kHz Crystal - optional (XTAL32K)
  The clock source for this `XTAL32K_CLK` can be either a 32 kHz crystal connecting to the `32K_XP` and `32K_XN` pins or a 32 kHz clock signal generated by an external circuit. The external signal must be connected to the `32K_XN` pin. Additionally, a 1 nF capacitor must be placed between the `32K_XP` pin and ground. In this case, the `32K_XP` pin cannot be used as a GPIO pin. `XTAL32K_CLK` can also be calibrated to get its exact frequency.

Typically, the frequency of the signal generated from an RC oscillator circuit is less accurate and more sensitive to the environment compared to the signal generated from a crystal. ESP32 provides several clock source options for the `RTC_SLOW_CLK`, and it is possible to make the choice based on the requirements for system time accuracy and power consumption. For more details, please refer to `RTC Timer Clock Sources`.

Module Clocks ESP32’s available module clocks are listed in `soc_module_clk_t`. Each module clock has a unique ID. You can get more information on each clock by checking the documented enum value.
Chapter 2. API Reference

API Usage

The clock tree driver provides an all-in-one API to get the frequency of the module clocks, `esp_clk_tree_src_get_freq_hz()`. This function allows you to obtain the clock frequency at any time by providing the clock name `soc_module_clk_t` and specifying the desired precision level for the returned frequency value `esp_clk_tree_src_freq_precision_t`.

API Reference

Header File

- components/soc/esp32/include/soc/clk_tree_defs.h

Macros

```
SOC_CLK_RC_FAST_FREQ_APPROX
Approximate RC_FAST_CLK frequency in Hz

SOC_CLK_RC_SLOW_FREQ_APPROX
Approximate RC_SLOW_CLK frequency in Hz

SOC_CLK_RC_FAST_D256_FREQ_APPROX
Approximate RC_FAST_D256_CLK frequency in Hz

SOC_CLK_XTAL32K_FREQ_APPROX
Approximate XTAL32K_CLK frequency in Hz

SOC_GPTIMER_CLKS
Array initializer for all supported clock sources of GPTimer.

The following code can be used to iterate all possible clocks:

```c
soc_periph_gptimer_clk_src_t gptimer_clks[] = (soc_periph_gptimer_clk_src_t*)SOC_GPTIMER_CLKS;
for (size_t i = 0; i < sizeof(gptimer_clks) / sizeof(gptimer_clks[0]); i++) {
    soc_periph_gptimer_clk_src_t clk = gptimer_clks[i];
    // Test GPTimer with the clock `clk`
}
```

SOC_LCD_CLKS
Array initializer for all supported clock sources of LCD.

SOC_RMT_CLKS
Array initializer for all supported clock sources of RMT.

SOC_MCPWM_TIMER_CLKS
Array initializer for all supported clock sources of MCPWM Timer.

SOC_MCPWM_capture_CLKS
Array initializer for all supported clock sources of MCPWM Capture Timer.

SOC_MCPWM_CARRIER_CLKS
Array initializer for all supported clock sources of MCPWM Carrier.
SOC_I2S_CLKS
Array initializer for all supported clock sources of I2S.

SOC_I2C_CLKS
Array initializer for all supported clock sources of I2C.

SOC_SPI_CLKS
Array initializer for all supported clock sources of SPI.

SOC_SDM_CLKS
Array initializer for all supported clock sources of SDM.

SOC_DAC_DIGI_CLKS
Array initializer for all supported clock sources of DAC digital controller.

SOC_DAC_COSINE_CLKS
Array initializer for all supported clock sources of DAC cosine wave generator.

SOC_TWAI_CLKS
Array initializer for all supported clock sources of TWAI.

SOC_ADC_DIGI_CLKS
Array initializer for all supported clock sources of ADC digital controller.

SOC_ADC_RTC_CLKS
Array initializer for all supported clock sources of ADC RTC controller.

SOC_MWDT_CLKS
Array initializer for all supported clock sources of MWDT.

SOC_LEDC_CLKS
Array initializer for all supported clock sources of LEDC.

Enumerations

defined

class soc_root_clk_t
Root clock.

Values:

enumerator SOC_ROOT_CLK_INT_RC_FAST
Internal 8MHz RC oscillator

enumerator SOC_ROOT_CLK_INT_RC_SLOW
Internal 150kHz RC oscillator

enumerator SOC_ROOT_CLK_EXT_XTAL
External 2~40MHz crystal
enumerator `SOC_ROOT_CLK_EXT_XTAL32K`
External 32kHz crystal/clock signal

enum `soc_cpu_clk_src_t`
CPU_CLK mux inputs, which are the supported clock sources for the CPU_CLK.

**Note:** Enum values are matched with the register field values on purpose

**Values:**

enumerator `SOC_CPU_CLK_SRC_XTAL`
Select XTAL_CLK as CPU_CLK source

enumerator `SOC_CPU_CLK_SRC_PLL`
Select PLL_CLK as CPU_CLK source (PLL_CLK is the output of 40MHz crystal oscillator frequency multiplier, can be 480MHz or 320MHz)

enumerator `SOC_CPU_CLK_SRC_RC_FAST`
Select RC_FAST_CLK as CPU_CLK source

enumerator `SOC_CPU_CLK_SRC_APLL`
Select APLL_CLK as CPU_CLK source

enumerator `SOC_CPU_CLK_SRC_INVALID`
Invalid CPU_CLK source

enum `soc_rtc_slow_clk_src_t`
RTC_SLOW_CLK mux inputs, which are the supported clock sources for the RTC_SLOW_CLK.

**Note:** Enum values are matched with the register field values on purpose

**Values:**

enumerator `SOC_RTC_SLOW_CLK_SRC_RC_SLOW`
Select RC_SLOW_CLK as RTC_SLOW_CLK source

enumerator `SOC_RTC_SLOW_CLK_SRC_XTAL32K`
Select XTAL32K_CLK as RTC_SLOW_CLK source

enumerator `SOC_RTC_SLOW_CLK_SRC_RC_FAST_D256`
Select RC_FAST_D256_CLK (referred as FOSC_DIV or 8m_d256/8md256 in TRM and reg. description) as RTC SLOW_CLK source

enumerator `SOC_RTC_SLOW_CLK_SRC_INVALID`
Invalid RTC_SLOW_CLK source

enum `soc_rtc_fast_clk_src_t`
RTC_FAST_CLK mux inputs, which are the supported clock sources for the RTC_FAST_CLK.
Chapter 2. API Reference

**Note:** Enum values are matched with the register field values on purpose

**Values:**

enumerator `SOC_RTC_FAST_CLK_SRC_XTAL_D4`  
Select XTAL_D4_CLK (may referred as XTAL_CLK_DIV_4) as RTC_FAST_CLK source

enumerator `SOC_RTC_FAST_CLK_SRC_XTAL_DIV`  
Alias name for `SOC_RTC_FAST_CLK_SRC_XTAL_D4`

enumerator `SOC_RTC_FAST_CLK_SRC_RC_FAST`  
Select RC_FAST_CLK as RTC_FAST_CLK source

enumerator `SOC_RTC_FAST_CLK_SRC_INVALID`  
Invalid RTC_FAST_CLK source

enum `soc_module_clk_t`  
Supported clock sources for modules (CPU, peripherals, RTC, etc.)

**Note:** enum starts from 1, to save 0 for special purpose

**Values:**

enumerator `SOC_MOD_CLK_CPU`  
CPU_CLK can be sourced from XTAL, PLL, RC_FAST, or APLL by configuring `soc_cpu_clk_src_t`

enumerator `SOC_MOD_CLK_RTC_FAST`  
RTC_FAST_CLK can be sourced from XTAL_D4 or RC_FAST by configuring `soc_rtc_fast_clk_src_t`

enumerator `SOC_MOD_CLK_RTC_SLOW`  
RTC_SLOW_CLK can be sourced from RC_SLOW, XTAL32K, or RC_FAST_D256 by configuring `soc_rtc_slow_clk_src_t`

enumerator `SOC_MOD_CLK_APB`  
APB_CLK is highly dependent on the CPU_CLK source

enumerator `SOC_MOD_CLK_PLL_D2`  
PLL_D2_CLK is derived from PLL, it has a fixed divider of 2

enumerator `SOC_MOD_CLK_PLL_F160M`  
PLL_F160M_CLK is derived from PLL, and has a fixed frequency of 160MHz

enumerator `SOC_MOD_CLK_XTAL32K`  
XTAL32K_CLK comes from the external 32kHz crystal, passing a clock gating to the peripherals

enumerator `SOC_MOD_CLK_RC_FAST`  
RC_FAST_CLK comes from the internal 8MHz rc oscillator, passing a clock gating to the peripherals
enumerator **SOC_MOD_CLK_RC_FAST_D256**

RC_FAST_D256_CLK comes from the internal 8MHz RC oscillator, divided by 256, and passing a clock gating to the peripherals

enumerator **SOC_MOD_CLK_XTAL**

XTAL_CLK comes from the external crystal (2~40MHz)

destructor **SOC_MOD_CLK_REF_TICK**

REF_TICK is derived from APB, it has a fixed frequency of 1MHz even when APB frequency changes

enumerator **SOC_MOD_CLK_APLL**

APLL is sourced from PLL, and its frequency is configurable through APLL configuration registers

enumerator **SOC_MOD_CLK_INVALID**

Indication of the end of the available module clock sources

enum **soc_periph_systimer_clk_src_t**

Type of SYSTIMER clock source.

*Values:*

enumerator **SYSTIMER_CLK_SRC_XTAL**

SYSTIMER source clock is XTAL

enumerator **SYSTIMER_CLK_SRC_DEFAULT**

SYSTIMER source clock default choice is XTAL

enum **soc_periph_gptimer_clk_src_t**

Type of GPTimer clock source.

*Values:*

enumerator **GPTIMER_CLK_SRC_APB**

Select APB as the source clock

enumerator **GPTIMER_CLK_SRC_DEFAULT**

Select APB as the default choice

enum **soc_periph_tg_clk_src_legacy_t**

Type of Timer Group clock source, reserved for the legacy timer group driver.

*Values:*

enumerator **TIMER_SRC_CLK_APB**

Timer group source clock is APB

enumerator **TIMER_SRC_CLK_DEFAULT**

Timer group source clock default choice is APB
enum `soc_periph_lcd_clk_src_t`  
Type of LCD clock source.

*Values:*

enumerator `LCD_CLK_SRC_PLL160M`  
Select PLL_160M as the source clock

eenumerator `LCD_CLK_SRC_DEFAULT`  
Select PLL_160M as the default choice

enum `soc_periph_rmt_clk_src_t`  
Type of RMT clock source.

*Values:*

enumerator `RMT_CLK_SRC_APB`  
Select APB as the source clock

eenumerator `RMT_CLK_SRC_REF_TICK`  
Select REF_TICK as the source clock

eenumerator `RMT_CLK_SRC_DEFAULT`  
Select APB as the default choice

enum `soc_periph_rmt_clk_src_legacy_t`  
Type of RMT clock source, reserved for the legacy RMT driver.

*Values:*

enumerator `RMT_BASECLK_APB`  
RMT source clock is APB CLK

eenumerator `RMT_BASECLK_REF`  
RMT source clock is REF_TICK

eenumerator `RMT_BASECLK_DEFAULT`  
RMT source clock default choice is APB

enum `soc_periph_uart_clk_src_legacy_t`  
Type of UART clock source, reserved for the legacy UART driver.

*Values:*

enumerator `UART_SCLK_APB`  
UART source clock is APB CLK

eenumerator `UART_SCLK_REF_TICK`  
UART source clock is REF_TICK

eenumerator `UART_SCLK_DEFAULT`  
UART source clock default choice is APB
enum `soc_periph_mcpwm_timer_clk_src_t`
Type of MCPWM timer clock source.

*Values:*

- `MCPWM_TIMER_CLK_SRC_PLL160M`  
  Select PLL_F160M as the source clock

- `MCPWM_TIMER_CLK_SRC_DEFAULT`  
  Select PLL_F160M as the default clock choice

enum `soc_periph_mcpwm_capture_clk_src_t`
Type of MCPWM capture clock source.

*Values:*

- `MCPWM_CAPTURE_CLK_SRC_APB`  
  Select APB as the source clock

- `MCPWM_CAPTURE_CLK_SRC_DEFAULT`  
  Select APB as the default clock choice

enum `soc_periph_mcpwm_carrier_clk_src_t`
Type of MCPWM carrier clock source.

*Values:*

- `MCPWM_CARRIER_CLK_SRC_PLL160M`  
  Select PLL_F160M as the source clock

- `MCPWM_CARRIER_CLK_SRC_DEFAULT`  
  Select PLL_F160M as the default clock choice

enum `soc_periph_i2s_clk_src_t`
I2S clock source enum.

*Values:*

- `I2S_CLK_SRC_DEFAULT`  
  Select PLL_F160M as the default source clock

- `I2S_CLK_SRC_PLL_160M`  
  Select PLL_F160M as the source clock

- `I2S_CLK_SRC_APLL`  
  Select APLL as the source clock

enum `soc_periph_i2c_clk_src_t`
Type of I2C clock source.

*Values:*

enumerator I2C_CLK_SRC_APB
enumerator I2C_CLK_SRC_DEFAULT

enum soc_periph_spi_clk_src_t
   Type of SPI clock source.
   Values:
   enumerator SPI_CLK_SRC_DEFAULT
      Select APB as SPI source clock
   enumerator SPI_CLK_SRC_APB
      Select APB as SPI source clock

enum soc_periph_sdm_clk_src_t
   Sigma Delta Modulator clock source.
   Values:
   enumerator SDM_CLK_SRC_APB
      Select APB as the source clock
   enumerator SDM_CLK_SRC_DEFAULT
      Select APB as the default clock choice

enum soc_periph_dac_digi_clk_src_t
   DAC digital controller clock source.
   Values:
   enumerator DAC_DIGI_CLK_SRC_PLLD2
      Select PLL_D2 as the source clock
   enumerator DAC_DIGI_CLK_SRC_APLL
      Select PLL as the source clock
   enumerator DAC_DIGI_CLK_SRC_DEFAULT
      Select PLL_D2 as the default source clock

enum soc_periph_dac_cosine_clk_src_t
   DAC cosine wave generator clock source.
   Values:
   enumerator DAC_COSINE_CLK_SRC_RTC_FAST
      Select RTC FAST as the source clock
   enumerator DAC_COSINE_CLK_SRC_DEFAULT
      Select RTC FAST as the default source clock
enum **soc_periph_twai_clk_src_t**  
TWAIl clock source.

**Values:**

enumerator **TWAI_CLK_SRC_APB**  
Select APB as the source clock

enumerator **TWAI_CLK_SRC_DEFAULT**  
Select APB as the default clock choice

enum **soc_periph_adc_digi_clk_src_t**  
ADC digital controller clock source.

**Note:** ADC DMA mode is clocked from I2S on ESP32, using ADC_DIGI_ here for compatibility Its clock source is same as I2S

**Values:**

enumerator **ADC_DIGI_CLK_SRC_PLL_F160M**  
Select F160M as the source clock

enumerator **ADC_DIGI_CLK_SRC_APLL**  
Select APLL as the source clock

enumerator **ADC_DIGI_CLK_SRC_DEFAULT**  
Select F160M as the default clock choice

enum **soc_periph_adc_rtc_clk_src_t**  
ADC RTC controller clock source.

**Values:**

enumerator **ADC_RTC_CLK_SRC_RC_FAST**  
Select RC_FAST as the source clock

enumerator **ADC_RTC_CLK_SRC_DEFAULT**  
Select RC_FAST as the default clock choice

enum **soc_periph_mwdt_clk_src_t**  
MWDT clock source.

**Values:**

enumerator **MWDT_CLK_SRC_APB**  
Select APB as the source clock

enumerator **MWDT_CLK_SRC_DEFAULT**  
Select APB as the default clock choice
enum **soc_periph_ledc_clk_src_legacy_t**

Type of LEDC clock source, reserved for the legacy LEDC driver.

*Values:*

enumerator **LEDC_AUTO_CLK**

LEDC source clock will be automatically selected based on the giving resolution and duty parameter when init the timer

denumerator **LEDC_USE_APB_CLK**

Select APB as the source clock

denumerator **LEDC_USE_RC_FAST_CLK**

Select RC_FAST as the source clock

denumerator **LEDC_USE_REF_TICK**

Select REF_TICK as the source clock

denumerator **LEDC_USE_RTC8M_CLK**

 Alias of ‘LEDC_USE_RC_FAST_CLK’

**Header File**

* components/esp_hw_support/include/esp_clk_tree.h

**Functions**

```c
esp_err_t esp_clk_tree_src_get_freq_hz (soc_module_clk_t clk_src, esp_clk_tree_src_freq_precision_t precision, uint32_t *freq_value)
```

Get frequency of module clock source.

*Parameters:*

- `clk_src` - [in] Clock source available to modules, in soc_module_clk_t
- `precision` - [in] Degree of precision, one of `esp_clk_tree_src_freq_precision_t` values This arg only applies to the clock sources that their frequencies can vary: SOC_MOD_CLK_RTC_FAST, SOC_MOD_CLK_RTC_SLOW, SOC_MOD_CLK_RC_FAST, SOC_MOD_CLK_RC_FAST_D256, SOC_MOD_CLK_XTAL32K For other clock sources, this field is ignored.
- `freq_value` - [out] Frequency of the clock source, in Hz

*Returns:*

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Calibration failed

**Enumerations**

enum **esp_clk_tree_src_freq_precision_t**

Degree of precision of frequency value to be returned by `esp_clk_tree_src_get_freq_hz()`

*Values:*

enumerator **ESP_CLK_TREE_SRC_FREQ_PRECISION_CACHED**
2.6.5 Digital To Analog Converter (DAC)

Overview

ESP32 has two 8-bit DAC (digital to analog converter) channels respectively connected to GPIO25 (Channel 1) and GPIO26 (Channel 2). Each DAC channel can convert the digital value 0~255 to the analog voltage 0~Vref (the reference voltage ‘Vref’ here is input from the pin VDD3P3_RTC, which ideally equals to the power supply VDD). The output voltage can be calculated as the following:

\[
\text{out\_voltage} = \frac{\text{Vref} \times \text{digi\_val}}{255}
\]

The DAC peripheral supports outputting analog signal in the following ways:

1. Outputting a voltage directly. The DAC channel will keep outputting a specified voltage.
2. Outputting continuous analog signal by DMA. The DAC will convert the data in a buffer at a specified frequency.
3. Outputting a cosine wave by the cosine wave generator. The DAC channel can output a cosine wave with specified frequency and amplitude.

For other analog output options, see Sigma-Delta Modulation and LED Control. Both modules produce high-frequency PWM/PDM output, which can be hardware low-pass filtered in order to generate a lower frequency analog output.

DAC File Structure

![DAC File Structure Diagram]

Fig. 7: DAC File Structure

Public headers that need to be included in the DAC application are listed as follows:
Chapter 2. API Reference

- **dac.h**: The top header file of the legacy DAC driver, which should be only included in the apps which use the legacy driver API.
- **dac_oneshot.h**: The top header file of the new DAC driver, which should be included in the apps which use the new driver API with one-shot mode.
- **dac_cosine.h**: The top header file of the new DAC driver, which should be included in the apps which use the new driver API with cosine mode.
- **dac_continuous.h**: The top header file of the new DAC driver, which should be included in the apps which use the new driver API with continuous mode.

**Note:** The legacy driver cannot coexist with the new driver. Include dac.h to use the legacy driver or dac_oneshot.h, dac_cosine.h, and dac_continuous.h to use the new driver. The legacy driver might be removed in the future.

---

**Functional Overview**

**Resources Management** The DAC on ESP32 has two channels. The channels have separate software resources and can be managed by dac_oneshot_handle_t, dac_cosine_handle_t, or dac_continuous_handle_t according to the usage. Registering different modes on a same DAC channel is not allowed.

**Direct Voltage Output (One-shot/Direct Mode)** The DAC channels in the group can convert an 8-bit digital value into the analog when dac_oneshot_output_voltage() is called (it can be called in ISR). The analog voltage will be kept on the DAC channel until the next conversion starts. To start the voltage conversion, the DAC channels need to be enabled first through registering by dac_oneshot_new_channel().

**Continuous Wave Output (Continuous/DMA Mode)** DAC channels can convert digital data continuously via the DMA. There are three ways to write the DAC data:

1. Normal writing (synchronous): Data can be transmitted at one time and kept blocked until all the data has been loaded into the DMA buffer, and the voltage will be kept as the last conversion value while no more data is inputted. It is usually used to transport a long signal like an audio. To convert data continuously, the continuous channel handle need to be allocated by calling dac_continuous_new_channels() and the DMA conversion should be enabled by calling dac_continuous_enable(). Then data can be written by dac_continuous_write() synchronously. Refer to peripherals/dac/dac_continuous/dac_audio for examples.

2. Cyclical writing: A piece of data can be converted cyclically without blocking, and no more operation is needed after the data are loaded into the DMA buffer. But note that the inputted buffer size is limited by the number of descriptors and the DMA buffer size. It is usually used to transport short signals that need to be repeated, e.g., a sine wave. To achieve cyclical writing, call dac_continuous_write_cyclically() after the DAC continuous mode is enabled. Refer to peripherals/dac/dac_continuous/signal_generator for examples.

3. Asynchronous writing: Data can be transmitted asynchronously based on the event callback. dac_event_callbacks_t::on_convert_done must be registered to use asynchronous mode. Users can get the dac_event_data_t in the callback which contains the DMA buffer address and length, allowing them to load the data into the buffer directly. To use the asynchronous writing, call dac_continuous_register_event_callback() to register the dac_event_callbacks_t::on_convert_done before enabling, and then dac_continuous_start_async_writing() to start the asynchronous writing. Note that once the asynchronous writing is started, the callback function will be triggered continuously. Call dac_continuous_write_asynchronously() to load the data either in a separate task or in the callback directly. Refer to peripherals/dac/dac_continuous/dac_audio for examples.

On ESP32, the DAC digital controller can be connected internally to the I2S0 and use its DMA for continuous conversion. Although the DAC only needs 8-bit data for conversion, it has to be the left-shifted 8 bits (i.e., the high 8 bits in a 16-bit slot) to satisfy the I2S communication format. By default, the driver helps to expand the data to...
16-bit wide automatically. To expand manually, please disable `CONFIG_DAC_DMA_AUTO_16BIT_ALIGN` in the menuconfig.

The clock of the DAC digital controller comes from I2S0 as well, so there are two clock sources for selection:

- `dac_continuous_digi_clk_src_t::DAC_DIGI_CLK_SRC_PLL_D2` supports frequency between 19.6 KHz to several MHz. It is the default clock which can also be selected by `dac_continuous_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT`.
- `dac_continuous_digi_clk_src_t::DAC_DIGI_CLK_SRC_APLL` supports frequency between 648 Hz to several MHz. However, it might be occupied by other peripherals, thus not providing the required frequency. In such case, this clock source is available only if APPLL still can be correctly divided into the target DAC DMA frequency.

**Cosine Wave Output (Cosine Mode)** The DAC peripheral has a cosine wave generator, which can generate cosine wave on the channels. Users can specify the frequency, amplitude, and phase of the cosine wave. To output the cosine wave, please acquire the DAC to cosine mode using `dac_cosine_new_channel()`, and then start the cosine wave generator by `dac_cosine_start()`.

Currently, the clock source of the cosine wave generator only comes from `RTC_FAST` which can be selected by `dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_RTC_FAST`. It is also the default clock source which is the same as `dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_RTC_DEFAULT`.

**Power Management** When the power management is enabled (i.e., `CONFIG_PM_ENABLE` is on), the system will adjust or stop the clock source of DAC before entering Light-sleep mode, thus potential influence to the DAC signals may lead to false data conversion.

When using DAC driver in continuous mode, it can prevent the system from changing or stopping the clock source in DMA or cosine mode by acquiring a power management lock. When the clock source is generated from APB, the lock type will be set to `esp_pm_lock_type_t::ESP_PM_APB_FREQ_MAX`. When the clock source is APPLL (only in DMA mode), it will be set to `esp_pm_lock_type_t::ESP_PM_NO_LIGHT_SLEEP`. Whenever the DAC is converting (i.e., DMA or cosine wave generator is working), the driver will guarantee that the power management lock is acquired after calling `dac_continuous_enable()`. Likewise, the driver will release the lock when `dac_continuous_disable()` is called.

**IRAM Safe** By default, the DAC DMA interrupt will be deferred when the cache is disabled for reasons like writing/erasing Flash. Thus the DMA EOF interrupt will not get executed in time.

To avoid such case in real-time applications, you can enable the Kconfig option `CONFIG_DAC_ISR_IRAM_SAFE` which will:

1. Enable the interrupt being serviced even when cache is disabled;
2. Place driver object into DRAM (in case it is linked to PSRAM by accident).

This will allow the interrupt to run while the cache is disabled but will come at the cost of increased IRAM consumption.

**Thread Safety** All the public DAC APIs are guaranteed to be thread safe by the driver, which means users can call them from different RTOS tasks without protection by extra locks. Notice that the DAC driver uses mutex lock to ensure the thread safety, thus the APIs except `dac_oneshot_output_voltage()` are not allowed to be used in ISR.

**Kconfig Options**

- `CONFIG_DAC_ISR_IRAM_SAFE` controls whether the default ISR handler can work when cache is disabled. See `IRAM Safe` for more information.
- `CONFIG_DAC_SUPPRESS_DEPRECATE_WARN` controls whether to suppress the warning message compilation while using the legacy DAC driver.
- `CONFIG_DAC_ENABLE_DEBUG_LOG` is used to enable the debug log output. Enable this option will increase the firmware binary size.
Chapter 2. API Reference

- **CONFIG_DAC_DMA_AUTO_16BIT_ALIGN** will auto expand the 8-bit data to 16-bit data in the driver to satisfy the I2S DMA format.

**Application Example**

The basic examples for the **One-shot Mode**, **Continuous Mode**, and **Cosine Mode** can be found in:
- peripherals/dac/dac_oneshot
- peripherals/dac/dac_continuous
- peripherals/dac/dac_cosine_wave

**API Reference**

**Header File**
- components/driver/dac/include/driver/dac_oneshot.h

**Functions**

```c
esp_err_t dac_oneshot_new_channel(const dac_oneshot_config_t *oneshot_cfg, dac_oneshot_handle_t *ret_handle)
```

Allocate a new DAC oneshot channel.

| Note: | The channel will be enabled as well when the channel allocated |

<table>
<thead>
<tr>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>oneshot_cfg</code> - [in] The configuration for the oneshot channel</td>
</tr>
<tr>
<td><code>ret_handle</code> - [out] The returned oneshot channel handle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>ESP_ERR_INVALID_ARG The input parameter is invalid</td>
</tr>
<tr>
<td>ESP_ERR_INVALID_STATE The DAC channel has been registered already</td>
</tr>
<tr>
<td>ESP_ERR_NO_MEM No memory for the DAC oneshot channel resources</td>
</tr>
<tr>
<td>ESP_OK Allocate the new DAC oneshot channel success</td>
</tr>
</tbody>
</table>

```c
esp_err_t dac_oneshot_del_channel(dac_oneshot_handle_t handle)
```

Delete the DAC oneshot channel.

| Note: | The channel will be disabled as well when the channel deleted |

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td><code>handle</code> - [in] The DAC oneshot channel handle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_ERR_INVALID_ARG The input parameter is invalid</td>
</tr>
<tr>
<td>ESP_ERR_INVALID_STATE The channel has already been de-registered</td>
</tr>
<tr>
<td>ESP_OK Delete the oneshot channel success</td>
</tr>
</tbody>
</table>

```c
esp_err_t dac_oneshot_output_voltage(dac_oneshot_handle_t handle, uint8_t digi_value)
```

Output the voltage.

| Note: | Generally it’ll take 7–11 us on ESP32 and 10–21 us on ESP32-S2 |

<table>
<thead>
<tr>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>handle</code> - [in] The DAC oneshot channel handle</td>
</tr>
<tr>
<td><code>digi_value</code> - [in] The digital value that need to be converted</td>
</tr>
</tbody>
</table>
Chapter 2. API Reference

Returns

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_OK Convert the digital value success

Structures

struct **dac_oneshot_config_t**

DAC oneshot channel configuration.

Public Members


```c
struct dac_channel_t chan_id
```

DAC channel id

Type Definitions

typedef struct dac_oneshot_s * **dac_oneshot_handle_t**

DAC oneshot channel handle

Header File

- components/driver/dac/include/driver/dac_cosine.h

Functions

```c
esp_err_t dac_cosine_new_channel (const dac_cosine_config_t *cos_cfg, dac_cosine_handle_t *ret_handle)
```

Allocate a new DAC cosine wave channel.

**Note:** Since there is only one cosine wave generator, only the first channel can set the frequency of the cosine wave. Normally, the latter one is not allowed to set a different frequency, but the it can be forced to set by setting the bit `force_set_freq` in the configuration, notice that another channel will be affected as well when the frequency is updated.

**Parameters**

- **cos_cfg** –[in] The configuration of cosine wave channel
- **ret_handle** –[out] The returned cosine wave channel handle

**Returns**

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The DAC channel has been registered already
- ESP_ERR_NO_MEM No memory for the DAC cosine wave channel resources
- ESP_OK Allocate the new DAC cosine wave channel success

```c
esp_err_t dac_cosine_del_channel (dac_cosine_handle_t handle)
```

Delete the DAC cosine wave channel.

**Parameters**

- **handle** –[in] The DAC cosine wave channel handle

**Returns**

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The channel has already been deregistered
- ESP_OK Delete the cosine wave channel success
**Chapter 2. API Reference**

**esp_err_t dac_cosine_start (dac_cosine_handle_t handle)**

Start outputting the cosine wave on the channel.

**Parameters handle** — [in] The DAC cosine wave channel handle

**Returns**
- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The channel has been started already
- ESP_OK Start the cosine wave success

**esp_err_t dac_cosine_stop (dac_cosine_handle_t handle)**

Stop outputting the cosine wave on the channel.

**Parameters handle** — [in] The DAC cosine wave channel handle

**Returns**
- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The channel has been stopped already
- ESP_OK Stop the cosine wave success

**Structures**

struct **dac_cosine_config_t**

DAC cosine channel configurations.

**Public Members**

**dac_channel_t chan_id**
The cosine wave channel id

uint32_t **freq_hz**
The frequency of cosine wave, unit: Hz. The cosine wave generator is driven by RTC_FAST clock which is divide from RC_FAST. With the default RTC clock, the minimum frequency of cosine wave is about 130 Hz. Although it can support up to several MHz frequency theoretically, the waveform will distort at high frequency due to the hardware limitation. Typically not suggest to set the frequency higher than 200 KHz

**dac_cosine_clk_src_t clk_src**
The clock source of the cosine wave generator, currently only support DAC_COSINE_CLK_SRC_DEFAULT

**dac_cosine_atten_t atten**
The attenuation of cosine wave amplitude

**dac_cosine_phase_t phase**
The phase of cosine wave, can only support DAC_COSINE_PHASE_0 or DAC_COSINE_PHASE_180, default as 0 while setting an unsupported phase

int8_t **offset**
The DC offset of cosine wave

bool **force_set_freq**
Force to set the cosine wave frequency

struct **dac_cosine_config_t::[anonymous] flags**
Flags of cosine mode
Type Definitions

```c
typedef struct dac_cosine_s *dac_cosine_handle_t

DAC cosine wave channel handle
```

Header File

- components/driver/dac/include/driver/dac_continuous.h

Functions

```c
esp_err_t dac_continuous_new_channels (const dac_continuous_config_t *cont_cfg,
                                       dac_continuous_handle_t *ret_handle)
```

Allocate new DAC channels in continuous mode.

**Note:** The DAC channels can’t be registered to continuous mode separately

**Parameters**

- `cont_cfg` [in] Continuous mode configuration
- `ret_handle` [out] The returned continuous mode handle

**Returns**

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The DAC channel has been registered already
- ESP_ERR_NOT_FOUND Not found the available dma peripheral, might be occupied
- ESP_ERR_NO_MEM No memory for the DAC continuous mode resources
- ESP_OK Allocate the new DAC continuous mode success

```c
esp_err_t dac_continuous_del_channels (dac_continuous_handle_t handle)
```

Delete the DAC continuous handle.

**Parameters** handle [in] The DAC continuous channel handle that obtained from

**Returns**

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The channels have already been deregistered or not dis-
  abled
- ESP_OK Delete the continuous channels success

```c
esp_err_t dac_continuous_enable (dac_continuous_handle_t handle)
```

Enabled the DAC continuous mode.

**Note:** Must enable the channels before

**Parameters** handle [in] The DAC continuous channel handle that obtained from

**Returns**

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The channels have been enabled already
- ESP_OK Enable the continuous output success

```c
esp_err_t dac_continuous_disable (dac_continuous_handle_t handle)
```

Disable the DAC continuous mode.

**Parameters** handle [in] The DAC continuous channel handle that obtained from

**Returns**
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The channels have been enabled already
- ESP_OK Disable the continuous output success

```c
esp_err_t dac_continuous_write(dac_continuous_handle_t handle, uint8_t* buf, size_t buf_size, size_t *bytes_loaded, int timeout_ms)
```

Write DAC data continuously.

**Note:** The data in buffer will only be converted one time. This function will be blocked until all data loaded or timeout then the DAC output will keep outputting the voltage of the last data in the buffer.

**Note:** Specially, on ESP32, the data bit width of DAC continuous data is fixed to 16 bits while only the high 8 bits are available. The driver will help to expand the inputted buffer automatically by default, you can also align the data to 16 bits manually by clearing `CONFIG_DAC_DMA_AUTO_16BIT_ALIGN` in menuconfig.

### Parameters
- **handle** - [in] The DAC continuous channel handle that obtained from `dac_continuous_new_channels`
- **buf** - [in] The digital data buffer to convert
- **buf_size** - [in] The buffer size of digital data buffer
- **bytes_loaded** - [out] The bytes that has been loaded into DMA buffer, can be NULL if don’t need it
- **timeout_ms** - [in] The timeout time in millisecond, set a minus value means will block forever

### Returns
- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The DAC continuous mode has not been enabled yet
- ESP_ERR_TIMEOUT Waiting for semaphore or message queue timeout
- ESP_OK Success to output the acyclic DAC data

```c
esp_err_t dac_continuous_write_cyclically(dac_continuous_handle_t handle, uint8_t* buf, size_t buf_size, size_t *bytes_loaded)
```

Write DAC continuous data cyclically.

**Note:** The data in buffer will be converted cyclically using DMA once this function is called, This function will return once the data loaded into DMA buffers.

**Note:** The buffer size of cyclically output is limited by the descriptor number and dma buffer size while initializing the continuous mode. Concretely, in order to load all the data into descriptors, the cyclic buffer size is not supposed to be greater than `desc_num * buf_size`

**Note:** Specially, on ESP32, the data bit width of DAC continuous data is fixed to 16 bits while only the high 8 bits are available. The driver will help to expand the inputted buffer automatically by default, you can also align the data to 16 bits manually by clearing `CONFIG_DAC_DMA_AUTO_16BIT_ALIGN` in menuconfig.

### Parameters
- **handle** - [in] The DAC continuous channel handle that obtained from `dac_continuous_new_channels`
- **buf** - [in] The digital data buffer to convert
- **buf_size** - [in] The buffer size of digital data buffer
Chapter 2. API Reference

- **bytes_loaded** - [out] The bytes that has been loaded into DMA buffer, can be NULL if don’t need it

**Returns**
- ESP_ERR_INVALID_ARG The input parameter is invalid
- ESP_ERR_INVALID_STATE The DAC continuous mode has not been enabled yet
- ESP_OK Success to output the acyclic DAC data

```c
esp_err_t dac_continuous_register_event_callback(dac_continuous_handle_t handle, const dac_event_callbacks_t *callbacks, void *user_data)
```

Set event callbacks for DAC continuous mode.

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the `callbacks` structure to NULL.

**Note:** When CONFIG_DAC_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in this function, including the `user_data`, should be in the internal RAM as well.

**Parameters**
- **handle** - [in] The DAC continuous channel handle that obtained from `dac_continuous_new_channels`
- **callbacks** - [in] Group of callback functions, input NULL to clear the former callbacks
- **user_data** - [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK Set event callbacks successfully
- ESP_ERR_INVALID_ARG Set event callbacks failed because of invalid argument

```c
esp_err_t dac_continuous_start_async_writing(dac_continuous_handle_t handle)
```

Start the async writing.

**Note:** When the asynchronous writing start, the DAC will keep outputting ‘0’ until the data are loaded into the DMA buffer. To loaded the data into DMA buffer, ‘on_convert_done’ callback is required, which can be registered by ‘dac_continuous_register_event_callback’ before enabling.

**Parameters**
- **handle** - [in] The DAC continuous channel handle that obtained from `dac_continuous_new_channels`

**Returns**
- ESP_OK Start asynchronous writing successfully
- ESP_ERR_INVALID_ARG The handle is NULL
- ESP_ERR_INVALID_STATE The channel is not enabled or the ‘on_convert_done’ callback is not registered

```c
esp_err_t dac_continuous_stop_async_writing(dac_continuous_handle_t handle)
```

Stop the async writing.

**Parameters**
- **handle** - [in] The DAC continuous channel handle that obtained from `dac_continuous_new_channels`

**Returns**
- ESP_OK Stop asynchronous writing successfully
- ESP_ERR_INVALID_ARG The handle is NULL
- ESP_ERR_INVALID_STATE Asynchronous writing has not started
**esp_err_t** **dac_continuous_write_asynchronously** *(dac_continuous_handle_t handle, uint8_t *dma_buf, size_t dma_buf_len, const uint8_t *data, size_t data_len, size_t *bytes_loaded)*

Write DAC data asynchronously.

**Note:** This function can be called when the asynchronous writing started, and it can be called in the callback directly but recommend to writing data in a task, referring to :example:`peripherals/dac/dac_continuous/dac_audio`

### Parameters
- **handle** *-in* The DAC continuous channel handle that obtained from `dac_continuous_new_channels`
- **dma_buf** *-in* The DMA buffer address, it can be acquired from `dac_event_data_t` in the `on_convert_done` callback
- **dma_buf_len** *-in* The DMA buffer length, it can be acquired from `dac_event_data_t` in the `on_convert_done` callback
- **data** *-in* The data that need to be written
- **data_len** *-in* The data length the need to be written
- **bytes_loaded** *-out* The bytes number that has been loaded/written into the DMA buffer

### Returns
- ESP_OK Write the data into DMA buffer successfully
- ESP_ERR_INVALID_ARG NULL pointer
- ESP_ERR_INVALID_STATE The channels haven’t start the asynchronous writing
- ESP_ERR_NOT_FOUND The param ‘dam_buf’ not match any existed DMA buffer

### Structures

```c
struct dac_continuous_config_t

DAC continuous channels’ configurations.
```

### Public Members

```c
dac_channel_mask_t chan_mask

DAC channels’ mask for selecting which channels are used
```

```c
uint32_t desc_num

The number of DMA descriptor, at least 2 descriptors are required The number of descriptors is directly proportional to the max data buffer size while converting in cyclic output but only need to ensure it is greater than ‘1’ in acyclic output Typically, suggest to set the number bigger than 5, in case the DMA stopped while sending a short buffer
```

```c
size_t buf_size

The DMA buffer size, should be within 32~4092 bytes. Each DMA buffer will be attached to a DMA descriptor, i.e. the number of DMA buffer will be equal to the DMA descriptor number The DMA buffer size is not allowed to be greater than 4092 bytes The total DMA buffer size equal to `desc_num` * `buf_size` Typically, suggest to set the size to the multiple of 4
```

```c
uint32_t freq_hz

The frequency of DAC conversion in continuous mode, unit: Hz The supported range is related to the target and the clock source. For the clock `DAC_DIGI_CLK_SRC_DEFAULT`: the range is 19.6 KHz to several MHz on ESP32 and 77 Hz to several MHz on ESP32-S2. For the clock
```

---

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1076  
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DAC_DIGI_CLK_SRC_APLL: the range is 648 Hz to several MHz on ESP32 and 6 Hz to several MHz on ESP32-S2. Typically not suggest to set the frequency higher than 2 MHz, otherwise the severe distortion will appear.

int8_t offset
The offset of the DAC digital data. Range -128~127

dac_continuous_digi_clk_src_t clk_src
The clock source of digital controller, which can affect the range of supported frequency. Currently DAC_DIGI_CLK_SRC_DEFAULT and DAC_DIGI_CLK_SRC_APLL are available.

dac_continuous_channel_mode_t chan_mode
The channel mode of continuous mode, only take effect when multiple channels enabled, depends converting the buffer alternately or simultaneously.

struct dac_event_data_t
Event structure used in DAC event queue.

Public Members

void *buf
The pointer of DMA buffer that just finished sending.

size_t buf_size
The writable buffer size of the DMA buffer, equal to `dac_continuous_config_t::buf_size`.

size_t write_bytes
The number of bytes that be written successfully.

struct dac_event_callbacks_t
Group of DAC callbacks.

Note: The callbacks are all running under ISR environment.

Note: When CONFIG_DAC_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well.

Public Members

dac_isr_callback_t on_convert_done
Callback of data conversion done event An event data buffer previously loaded to the driver has been output and converted. The event data includes DMA buffer address and size that just finished converting.

dac_isr_callback_t on_stop
Callback of finished sending all the data. All loaded event data buffers are converted. Driver is pending for new data buffers to be loaded. The event data will be NULL in this callback.
Chapter 2. API Reference

Type Definitions

typedef struct dac_continuous_s *dac_continuous_handle_t
  DAC continuous channel handle

typedef bool (*dac_isr_callback_t)(dac_continuous_handle_t handle, const dac_event_data_t *event, void *user_data)
  DAC event callback.

  Param handle [in] DAC channel handle, created from dac_continuous_new_channels()
  Param event [in] DAC event data
  Param user_data [in] User registered context, passed from dac_continuous_register_event_callback()
  Return Whether a high priority task has been waken up by this callback function

Enumerations

enum dac_channel_mask_t
  DAC channel mask.

  Values:

  enumerator DAC_CHANNEL_MASK_CH0
    DAC channel 0 is GPIO25(ESP32) / GPIO17(ESP32S2)

  enumerator DAC_CHANNEL_MASK_CH1
    DAC channel 1 is GPIO26(ESP32) / GPIO18(ESP32S2)

  enumerator DAC_CHANNEL_MASK_ALL
    Both DAC channel 0 and channel 1

Header File

  • components/driver/dac/include/driver/dac_types.h

Type Definitions

typedef soc_periph_dac_digi_clk_src_t dac_continuous_digi_clk_src_t
  DAC DMA (digital controller) clock source.

typedef soc_periph_dac_cosine_clk_src_t dac_cosine_clk_src_t
  DAC cosine wave generator clock source.

Enumerations

enum dac_continuous_channel_mode_t
  DAC channel work mode in dma mode.

  Note: Only take effect when multiple channels enabled.

  Note: Assume the data in buffer is ‘A B C D E F’ DAC_CHANNEL_MODE_SIMUL:
  • channel 0: A B C D E F
  • channel 1: A B C D E F DAC_CHANNEL_MODEALTER:
Chapter 2. API Reference

- channel 0: A C E
- channel 1: B D F

Values:

enumerator DAC_CHANNEL_MODE_SIMUL
The data in the DMA buffer is simultaneously output to the enable channel of the DAC.

enumerator DAC_CHANNEL_MODE_ALTER
The data in the DMA buffer is alternately output to the enable channel of the DAC.

Header File

- components/hal/include/hal/dac_types.h

Enumerations

enum dac_channel_t

Values:

enumerator DAC_CHAN_0
DAC channel 0 is GPIO25(ESP32) / GPIO17(ESP32S2)

enumerator DAC_CHAN_1
DAC channel 1 is GPIO26(ESP32) / GPIO18(ESP32S2)

enumerator DAC_CHANNEL_1
Alias of ‘DAC_CHAN_0’, now the channel index start from ‘0’

enumerator DAC_CHANNEL_2
Alias of ‘DAC_CHAN_1’, now the channel index start from ‘0’

enum dac_cosine_atten_t
The attenuation of the amplitude of the cosine wave generator. The max amplitude is VDD3P3_RTC.

Values:

enumerator DAC_COSINE_ATTEN_DEFAULT
No attenuation to the DAC cosine wave amplitude. Default.

enumerator DAC_COSINE_ATTEN_DB_0
Original amplitude of the DAC cosine wave, equals to DAC_COSINE_ATTEN_DEFAULT

enumerator DAC_COSINE_ATTEN_DB_6
1/2 amplitude of the DAC cosine wave

enumerator DAC_COSINE_ATTEN_DB_12
1/4 amplitude of the DAC cosine wave

enumerator DAC_COSINE_ATTEN_DB_18
1/8 amplitude of the DAC cosine wave
enum \texttt{dac\_cosine\_phase\_t}

Set the phase of the cosine wave generator output.

\textbf{Note:} Only 0 or 180 are supported, it will be set to 0 as default if configured to an unsupported phase.

\textit{Values:}

enumerator \texttt{DAC\_COSINE\_PHASE\_0}

Phase shift +0°

enumerator \texttt{DAC\_COSINE\_PHASE\_180}

Phase shift +180°

\subsection*{2.6.6 GPIO \& RTC GPIO}

\textbf{GPIO Summary}

The ESP32 chip features 34 physical GPIO pins (GPIO0 ~ GPIO19, GPIO21 ~ GPIO23, GPIO25 ~ GPIO27, and GPIO32 ~ GPIO39). Each pin can be used as a general-purpose I/O, or be connected to an internal peripheral signal. Through IO MUX, RTC IO MUX and the GPIO matrix, peripheral input signals can be from any IO pins, and peripheral output signals can be routed to any IO pins. Together these modules provide highly configurable I/O. For more details, see \textit{ESP32 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX)} [PDF].

The table below provides more information on pin usage, and please note the comments in the table for GPIOs with restrictions.

<table>
<thead>
<tr>
<th>GPIO</th>
<th>Analog Function</th>
<th>RTC_GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO0</td>
<td>ADC2_CH1</td>
<td>RTC_GPIO11</td>
<td>Strapping pin</td>
</tr>
<tr>
<td>GPIO1</td>
<td></td>
<td>TXD</td>
<td></td>
</tr>
<tr>
<td>GPIO2</td>
<td>ADC2_CH2</td>
<td>RTC_GPIO12</td>
<td>Strapping pin</td>
</tr>
<tr>
<td>GPIO3</td>
<td></td>
<td>RXD</td>
<td></td>
</tr>
<tr>
<td>GPIO4</td>
<td>ADC2_CH0</td>
<td>RTC_GPIO10</td>
<td></td>
</tr>
<tr>
<td>GPIO5</td>
<td></td>
<td></td>
<td>Strapping pin</td>
</tr>
<tr>
<td>GPIO6</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO7</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO8</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO9</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO10</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO11</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO12</td>
<td>ADC2_CH5</td>
<td>RTC_GPIO15</td>
<td>Strapping pin; JTAG</td>
</tr>
<tr>
<td>GPIO13</td>
<td>ADC2_CH4</td>
<td>RTC_GPIO14</td>
<td>JTAG</td>
</tr>
<tr>
<td>GPIO14</td>
<td>ADC2_CH6</td>
<td>RTC_GPIO16</td>
<td>JTAG</td>
</tr>
<tr>
<td>GPIO15</td>
<td>ADC2_CH3</td>
<td>RTC_GPIO13</td>
<td>Strapping pin; JTAG</td>
</tr>
<tr>
<td>GPIO16</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO17</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO18</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO19</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO21</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO22</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
<tr>
<td>GPIO23</td>
<td></td>
<td>SP10/1</td>
<td></td>
</tr>
</tbody>
</table>

continues on next page
Table 2 – continued from previous page

<table>
<thead>
<tr>
<th>GPIO</th>
<th>Analog Function</th>
<th>RTC GPIO</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO25</td>
<td>ADC2_CH8</td>
<td>RTC_GPIO6</td>
<td></td>
</tr>
<tr>
<td>GPIO26</td>
<td>ADC2_CH9</td>
<td>RTC_GPIO7</td>
<td></td>
</tr>
<tr>
<td>GPIO27</td>
<td>ADC2_CH7</td>
<td>RTC_GPIO17</td>
<td></td>
</tr>
<tr>
<td>GPIO32</td>
<td>ADC1_CH4</td>
<td>RTC_GPIO9</td>
<td></td>
</tr>
<tr>
<td>GPIO33</td>
<td>ADC1_CH5</td>
<td>RTC_GPIO8</td>
<td></td>
</tr>
<tr>
<td>GPIO34</td>
<td>ADC1_CH6</td>
<td>RTC_GPIO4</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO35</td>
<td>ADC1_CH7</td>
<td>RTC_GPIO5</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO36</td>
<td>ADC1_CH0</td>
<td>RTC_GPIO0</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO37</td>
<td>ADC1_CH1</td>
<td>RTC_GPIO1</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO38</td>
<td>ADC1_CH2</td>
<td>RTC_GPIO2</td>
<td>GPI</td>
</tr>
<tr>
<td>GPIO39</td>
<td>ADC1_CH3</td>
<td>RTC_GPIO3</td>
<td>GPI</td>
</tr>
</tbody>
</table>

Note:

- Strapping pin: GPIO0, GPIO2, GPIO5, GPIO12 (MTDI), and GPIO15 (MTDO) are strapping pins. For more information, please refer to ESP32 datasheet.
- SPI0/1: GPIO6-11 and GPIO16-17 are usually connected to the SPI flash and PSRAM integrated on the module and therefore should not be used for other purposes.
- JTAG: GPIO12-15 are usually used for inline debug.
- GPI: GPIO34-39 can only be set as input mode and do not have software-enabled pullup or pulldown functions.
- TXD & RXD are usually used for flashing and debugging.
- ADC2: ADC2 pins cannot be used when Wi-Fi is used. So, if you are having trouble getting the value from an ADC2 GPIO while using Wi-Fi, you may consider using an ADC1 GPIO instead, which should solve your problem. For more details, please refer to Hardware Limitations of ADC Continuous Mode and Hardware Limitations of ADC Oneshot Mode.
- Please do not use the interrupt of GPIO36 and GPIO39 when using ADC or Wi-Fi and Bluetooth with sleep mode enabled. Please refer to ESP32 ECO and Workarounds for Bugs > Section 3.11 for the detailed description of the issue.

There is also separate “RTC GPIO” support, which functions when GPIOs are routed to the “RTC” low-power and analog subsystem. These pin functions can be used when:

- In Deep-sleep mode
- The Ultra Low Power co-processor is running
- Analog functions such as ADC/DAC/etc are in use.

Application Example

- GPIO output and input interrupt example: peripherals/gpio/generic_gpio.

API Reference - Normal GPIO

Header File

- components/driver/gpio/include/driver/gpio.h

Functions

```c
esp_err_t gpio_config(const gpio_config_t *pGPIOConfig)
```

GPIO common configuration.
Configure GPIO's Mode, pull-up, pull-down, IntrType

**Parameters**

- pGPIOConfig - Pointer to GPIO configure struct

**Returns**

- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t gpio_reset_pin (gpio_num_t gpio_num)
```

Reset an gpio to default state (select gpio function, enable pullup and disable input and output).

**Note:** This function also configures the IOMUX for this pin to the GPIO function, and disconnects any other peripheral output configured via GPIO Matrix.

**Parameters**

- gpio_num - GPIO number.

**Returns**

- Always return ESP_OK.

```c
esp_err_t gpio_set_intr_type (gpio_num_t gpio_num, gpio_int_type_t intr_type)
```

GPIO set interrupt trigger type.

**Parameters**

- gpio_num - GPIO number. If you want to set the trigger type of e.g. of GPIO16, gpio_num should be GPIO_NUM_16 (16);
- intr_type - Interrupt type, select from gpio_int_type_t

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t gpio_intr_enable (gpio_num_t gpio_num)
```

Enable GPIO module interrupt signal.

**Note:** ESP32: Please do not use the interrupt of GPIO36 and GPIO39 when using ADC or Wi-Fi and Bluetooth with sleep mode enabled. Please refer to the comments of adc1_get_raw. Please refer to Section 3.11 of ESP32 ECO and Workarounds for Bugs for the description of this issue.

**Parameters**

- gpio_num - GPIO number. If you want to enable an interrupt on e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t gpio_intr_disable (gpio_num_t gpio_num)
```

Disable GPIO module interrupt signal.

**Note:** This function is allowed to be executed when Cache is disabled within ISR context, by enabling CONFIG_GPIO_CTRL_FUNC_IN_IRAM

**Parameters**

- gpio_num - GPIO number. If you want to disable the interrupt of e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);

**Returns**

- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
**esp_err_t gpio_set_level(gpio_num_t gpio_num, uint32_t level)**

GPIO set output level.

### Note:
This function is allowed to be executed when Cache is disabled within ISR context, by enabling CONFIG_GPIO_CTRL_FUNC_IN_IRAM

**Parameters**
- **gpio_num** – GPIO number. If you want to set the output level of e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);
- **level** – Output level. 0: low; 1: high

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO number error

**int gpio_get_level(gpio_num_t gpio_num)**

GPIO get input level.

### Warning:
If the pad is not configured for input (or input and output) the returned value is always 0.

**Parameters**
- **gpio_num** – GPIO number. If you want to get the logic level of e.g. pin GPIO16, gpio_num should be GPIO_NUM_16 (16);

**Returns**
- 0 the GPIO input level is 0
- 1 the GPIO input level is 1

**esp_err_t gpio_set_direction(gpio_num_t gpio_num, gpio_mode_t mode)**

Configure GPIO direction, such as output_only,input_only,output_and_input

**Parameters**
- **gpio_num** – Configure GPIO pins number, it should be GPIO number. If you want to set direction of e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);
- **mode** – GPIO direction

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error

**esp_err_t gpio_set_pull_mode(gpio_num_t gpio_num, gpio_pull_mode_t pull)**

Configure GPIO pull-up/pull-down resistors.

### Note:
ESP32: Only pins that support both input & output have integrated pull-up and pull-down resistors. Input-only GPIOs 34-39 do not.

**Parameters**
- **gpio_num** – GPIO number. If you want to set pull up or down mode for e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);
- **pull** – GPIO pull up/down mode.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG : Parameter error
**esp_err_t gpio_wakeup_enable** (gpio_num_t gpio_num, gpio_int_type_t intr_type)

Enable GPIO wake-up function.

**Parameters**
- **gpio_num** – GPIO number.
- **intr_type** – GPIO wake-up type. Only GPIO_INTR_LOW_LEVEL or GPIO_INTR_HIGH_LEVEL can be used.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**esp_err_t gpio_wakeup_disable** (gpio_num_t gpio_num)

Disable GPIO wake-up function.

**Parameters**
- **gpio_num** – GPIO number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**esp_err_t gpio_isr_register** (void (*fn)(void*), void *arg, int intr_alloc_flags, gpio_isr_handle_t *handle)

Register GPIO interrupt handler, the handler is an ISR. The handler will be attached to the same CPU core that this function is running on.

This ISR function is called whenever any GPIO interrupt occurs. See the alternative gpio_install_isr_service() and gpio_isr_handler_add() API in order to have the driver support per GPIO ISRs.

To disable or remove the ISR, pass the returned handle to the interrupt allocation functions.

**Parameters**
- **fn** – Interrupt handler function.
- **arg** – Parameter for handler function
- **intr_alloc_flags** – Flags used to allocate the interrupt. One or multiple (ORred) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info.
- **handle** – Pointer to return handle. If non-NULL, a handle for the interrupt will be returned here.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error
- ESP_ERR_NOT_FOUND No free interrupt found with the specified flags

**esp_err_t gpio_pullup_en** (gpio_num_t gpio_num)

Enable pull-up on GPIO.

**Parameters**
- **gpio_num** – GPIO number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**esp_err_t gpio_pullup_dis** (gpio_num_t gpio_num)

Disable pull-up on GPIO.

**Parameters**
- **gpio_num** – GPIO number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**esp_err_t gpio_pulldown_en** (gpio_num_t gpio_num)

Enable pull-down on GPIO.

**Parameters**
- **gpio_num** – GPIO number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
**Chapter 2. API Reference**

*esp_err_t gpio_pulldown_dis (gpio_num_t gpio_num)*

Disable pull-down on GPIO.

**Parameters**
- `gpio_num` - GPIO number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

*esp_err_t gpio_install_isr_service (int intr_alloc_flags)*

Install the GPIO driver’s ETS_GPIO_INTR_SOURCE ISR handler service, which allows per-pin GPIO interrupt handlers.

This function is incompatible with gpio_isr_register() - if that function is used, a single global ISR is registered for all GPIO interrupts. If this function is used, the ISR service provides a global GPIO ISR and individual pin handlers are registered via the gpio_isr_handler_add() function.

**Parameters**
- `intr_alloc_flags` - Flags used to allocate the interrupt. One or multiple (ORed) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info.

**Returns**
- ESP_OK Success
- ESP_ERR_NO_MEM No memory to install this service
- ESP_ERR_INVALID_STATE ISR service already installed.
- ESP_ERR_NOT_FOUND No free interrupt found with the specified flags
- ESP_ERR_INVALID_ARG GPIO error

*void gpio_uninstall_isr_service (void)*

Uninstall the driver’s GPIO ISR service, freeing related resources.

*esp_err_t gpio_isr_handler_add (gpio_num_t gpio_num, gpio_isr_t isr_handler, void *args)*

Add ISR handler for the corresponding GPIO pin.

Call this function after using gpio_install_isr_service() to install the driver’s GPIO ISR handler service.

The pin ISR handlers no longer need to be declared with IRAM_ATTR, unless you pass the ESP_INTR_FLAG_IRAM flag when allocating the ISR in gpio_install_isr_service().

This ISR handler will be called from an ISR. So there is a stack size limit (configurable as “ISR stack size” in menuconfig). This limit is smaller compared to a global GPIO interrupt handler due to the additional level of indirection.

**Parameters**
- `gpio_num` - GPIO number
- `isr_handler` - ISR handler function for the corresponding GPIO number.
- `args` - parameter for ISR handler.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_STATE Wrong state, the ISR service has not been initialized.
- ESP_ERR_INVALID_ARG Parameter error

*esp_err_t gpio_isr_handler_remove (gpio_num_t gpio_num)*

Remove ISR handler for the corresponding GPIO pin.

**Parameters**
- `gpio_num` - GPIO number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_STATE Wrong state, the ISR service has not been initialized.
- ESP_ERR_INVALID_ARG Parameter error

*esp_err_t gpio_set_drive_capability (gpio_num_t gpio_num, gpio_drive_cap_t strength)*

Set GPIO pad drive capability.

**Parameters**
- `gpio_num` - GPIO number, only support output GPIOs
- `strength` - Drive capability of the pad
Returns

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t gpio_get_drive_capability (gpio_num_t gpio_num, gpio_drive_cap_t *strength)
```

Get GPIO pad drive capability.

**Parameters**

- `gpio_num` - GPIO number, only support output GPIOs
- `strength` - Pointer to accept drive capability of the pad

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t gpio_hold_en (gpio_num_t gpio_num)
```

Enable gpio pad hold function.

When a GPIO is set to hold, its state is latched at that moment and will not change when the internal signal or the IO MUX/GPIO configuration is modified (including input enable, output enable, output value, function, and drive strength values). This function can be used to retain the state of GPIOs when the chip or system is reset, for example, when watchdog timeout or Deep-sleep events are triggered.

This function works in both input and output modes, and only applicable to output-capable GPIOs. If this function is enabled: in output mode: the output level of the GPIO will be locked and cannot be changed. in input mode: the input read value can still reflect the changes of the input signal.

However, on ESP32/S2/C3/S3/C2, this function cannot be used to hold the state of a digital GPIO during Deep-sleep. Even if this function is enabled, the digital GPIO will be reset to its default state when the chip wakes up from Deep-sleep. If you want to hold the state of a digital GPIO during Deep-sleep, please call `gpio_deep_sleep_hold_en`.

Power down or call `gpio_hold_dis` will disable this function.

**Parameters** `gpio_num` - GPIO number, only support output-capable GPIOs

**Returns**

- ESP_OK Success
- ESP_ERR_NOT_SUPPORTED Not support pad hold function

```c
esp_err_t gpio_hold_dis (gpio_num_t gpio_num)
```

Disable gpio pad hold function.

When the chip is woken up from Deep-sleep, the gpio will be set to the default mode, so, the gpio will output the default level if this function is called. If you don’t want the level changes, the gpio should be configured to a known state before this function is called. e.g. If you hold gpio18 high during Deep-sleep, after the chip is woken up and `gpio_hold_dis` is called, gpio18 will output low level (because gpio18 is input mode by default). If you don’t want this behavior, you should configure gpio18 as output mode and set it to high level before calling `gpio_hold_dis`.

**Parameters** `gpio_num` - GPIO number, only support output-capable GPIOs

**Returns**

- ESP_OK Success
- ESP_ERR_NOT_SUPPORTED Not support pad hold function

```c
void gpio_deep_sleep_hold_en (void)
```

Enable all digital gpio pads hold function during Deep-sleep.

Enabling this feature makes all digital gpio pads be at the holding state during Deep-sleep. The state of each pad holds is its active configuration (not pad’s sleep configuration!).

Note that this pad hold feature only works when the chip is in Deep-sleep mode. When the chip is in active mode, the digital gpio state can be changed freely even you have called this function.

After this API is being called, the digital gpio Deep-sleep hold feature will work during every sleep process. You should call `gpio_deep_sleep_hold_dis` to disable this feature.
void **gpio_deep_sleep_hold_dis** (void)
Disable all digital gpio pads hold function during Deep-sleep.

void **gpio_iomux_in** (uint32_t gpio_num, uint32_t signal_idx)
SOC_GPIO_SUPPORT_HOLD_SINGLE_IO_IN_DSLP.
Set pad input to a peripheral signal through the IOMUX.

Parameters
- **gpio_num** - GPIO number of the pad.
- **signal_idx** - Peripheral signal id to input. One of the *_IN_IDX signals in soc/gpio_sig_map.h.

void **gpio_iomux_out** (uint8_t gpio_num, int func, bool oen_inv)
Set peripheral output to an GPIO pad through the IOMUX.

Parameters
- **gpio_num** - gpio_num GPIO number of the pad.
- **func** - The function number of the peripheral pin to output pin. One of the FUNC_X_ of specified pin (X) in soc/io_mux_reg.h.
- **oen_inv** - True if the output enable needs to be inverted, otherwise False.

**esp_err_t gpio_sleep_sel_en** (gpio_num_t gpio_num)
Enable SLP_SEL to change GPIO status automatically in lightsleep.

Parameters **gpio_num** - GPIO number of the pad.

Returns
- ESP_OK Success

**esp_err_t gpio_sleep_sel_dis** (gpio_num_t gpio_num)
Disable SLP_SEL to change GPIO status automatically in lightsleep.

Parameters **gpio_num** - GPIO number of the pad.

Returns
- ESP_OK Success

**esp_err_t gpio_sleep_set_direction** (gpio_num_t gpio_num, gpio_mode_t mode)
GPIO set direction at sleep.
Configure GPIO direction,such as output_only,input_only,output_and_input

Parameters
- **gpio_num** - Configure GPIO pins number, it should be GPIO number. If you want to set direction of e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);
- **mode** - GPIO direction

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error

**esp_err_t gpio_sleep_set_pull_mode** (gpio_num_t gpio_num, gpio_pull_mode_t pull)
Configure GPIO pull-up/pull-down resistors at sleep.

Parameters
- **gpio_num** - GPIO number. If you want to set pull up or down mode for e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);
- **pull** - GPIO pull up/down mode.

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG : Parameter error

Note: ESP32: Only pins that support both input & output have integrated pull-up and pull-down resistors. Input-only GPIOs 34-39 do not.
Chapter 2. API Reference

Structures

struct gpio_config_t
    Configuration parameters of GPIO pad for gpio_config function.

Public Members

uint64_t pin_bit_mask
    GPIO pin: set with bitmask, each bitmap to a GPIO

gpio_mode_t mode
    GPIO mode: set input/output mode

gpio_pullup_t pull_up_en
    GPIO pull-up

gpio_pulldown_t pull_down_en
    GPIO pull-down

gpio_int_type_t intr_type
    GPIO interrupt type

Macros

GPIO_PIN_COUNT
GPIO_IS_VALID_GPIO (gpio_num)
    Check whether it is a valid GPIO number.

GPIO_IS_VALID_OUTPUT_GPIO (gpio_num)
    Check whether it can be a valid GPIO number of output mode.

GPIO_IS_VALID_DIGITAL_IO_PAD (gpio_num)
    Check whether it can be a valid digital I/O pad.

Type Definitions

typedef intr_handle_t gpio_isr_handle_t

typedef void (*gpio_isr_t)(void *arg)
    GPIO interrupt handler.

    Param arg  User registered data

Header File

    • components/hal/include/hal/gpio_types.h

Macros

GPIO_PIN_REG_0

GPIO_PIN_REG_1
GPIO_PIN_REG_2
GPIO_PIN_REG_3
GPIO_PIN_REG_4
GPIO_PIN_REG_5
GPIO_PIN_REG_6
GPIO_PIN_REG_7
GPIO_PIN_REG_8
GPIO_PIN_REG_9
GPIO_PIN_REG_10
GPIO_PIN_REG_11
GPIO_PIN_REG_12
GPIO_PIN_REG_13
GPIO_PIN_REG_14
GPIO_PIN_REG_15
GPIO_PIN_REG_16
GPIO_PIN_REG_17
GPIO_PIN_REG_18
GPIO_PIN_REG_19
GPIO_PIN_REG_20
GPIO_PIN_REG_21
GPIO_PIN_REG_22
GPIO_PIN_REG_23
GPIO_PIN_REG_24
Chapter 2. API Reference

GPIO_PIN_REG_25
GPIO_PIN_REG_26
GPIO_PIN_REG_27
GPIO_PIN_REG_28
GPIO_PIN_REG_29
GPIO_PIN_REG_30
GPIO_PIN_REG_31
GPIO_PIN_REG_32
GPIO_PIN_REG_33
GPIO_PIN_REG_34
GPIO_PIN_REG_35
GPIO_PIN_REG_36
GPIO_PIN_REG_37
GPIO_PIN_REG_38
GPIO_PIN_REG_39
GPIO_PIN_REG_40
GPIO_PIN_REG_41
GPIO_PIN_REG_42
GPIO_PIN_REG_43
GPIO_PIN_REG_44
GPIO_PIN_REG_45
GPIO_PIN_REG_46
GPIO_PIN_REG_47
GPIO_PIN_REG_48

Enumerations

enum gpio_port_t

Values:

enumerator GPIO_PORT_0

enumerator GPIO_PORT_MAX

enum gpio_num_t

Values:

enumerator GPIO_NUM_NC
Use to signal not connected to S/W

enumerator GPIO_NUM_0
GPIO0, input and output

enumerator GPIO_NUM_1
GPIO1, input and output

enumerator GPIO_NUM_2
GPIO2, input and output

enumerator GPIO_NUM_3
GPIO3, input and output

enumerator GPIO_NUM_4
GPIO4, input and output

enumerator GPIO_NUM_5
GPIO5, input and output

enumerator GPIO_NUM_6
GPIO6, input and output

enumerator GPIO_NUM_7
GPIO7, input and output

enumerator GPIO_NUM_8
GPIO8, input and output

enumerator GPIO_NUM_9
GPIO9, input and output

enumerator GPIO_NUM_10
GPIO10, input and output
enumerator GPIO_NUM_11
   GPIO11, input and output

enumerator GPIO_NUM_12
   GPIO12, input and output

enumerator GPIO_NUM_13
   GPIO13, input and output

enumerator GPIO_NUM_14
   GPIO14, input and output

enumerator GPIO_NUM_15
   GPIO15, input and output

enumerator GPIO_NUM_16
   GPIO16, input and output

enumerator GPIO_NUM_17
   GPIO17, input and output

enumerator GPIO_NUM_18
   GPIO18, input and output

enumerator GPIO_NUM_19
   GPIO19, input and output

enumerator GPIO_NUM_20
   GPIO20, input and output

enumerator GPIO_NUM_21
   GPIO21, input and output

enumerator GPIO_NUM_22
   GPIO22, input and output

enumerator GPIO_NUM_23
   GPIO23, input and output

enumerator GPIO_NUM_25
   GPIO25, input and output

enumerator GPIO_NUM_26
   GPIO26, input and output

enumerator GPIO_NUM_27
   GPIO27, input and output
enumerator **GPIO_NUM_28**
GPIO28, input and output

enumerator **GPIO_NUM_29**
GPIO29, input and output

enumerator **GPIO_NUM_30**
GPIO30, input and output

enumerator **GPIO_NUM_31**
GPIO31, input and output

enumerator **GPIO_NUM_32**
GPIO32, input and output

enumerator **GPIO_NUM_33**
GPIO33, input and output

enumerator **GPIO_NUM_34**
GPIO34, input mode only

enumerator **GPIO_NUM_35**
GPIO35, input mode only

enumerator **GPIO_NUM_36**
GPIO36, input mode only

enumerator **GPIO_NUM_37**
GPIO37, input mode only

enumerator **GPIO_NUM_38**
GPIO38, input mode only

enumerator **GPIO_NUM_39**
GPIO39, input mode only

enumerator **GPIO_NUM_MAX**

e num **gpio_int_type_t**

*Values:*

enumerator **GPIO_INTR_DISABLE**
Disable GPIO interrupt

enumerator **GPIO_INTR_POSEDGE**
GPIO interrupt type: rising edge

enumerator **GPIO_INTR_NEGEDGE**
GPIO interrupt type: falling edge
enumerator GPIO_INTR_ANYEDGE
    GPIO interrupt type: both rising and falling edge

enumerator GPIO_INTR_LOW_LEVEL
    GPIO interrupt type: input low level trigger

enumerator GPIO_INTR_HIGH_LEVEL
    GPIO interrupt type: input high level trigger

enumerator GPIO_INTR_MAX

enum gpio_mode_t
    Values:

    enumerator GPIO_MODE_DISABLE
        GPIO mode: disable input and output

    enumerator GPIO_MODE_INPUT
        GPIO mode: input only

    enumerator GPIO_MODE_OUTPUT
        GPIO mode: output only mode

    enumerator GPIO_MODE_OUTPUT_OD
        GPIO mode: output only with open-drain mode

    enumerator GPIO_MODE_INPUT_OUTPUT_OD
        GPIO mode: output and input with open-drain mode

    enumerator GPIO_MODE_INPUT_OUTPUT
        GPIO mode: output and input mode

enum gpio_pullup_t
    Values:

    enumerator GPIO_PULLUP_DISABLE
        Disable GPIO pull-up resistor

    enumerator GPIO_PULLUP_ENABLE
        Enable GPIO pull-up resistor

enum gpio_pulldown_t
    Values:

    enumerator GPIO_PULLDOWN_DISABLE
        Disable GPIO pull-down resistor

    enumerator GPIO_PULLDOWN_ENABLE
        Enable GPIO pull-down resistor
enum gpio_pull_mode_t
   Values:
   enumerator GPIO_PULLUP_ONLY
       Pad pull up
   enumerator GPIO_PULLDOWN_ONLY
       Pad pull down
   enumerator GPIO_PULLUP_PULLDOWN
       Pad pull up + pull down
   enumerator GPIO_FLOATING
       Pad floating

enum gpio_drive_cap_t
   Values:
   enumerator GPIO_DRIVE_CAP_0
       Pad drive capability: weak
   enumerator GPIO_DRIVE_CAP_1
       Pad drive capability: stronger
   enumerator GPIO_DRIVE_CAP_2
       Pad drive capability: medium
   enumerator GPIO_DRIVE_CAP_DEFAULT
       Pad drive capability: medium
   enumerator GPIO_DRIVE_CAP_3
       Pad drive capability: strongest
   enumerator GPIO_DRIVE_CAP_MAX

enum gpio_hys_ctrl_mode_t
   Available option for configuring hysteresis feature of GPIOs.
   Values:
   enumerator GPIO_HYS_CTRL_EFUSE
       Pad input hysteresis ctrl by efuse
   enumerator GPIO_HYS_SOFT_ENABLE
       Pad input hysteresis enable by software
   enumerator GPIO_HYS_SOFT_DISABLE
       Pad input hysteresis disable by software
API Reference - RTC GPIO

Header File

- components/driver/gpio/include/driver/rtc_io.h

Functions

**bool rtc_gpio_is_valid_gpio (gpio_num_t gpio_num)**

Determine if the specified GPIO is a valid RTC GPIO.

- **Parameters**: gpio_num - GPIO number
  - **Returns**: true if GPIO is valid for RTC GPIO use. false otherwise.

**int rtc_io_number_get (gpio_num_t gpio_num)**

Get RTC IO index number by gpio number.

- **Parameters**: gpio_num - GPIO number
  - **Returns**: >=0: Index of rtcio. -1: The gpio is not rtcio.

**esp_err_t rtc_gpio_init (gpio_num_t gpio_num)**

Init a GPIO as RTC GPIO.

This function must be called when initializing a pad for an analog function.

- **Parameters**: gpio_num - GPIO number (e.g. GPIO_NUM_12)
  - **Returns**: 
    - ESP_OK success
    - ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**esp_err_t rtc_gpio_deinit (gpio_num_t gpio_num)**

Init a GPIO as digital GPIO.

- **Parameters**: gpio_num - GPIO number (e.g. GPIO_NUM_12)
  - **Returns**: 
    - ESP_OK success
    - ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**uint32_t rtc_gpio_get_level (gpio_num_t gpio_num)**

Get the RTC IO input level.

- **Parameters**: gpio_num - GPIO number (e.g. GPIO_NUM_12)
  - **Returns**: 
    - 1 High level
    - 0 Low level
    - ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**esp_err_t rtc_gpio_set_level (gpio_num_t gpio_num, uint32_t level)**

Set the RTC IO output level.

- **Parameters**: 
  - gpio_num - GPIO number (e.g. GPIO_NUM_12)
  - level - output level
  - **Returns**: 
    - ESP_OK Success
    - ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**esp_err_t rtc_gpio_set_direction (gpio_num_t gpio_num, rtc_gpio_mode_t mode)**

RTC GPIO set direction.

Configure RTC GPIO direction, such as output only, input only, output and input.

- **Parameters**: 
  - gpio_num - GPIO number (e.g. GPIO_NUM_12)
  - mode - GPIO direction
Returns

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

*esp_err_t rtc_gpio_set_direction_in_sleep(gpio_num_t gpio_num, rtc_gpio_mode_t mode)*

RTC GPIO set direction in deep sleep mode or disable sleep status (default). In some application scenarios, IO needs to have another states during deep sleep.

NOTE: ESP32 support INPUT_ONLY mode. ESP32S2 support INPUT_ONLY, OUTPUT_ONLY, INPUT_OUTPUT mode.

Parameters

- *gpio_num* - GPIO number (e.g. GPIO_NUM_12)
- *mode* - GPIO direction

Returns

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

*esp_err_t rtc_gpio_pullup_en(gpio_num_t gpio_num)*

RTC GPIO pullup enable.

This function only works for RTC IOs. In general, call gpio_pullup_en, which will work both for normal GPIOs and RTC IOs.

Parameters *gpio_num* - GPIO number (e.g. GPIO_NUM_12)

Returns

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

*esp_err_t rtc_gpio_pulldown_en(gpio_num_t gpio_num)*

RTC GPIO pulldown enable.

This function only works for RTC IOs. In general, call gpio_pulldown_en, which will work both for normal GPIOs and RTC IOs.

Parameters *gpio_num* - GPIO number (e.g. GPIO_NUM_12)

Returns

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

*esp_err_t rtc_gpio_pullup_dis(gpio_num_t gpio_num)*

RTC GPIO pullup disable.

This function only works for RTC IOs. In general, call gpio_pullup_dis, which will work both for normal GPIOs and RTC IOs.

Parameters *gpio_num* - GPIO number (e.g. GPIO_NUM_12)

Returns

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

*esp_err_t rtc_gpio_pulldown_dis(gpio_num_t gpio_num)*

RTC GPIO pulldown disable.

This function only works for RTC IOs. In general, call gpio_pulldown_dis, which will work both for normal GPIOs and RTC IOs.

Parameters *gpio_num* - GPIO number (e.g. GPIO_NUM_12)

Returns

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

*esp_err_t rtc_gpio_set_drive_capability(gpio_num_t gpio_num, gpio_drive_cap_t strength)*

Set RTC GPIO pad drive capability.
Parameters
- `gpio_num` - GPIO number, only support output GPIOs
- `strength` - Drive capability of the pad

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t rtc_gpio_get_drive_capability(gpio_num_t gpio_num, gpio_drive_cap_t *strength)
```

Get RTC GPIO pad drive capability.

Parameters
- `gpio_num` - GPIO number, only support output GPIOs
- `strength` - Pointer to accept drive capability of the pad

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t rtc_gpio_hold_en(gpio_num_t gpio_num)
```

Enable hold function on an RTC IO pad.

Enabling HOLD function will cause the pad to latch current values of input enable, output enable, output value, function, drive strength values. This function is useful when going into light or deep sleep mode to prevent the pin configuration from changing.

Parameters `gpio_num` - GPIO number (e.g. GPIO_NUM_12)

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

```c
esp_err_t rtc_gpio_hold_dis(gpio_num_t gpio_num)
```

Disable hold function on an RTC IO pad.

Disabling hold function will allow the pad receive the values of input enable, output enable, output value, function, drive strength from RTC_IO peripheral.

Parameters `gpio_num` - GPIO number (e.g. GPIO_NUM_12)

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO is not an RTC IO

```c
esp_err_t rtc_gpio_force_hold_en_all(void)
```

Enable force hold signal for all RTC IOs.

Each RTC pad has a “force hold” input signal from the RTC controller. If this signal is set, pad latches current values of input enable, function, output enable, and other signals which come from the RTC mux. Force hold signal is enabled before going into deep sleep for pins which are used for EXT1 wakeup.

```c
esp_err_t rtc_gpio_force_hold_dis_all(void)
```

Disable force hold signal for all RTC IOs.

```c
esp_err_t rtc_gpio_wakeup_enable(gpio_num_t gpio_num, gpio_int_type_t intr_type)
```

Enable wakeup from sleep mode using specific GPIO.

Parameters
- `gpio_num` - GPIO number
- `intr_type` - Wakeup on high level (GPIO_INTR_HIGH_LEVEL) or low level (GPIO_INTR_LOW_LEVEL)

Returns
- ESP_OK on success
- ESP_ERR_INVALID_ARG if gpio_num is not an RTC IO, or intr_type is not one of GPIO_INTR_HIGH_LEVEL, GPIO_INTR_LOW_LEVEL.
**esp_err_t rtc_gpio_wakeup_disable(gpio_num_t gpio_num)**

Disable wakeup from sleep mode using specific GPIO.

**Parameters**: `gpio_num` - GPIO number

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if `gpio_num` is not an RTC IO

**Macros**

`RTC_GPIO_IS_VALID_GPIO(gpio_num)`

**Header File**

- `components/hal/include/hal/rtc_io_types.h`

**Enumerations**

`enum rtc_gpio_mode_t`

RTCIO output/input mode type.

**Values**:

- `RTC_GPIO_MODE_INPUT_ONLY` - Pad input
- `RTC_GPIO_MODE_OUTPUT_ONLY` - Pad output
- `RTC_GPIO_MODE_INPUT_OUTPUT` - Pad input + output
- `RTC_GPIO_MODE_DISABLED` - Pad (output + input) disable
- `RTC_GPIO_MODE_OUTPUT_OD` - Pad open-drain output
- `RTC_GPIO_MODE_INPUT_OUTPUT_OD` - Pad input + open-drain output

### 2.6.7 General Purpose Timer (GPTimer)

**Introduction**

GPTimer (General Purpose Timer) is the driver of ESP32 Timer Group peripheral. The hardware timer features high resolution and flexible alarm action. The behavior when the internal counter of a timer reaches a specific target value is called a timer alarm. When a timer alarms, a user registered per-timer callback would be called.

Typically, a general purpose timer can be used in scenarios like:

- Free running as a wall clock, fetching a high-resolution timestamp at any time and any places
- Generate period alarms, trigger events periodically
- Generate one-shot alarm, respond in target time
Chapter 2. API Reference

Functional Overview

The following sections of this document cover the typical steps to install and operate a timer:

- **Resource Allocation** - covers which parameters should be set up to get a timer handle and how to recycle the resources when GPTimer finishes working.
- **Set and Get Count Value** - covers how to force the timer counting from a start point and how to get the count value at anytime.
- **Set up Alarm Action** - covers the parameters that should be set up to enable the alarm event.
- **Register Event Callbacks** - covers how to hook user specific code to the alarm event callback function.
- **Enable and Disable Timer** - covers how to enable and disable the timer.
- **Start and Stop Timer** - shows some typical use cases that start the timer with different alarm behavior.
- **Power Management** - describes how different source clock selections can affect power consumption.
- **IRAM Safe** - describes tips on how to make the timer interrupt and IO control functions work better along with a disabled cache.
- **Thread Safety** - lists which APIs are guaranteed to be thread safe by the driver.
- **Kconfig Options** - lists the supported Kconfig options that can be used to make a different effect on driver behavior.

**Resource Allocation**

Different ESP chips might have different numbers of independent timer groups, and within each group, there could also be several independent timers. A GPTimer instance is represented by `gptimer_handle_t`. The driver behind will manage all available hardware resources in a pool, so that you do not need to care about which timer and which group it belongs to.

To install a timer instance, there is a configuration structure that needs to be given in advance: `gptimer_config_t`:

- `gptimer_config_t::clk_src` selects the source clock for the timer. The available clocks are listed in `gptimer_clock_source_t`, you can only pick one of them. For the effect on power consumption of different clock source, please refer to Section **Power Management**.
- `gptimer_config_t::direction` sets the counting direction of the timer, supported directions are listed in `gptimer_count_direction_t`, you can only pick one of them.
- `gptimer_config_t::resolution_hz` sets the resolution of the internal counter. Each count step is equivalent to \( \frac{1}{\text{resolution}_hz} \) seconds.
- `gptimer_config::intr_priority` sets the priority of the timer interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.
- Optional `gptimer_config_t::intr_shared` sets whether or not mark the timer interrupt source as a shared one. For the pros/cons of a shared interrupt, you can refer to **Interrupt Handling**.

With all the above configurations set in the structure, the structure can be passed to `gptimer_new_timer()` which will instantiate the timer instance and return a handle of the timer.

The function can fail due to various errors such as insufficient memory, invalid arguments, etc. Specifically, when there are no more free timers (i.e. all hardware resources have been used up), then `ESP_ERR_NOT_FOUND` will be returned. The total number of available timers is represented by the `SOC_TIMER_GROUP_TOTAL_TIMERS` and its value will depend on the ESP chip.

If a previously created GPTimer instance is no longer required, you should recycle the timer by calling `gptimer_del_timer()`. This will allow the underlying HW timer to be used for other purposes. Before deleting a GPTimer handle, please disable it by `gptimer_disable()` in advance or make sure it has not enabled yet by `gptimer_enable()`.

**Creating a GPTimer Handle with Resolution of 1 MHz**

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1 Different ESP chip series might have different numbers of GPTimer instances. For more details, please refer to ESP32 Technical Reference Manual Chapter Timer Group (TIMG) [PDF]. The driver will not forbid you from applying for more timers, but it will return error when all available hardware resources are used up. Please always check the return value when doing resource allocation (e.g. `gptimer_new_timer()`).
Set and Get Count Value  When the GPTimer is created, the internal counter will be reset to zero by default. The counter value can be updated asynchronously by `gptimer_set_raw_count()`. The maximum count value is dependent on the bit width of the hardware timer, which is also reflected by the SOC macro `SOC_TIMER_GROUP_COUNTER_BIT_WIDTH`. When updating the raw count of an active timer, the timer will immediately start counting from the new value.

Count value can be retrieved by `gptimer_get_raw_count()`, at any time.

Set up Alarm Action  For most of the use cases of GPTimer, you should set up the alarm action before starting the timer, except for the simple wall-clock scenario, where a free running timer is enough. To set up the alarm action, you should configure several members of `gptimer_alarm_config_t` based on how you make use of the alarm event:

- `gptimer_alarm_config_t::alarm_count` sets the target count value that will trigger the alarm event. You should also take the counting direction into consideration when setting the alarm value. Specially, `gptimer_alarm_config_t::alarm_count` and `gptimer_alarm_config_t::reload_count` cannot be set to the same value when `gptimer_alarm_config_t::auto_reload_on_alarm` is true, as keeping reload with a target alarm count is meaningless.
- `gptimer_alarm_config_t::reload_count` sets the count value to be reloaded when the alarm event happens. This configuration only takes effect when `gptimer_alarm_config_t::auto_reload_on_alarm` is set to true.
- `gptimer_alarm_config_t::auto_reload_on_alarm` flag sets whether to enable the auto-reload feature. If enabled, the hardware timer will reload the value of `gptimer_alarm_config_t::reload_count` into counter immediately when an alarm event happens.

To make the alarm configurations take effect, you should call `gptimer_set_alarm_action()`. Especially, if `gptimer_alarm_config_t` is set to `NULL`, the alarm function will be disabled.

**Note:** If an alarm value is set and the timer has already exceeded this value, the alarm will be triggered immediately.

Register Event Callbacks  After the timer starts up, it can generate a specific event (e.g. the “Alarm Event”) dynamically. If you have some functions that should be called when the event happens, please hook your function to the interrupt service routine by calling `gptimer_register_event_callbacks()`. All supported event callbacks are listed in `gptimer_event_callbacks_t`:

- `gptimer_event_callbacks_t::on_alarm` sets a callback function for alarm events. As this function is called within the ISR context, you must ensure that the function does not attempt to block (e.g., by making sure that only FreeRTOS APIs with `ISR` suffix are called from within the function). The function prototype is declared in `gptimer_alarm_cb_t`.

You can save your own context to `gptimer_register_event_callbacks()` as well, via the parameter `user_data`. The user data will be directly passed to the callback function.

This function will lazy install the interrupt service for the timer but not enable it. So please call this function before `gptimer_enable()`, otherwise the `ESP_ERR_INVALID_STATE` error will be returned. See Section **Enable and Disable Timer** for more information.
Enable and Disable Timer  
Before doing IO control to the timer, you need to enable the timer first, by calling
`gptimer_enable()`. This function will:

- Switch the timer driver state from `init` to `enable`.
- Enable the interrupt service if it has been lazy installed by `gptimer_register_event_callbacks()`.
- Acquire a proper power management lock if a specific clock source (e.g. APB clock) is selected. See Section Power Management for more information.

Calling `gptimer_disable()` will do the opposite, that is, put the timer driver back to the `init` state, disable the interrupts service and release the power management lock.

Start and Stop Timer  
The basic IO operation of a timer is to start and stop. Calling `gptimer_start()` can make the internal counter work, while calling `gptimer_stop()` can make the counter stop working. The following illustrates how to start a timer with or without an alarm event. Calling `gptimer_start()` will transit the driver state from `enable` to `run`, and vice versa. You need to make sure the start and stop functions are used in pairs, otherwise, the functions may return `ESP_ERR_INVALID_STATE`. Most of the time, this error means that the timer is already stopped or in the “start protection” state (i.e. `gptimer_start()` is called but not finished).

Start Timer as a Wall Clock

```c
ESP_ERROR_CHECK(gptimer_enable(gptimer));
ESP_ERROR_CHECK(gptimer_start(gptimer));
// Retrieve the timestamp at any time
uint64_t count;
ESP_ERROR_CHECK(gptimer_get_raw_count(gptimer, &count));
```

Trigger Period Events

```c
typedef struct {
    uint64_t event_count;
} example_queue_element_t;

static bool example_timer_on_alarm(gptimer_handle_t timer, const gptimer_alarm_event_data_t *edata, void *user_ctx)
{
    BaseType_t high_task_awoken = pdFALSE;
    QueueHandle_t queue = (QueueHandle_t)user_ctx;
    // Retrieve the count value from event data
    example_queue_element_t ele = {
        .event_count = edata->count_value
    };
    // Optional: send the event data to other task by OS queue
    // Do not introduce complex logics in callbacks
    // Suggest dealing with event data in the main loop, instead of in this callback
    xQueueSendFromISR(queue, &ele, &high_task_awoken);
    // return whether we need to yield at the end of ISR
    return high_task_awoken == pdTRUE;
}

gptimer_alarm_config_t alarm_config = {
    .reload_count = 0, // counter will reload with 0 on alarm event
    .alarm_count = 1000000, // period = 1s @resolution 1MHz
    .flags.auto_reload_on_alarm = true, // enable auto-reload
};
ESP_ERROR_CHECK(gptimer_set_alarm_action(gptimer, &alarm_config));

gptimer_event_callbacks_t cbs = {
    .on_alarm = example_timer_on_alarm_cb, // register user callback
};
```

(continues on next page)
ESP_ERROR_CHECK(gptimer_register_event_callbacks(gptimer, &cbs, queue));
ESP_ERROR_CHECK(gptimer_enable(gptimer));
ESP_ERROR_CHECK(gptimer_start(gptimer));

Trigger One-Shot Event

typedef struct
{
    uint64_t event_count;
} example_queue_element_t;

static bool example_timer_on_alarm_cb(gptimer_handle_t timer, const gptimer_alarm_event_data_t *edata, void *user_ctx)
{
    BaseType_t high_task_awoken = pdFALSE;
    QueueHandle_t queue = (QueueHandle_t)user_ctx;
    // Stop timer the sooner the better
    gptimer_stop(timer);
    // Retrieve the count value from event data
    example_queue_element_t ele = {
        .event_count = edata->count_value
    };
    // Optional: send the event data to other task by OS queue
    xQueueSendFromISR(queue, &ele, &high_task_awoken);
    // return whether we need to yield at the end of ISR
    return high_task_awoken = pdTRUE;
}

gptimer_alarm_config_t alarm_config = {
    .alarm_count = 1 * 1000 * 1000, // alarm target = 1s @resolution 1MHz
};
ESP_ERROR_CHECK(gptimer_set_alarm_action(gptimer, &alarm_config));
gptimer_event_callbacks_t cbs = {
    .on_alarm = example_timer_on_alarm_cb, // register user callback
};
ESP_ERROR_CHECK(gptimer_register_event_callbacks(gptimer, &cbs, queue));
ESP_ERROR_CHECK(gptimer_enable(gptimer));
ESP_ERROR_CHECK(gptimer_start(gptimer));

Dynamic Alarm Update  Alarm value can be updated dynamically inside the ISR handler callback, by changing
gptimer_alarm_event_data_t::alarm_value. Then the alarm value will be updated after the callback
function returns.

typedef struct
{
    uint64_t event_count;
} example_queue_element_t;

static bool example_timer_on_alarm_cb(gptimer_handle_t timer, const gptimer_alarm_event_data_t *edata, void *user_ctx)
{
    BaseType_t high_task_awoken = pdFALSE;
    QueueHandle_t queue = (QueueHandle_t)user_ctx;
    // Retrieve the count value from event data
    example_queue_element_t ele = {
        .event_count = edata->count_value
    };
    // Optional: send the event data to other task by OS queue
    xQueueSendFromISR(queue, &ele, &high_task_awoken);
    // reconfigure alarm value
}
gptimer_alarm_config_t alarm_config = {
    .alarm_count = edata->alarm_value + 1000000, // alarm in next 1s
};
gptimer_set_alarm_action(timer, &alarm_config);
// return whether we need to yield at the end of ISR
    return high_task_awoken == pdTRUE;

alarm_config = {
    .alarm_count = 1000000, // initial alarm target = 1s @resolution 1MHz
};
ESP_ERROR_CHECK(gptimer_set_alarm_action(gptimer, &alarm_config));

ESP_ERROR_CHECK(gptimer_enable(gptimer));
ESP_ERROR_CHECK(gptimer_start(gptimer, &alarm_config));

Power Management  There are some power management strategies, which might turn off or change the frequency of GPTimer’s source clock to save power consumption. For example, during DFS, APB clock will be scaled down. If light-sleep is also enabled, PLL and XTAL clocks will be powered off. Both of them can result in an inaccurate time keeping.

The driver can prevent the above situation from happening by creating different power management lock according to different clock source. The driver will increase the reference count of that power management lock in the `gptimer_enable()` and decrease it in the `gptimer_disable()`. So we can ensure the clock source is stable between `gptimer_enable()` and `gptimer_disable()`.

IRAM Safe  By default, the GPTimer interrupt will be deferred when the cache is disabled because of writing or erasing the flash. Thus the alarm interrupt will not get executed in time, which is not expected in a real-time application.

There is a Kconfig option `CONFIG_GPTIMER_ISR_IRAM_SAFE` that will:

- Enable the interrupt being serviced even when the cache is disabled
- Place all functions that used by the ISR into IRAM
- Place driver object into DRAM (in case it is mapped to PSRAM by accident)

This will allow the interrupt to run while the cache is disabled, but will come at the cost of increased IRAM consumption.

There is another Kconfig option `CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM` that can put commonly used IO control functions into IRAM as well. So, these functions can also be executable when the cache is disabled. These IO control functions are as follows:

- `gptimer_start`
- `gptimer_stop`
- `gptimer_get_raw_count`
- `gptimer_set_raw_count`
- `gptimer_set_alarm_action`

Thread Safety  All the APIs provided by the driver are guaranteed to be thread safe, which means you can call them from different RTOS tasks without protection by extra locks. The following functions are allowed to run under ISR context.

1 gptimer_event_callbacks_t::on_alarm callback and the functions invoked by the callback should also be placed in IRAM, please take care of them by yourself.
Chapter 2. API Reference

- `gptimer_start()`
- `gptimer_stop()`
- `gptimer_get_raw_count()`
- `gptimer_set_raw_count()`
- `gptimer_get_captured_count()`
- `gptimer_set_alarm_action()`

Kconfig Options

- `CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM` controls where to place the GPTimer control functions (IRAM or flash).
- `CONFIG_GPTIMER_ISR_HANDLER_IN_IRAM` controls where to place the GPTimer ISR handler (IRAM or flash).
- `CONFIG_GPTIMER_ISR_IRAM_SAFE` controls whether the default ISR handler should be masked when the cache is disabled, see Section IRAM Safe for more information.
- `CONFIG_GPTIMER_ENABLE_DEBUG_LOG` is used to enable the debug log output. Enable this option will increase the firmware binary size.

Application Examples

- Typical use cases of GPTimer are listed in the example peripherals/timer_group/gptimer.

API Reference

Header File

- components/driver/gptimer/include/driver/gptimer.h

Functions

```c
esp_err_t gptimer_new_timer(const gptimer_config_t *config, gptimer_handle_t *ret_timer)
```
Create a new General Purpose Timer, and return the handle.

Note: The newly created timer is put in the “init” state.

Parameters

- `config` [in] GPTimer configuration
- `ret_timer` [out] Returned timer handle

Returns

- ESP_OK: Create GPTimer successfully
- ESP_ERR_INVALID_ARG: Create GPTimer failed because of invalid argument
- ESP_ERR_NO_MEM: Create GPTimer failed because out of memory
- ESP_ERR_NOT_FOUND: Create GPTimer failed because all hardware timers are used up and no more free one
- ESP_FAIL: Create GPTimer failed because of other error

```c
esp_err_t gptimer_del_timer(gptimer_handle_t timer)
```
Delete the GPTimer handle.

Note: A timer must be in the “init” state before it can be deleted.

Parameters `timer` [in] Timer handle created by `gptimer_new_timer`

Returns
Chapter 2. API Reference

- ESP_OK: Delete GPTimer successfully
- ESP_ERR_INVALID_ARG: Delete GPTimer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Delete GPTimer failed because the timer is not in init state
- ESP_FAIL: Delete GPTimer failed because of other error

```c
esp_err_t gptimer_set_raw_count (gptimer_handle_t timer, uint64_t value)
```

Set GPTimer raw count value.

**Note:** When updating the raw count of an active timer, the timer will immediately start counting from the new value.

**Note:** This function is allowed to run within ISR context

**Note:** If CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM is enabled, this function will be placed in the IRAM by linker, makes it possible to execute even when the Flash Cache is disabled.

**Parameters**
- `timer` - [in] Timer handle created by `gptimer_new_timer`
- `value` - [in] Count value to be set

**Returns**
- ESP_OK: Set GPTimer raw count value successfully
- ESP_ERR_INVALID_ARG: Set GPTimer raw count value failed because of invalid argument
- ESP_FAIL: Set GPTimer raw count value failed because of other error

```c
esp_err_t gptimer_get_raw_count (gptimer_handle_t timer, uint64_t *value)
```

Get GPTimer raw count value.

**Note:** This function will trigger a software capture event and then return the captured count value.

**Note:** With the raw count value and the resolution returned from `gptimer_get_resolution`, you can convert the count value into seconds.

**Note:** This function is allowed to run within ISR context

**Note:** If CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM is enabled, this function will be placed in the IRAM by linker, makes it possible to execute even when the Flash Cache is disabled.

**Parameters**
- `timer` - [in] Timer handle created by `gptimer_new_timer`
- `value` - [out] Returned GPTimer count value

**Returns**
- ESP_OK: Get GPTimer raw count value successfully
- ESP_ERR_INVALID_ARG: Get GPTimer raw count value failed because of invalid argument
- ESP_FAIL: Get GPTimer raw count value failed because of other error


**esp_err_t gptimer_get_resolution (gptimer_handle_t timer, uint32_t *out_resolution)**

Return the real resolution of the timer.

**Note:** usually the timer resolution is same as what you configured in the gptimer_config_t::resolution_hz, but some unstable clock source (e.g. RC_FAST) will do a calibration, the real resolution can be different from the configured one.

**Parameters**

- **timer**  - [in] Timer handle created by gptimer_new_timer
- **out resolution**  - [out] Returned timer resolution, in Hz

**Returns**

- ESP_OK: Get GPTimer resolution successfully
- ESP_ERR_INVALID_ARG: Get GPTimer resolution failed because of invalid argument
- ESP_FAIL: Get GPTimer resolution failed because of other error

**esp_err_t gptimer_get_captured_count (gptimer_handle_t timer, uint64_t *value)**

Get GPTimer captured count value.

**Note:** The capture action can be issued either by ETM event or by software (see also gptimer_get_raw_count).

**Note:** This function is allowed to run within ISR context

**Note:** If CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM is enabled, this function will be placed in the IRAM by linker, makes it possible to execute even when the Flash Cache is disabled.

**Parameters**

- **timer**  - [in] Timer handle created by gptimer_new_timer
- **value**  - [out] Returned captured count value

**Returns**

- ESP_OK: Get GPTimer captured count value successfully
- ESP_ERR_INVALID_ARG: Get GPTimer captured count value failed because of invalid argument
- ESP_FAIL: Get GPTimer captured count value failed because of other error

**esp_err_t gptimer_register_event_callbacks (gptimer_handle_t timer, const gptimer_event_callbacks_t *cbs, void *user_data)**

Set callbacks for GPTimer.

**Note:** User registered callbacks are expected to be runnable within ISR context

**Note:** The first call to this function needs to be before the call to gptimer_enable

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the cbs structure to NULL.

**Parameters**
Chapter 2. API Reference

- **timer** - [in] Timer handle created by `gptimer_new_timer`
- **cbs** - [in] Group of callback functions
- **user_data** - [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set event callbacks failed because the timer is not in init state
- ESP_FAIL: Set event callbacks failed because of other error

```c
 esp_err_t gptimer_set_alarm_action ( gptimer_handle_t timer, const gptimer_alarm_config_t *config )
```

Set alarm event actions for GPTimer.

**Note:** This function is allowed to run within ISR context, so that user can set new alarm action immediately in the ISR callback.

**Note:** If `CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM` is enabled, this function will be placed in the IRAM by linker, makes it possible to execute even when the Flash Cache is disabled.

**Parameters**
- **timer** - [in] Timer handle created by `gptimer_new_timer`
- **config** - [in] Alarm configuration, especially, set config to NULL means disabling the alarm function

**Returns**
- ESP_OK: Set alarm action for GPTimer successfully
- ESP_ERR_INVALID_ARG: Set alarm action for GPTimer failed because of invalid argument
- ESP_FAIL: Set alarm action for GPTimer failed because of other error

```c
 esp_err_t gptimer_enable ( gptimer_handle_t timer )
```

Enable GPTimer.

**Note:** This function will transit the timer state from “init” to “enable”.

**Note:** If it’s lazy installed in `gptimer_register_event_callbacks`, this function will enable the interrupt service.

**Note:** This function will acquire a PM lock, if a specific source clock (e.g. APB) is selected in the `gptimer_config_t`, while `CONFIG_PM_ENABLE` is enabled.

**Note:** Enable a timer doesn’t mean to start it. See also `gptimer_start` for how to make the timer start counting.

**Parameters**
- **timer** - [in] Timer handle created by `gptimer_new_timer`

**Returns**
- ESP_OK: Enable GPTimer successfully
- ESP_ERR_INVALID_ARG: Enable GPTimer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Enable GPTimer failed because the timer is already enabled
Chapter 2. API Reference

- ESP_FAIL: Enable GPTimer failed because of other error

```c
esp_err_t gptimer_disable(gptimer_handle_t timer)
```
Disable GPTimer.

**Note:** This function will transit the timer state from “enable” to “init”.

**Note:** This function will disable the interrupt service if it’s installed.

**Note:** This function will release the PM lock if it’s acquired in the `gptimer_enable`.

**Note:** Disable a timer doesn’t mean to stop it. See also `gptimer_stop` for how to make the timer stop counting.

**Parameters**
- `timer` [in] Timer handle created by `gptimer_new_timer`

**Returns**
- ESP_OK: Disable GPTimer successfully
- ESP_ERR_INVALID_ARG: Disable GPTimer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Disable GPTimer failed because the timer is not enabled yet
- ESP_FAIL: Disable GPTimer failed because of other error

```c
esp_err_t gptimer_start(gptimer_handle_t timer)
```
Start GPTimer (internal counter starts counting)

**Note:** This function will transit the timer state from “enable” to “run”.

**Note:** This function is allowed to run within ISR context

**Note:** If `CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM` is enabled, this function will be placed in the IRAM by linker, makes it possible to execute even when the Flash Cache is disabled.

**Parameters**
- `timer` [in] Timer handle created by `gptimer_new_timer`

**Returns**
- ESP_OK: Start GPTimer successfully
- ESP_ERR_INVALID_ARG: Start GPTimer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Start GPTimer failed because the timer is not enabled or is already in running
- ESP_FAIL: Start GPTimer failed because of other error

```c
esp_err_t gptimer_stop(gptimer_handle_t timer)
```
Stop GPTimer (internal counter stops counting)

**Note:** This function will transit the timer state from “run” to “enable”.

Espressif Systems 1109 Release v5.1.2
Submit Document Feedback
Chapter 2. API Reference

**Note:** This function is allowed to run within ISR context

**Note:** If `CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM` is enabled, this function will be placed in the IRAM by linker, makes it possible to execute even when the Flash Cache is disabled.

**Parameters**

- `timer` [in] Timer handle created by `gptimer_new_timer`

**Returns**

- ESP_OK: Stop GPTimer successfully
- ESP_ERR_INVALID_ARG: Stop GPTimer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Stop GPTimer failed because the timer is not in running.
- ESP_FAIL: Stop GPTimer failed because of other error

**Structures**

```
struct gptimer_config_t
    General Purpose Timer configuration.
```

**Public Members**

```
gptimer_clock_source_t clk_src
    GPTimer clock source

gptimer_count_direction_t direction
    Count direction

uint32_t resolution_hz
    Counter resolution (working frequency) in Hz, hence, the step size of each count tick equals to (1 / resolution_hz) seconds

int intr_priority
    GPTimer interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1, 2, 3)

uint32_t intr_shared
    Set true, the timer interrupt number can be shared with other peripherals

struct gptimer_config_t::[anonymous] flags
    GPTimer config flags
```

```
struct gptimer_event_callbacks_t
    Group of supported GPTimer callbacks.
```

**Note:** The callbacks are all running under ISR environment

**Note:** When `CONFIG_GPTIMER_ISR_IRAM_SAFE` is enabled, the callback itself and functions called by it should be placed in IRAM.
Public Members

`gptimer_alarm_cb_t on_alarm`
Timer alarm callback

`struct gptimer_alarm_config_t`
General Purpose Timer alarm configuration.

Public Members

`uint64_t alarm_count`
Alarm target count value

`uint64_t reload_count`
Alarm reload count value, effect only when `auto_reload_on_alarm` is set to true

`uint32_t auto_reload_on_alarm`
Reload the count value by hardware, immediately at the alarm event

`struct gptimer_alarm_config_t::[anonymous] flags`
Alarm config flags

Header File

- components/driver/gptimer/include/driver/gptimer_etm.h

Functions

`esp_err_t gptimer_new_etm_event (gptimer_handle_t timer, const gptimer_etm_event_config_t *config, esp_etm_event_handle_t *out_event)`
Get the ETM event for GPTimer.

**Note:** The created ETM event object can be deleted later by calling `esp_etm_del_event`

**Parameters**

- `timer` - [in] Timer handle created by `gptimer_new_timer`
- `config` - [in] GPTimer ETM event configuration
- `out_event` - [out] Returned ETM event handle

**Returns**

- ESP_OK: Get ETM event successfully
- ESP_ERR_INVALID_ARG: Get ETM event failed because of invalid argument
- ESP_FAIL: Get ETM event failed because of other error

`esp_err_t gptimer_new_etm_task (gptimer_handle_t timer, const gptimer_etm_task_config_t *config, esp_etm_task_handle_t *out_task)`
Get the ETM task for GPTimer.

**Note:** The created ETM task object can be deleted later by calling `esp_etm_del_task`

**Parameters**
• **timer** [in] Timer handle created by `gptimer_new_timer`
• **config** [in] GPTimer ETM task configuration
• **out_task** [out] Returned ETM task handle

**Returns**
- ESP_OK: Get ETM task successfully
- ESP_ERR_INVALID_ARG: Get ETM task failed because of invalid argument
- ESP_FAIL: Get ETM task failed because of other error

**Structures**

struct `gptimer_etm_event_config_t`
GPTimer ETM event configuration.

**Public Members**

`gptimer_etm_event_type_t` **event_type**
GPTimer ETM event type

struct `gptimer_etm_task_config_t`
GPTimer ETM task configuration.

**Public Members**

`gptimer_etm_task_type_t` **task_type**
GPTimer ETM task type

**Header File**
- `components/driver/gptimer/include/driver/gptimer_types.h`

**Structures**

struct `gptimer_alarm_event_data_t`
GPTimer alarm event data.

**Public Members**

`uint64_t` **count_value**
Current count value

`uint64_t` **alarm_value**
Current alarm value

**Type Definitions**

typedef struct gptimer_t *`gptimer_handle_t`
Type of General Purpose Timer handle.
Chapter 2. API Reference

typedef bool (*gptimer_alarm_cb_t)(gptimer_handle_t timer, const gptimer_alarm_event_data_t *edata, void *user_ctx)

Timer alarm callback prototype.

- **Param timer** [in] Timer handle created by gptimer_new_timer
- **Param edata** [in] Alarm event data, fed by driver
- **Param user_ctx** [in] User data, passed from gptimer_register_event_callbacks
- **Return** Whether a high priority task has been waken up by this function

**Header File**

- components/hal/include/hal/timer_types.h

**Type Definitions**

typedef soc_periph_gptimer_clk_src_t gptimer_clock_source_t

GPTimer clock source.

---

**Note**: User should select the clock source based on the power and resolution requirement

**Enumerations**

enum gptimer_count_direction_t

GPTimer count direction.

**Values**:

- enumerator GPTIMER_COUNT_DOWN
  - Decrease count value
- enumerator GPTIMER_COUNT_UP
  - Increase count value

enum gptimer_etm_task_type_t

GPTimer specific tasks that supported by the ETM module.

**Values**:

- enumerator GPTIMER_ETM_TASK_START_COUNT
  - Start the counter
- enumerator GPTIMER_ETM_TASK_STOP_COUNT
  - Stop the counter
- enumerator GPTIMER_ETM_TASK_EN_ALARM
  - Enable the alarm
- enumerator GPTIMER_ETM_TASK_RELOAD
  - Reload preset value into counter
- enumerator GPTIMER_ETM_TASK_CAPTURE
  - Capture current count value into specific register
Chapter 2. API Reference

enumerator GPTIMER_ETM_TASK_MAX
   Maximum number of tasks

enum gptimer_etm_event_type_t
   GPTimer specific events that supported by the ETM module.
   Values:

enumerator GPTIMER_ETM_EVENT_ALARM_MATCH
   Count value matches the alarm target value

enumerator GPTIMER_ETM_EVENT_MAX
   Maximum number of events

2.6.8 Inter-Integrated Circuit (I2C)

Overview

I2C is a serial, synchronous, half-duplex communication protocol that allows co-existence of multiple masters and slaves on the same bus. The I2C bus consists of two lines: serial data line (SDA) and serial clock (SCL). Both lines require pull-up resistors.

With such advantages as simplicity and low manufacturing cost, I2C is mostly used for communication of low-speed peripheral devices over short distances (within one foot).

ESP32 has 2 I2C controller (also referred to as port), responsible for handling communications on the I2C bus. A single I2C controller can operate as master or slave.

Driver Features

I2C driver governs communications of devices over the I2C bus. The driver supports the following features:

- Reading and writing bytes in Master mode
- Slave mode
- Reading and writing to registers which are in turn read/written by the master

Driver Usage

The following sections describe typical steps of configuring and operating the I2C driver:

1. Configuration - set the initialization parameters (master or slave mode, GPIO pins for SDA and SCL, clock speed, etc.)
2. Install Driver - activate the driver on one of the two I2C controllers as a master or slave
3. Depending on whether you configure the driver for a master or slave, choose the appropriate item
   a) Communication as Master - handle communications (master)
   b) Communication as Slave - respond to messages from the master (slave)
4. Interrupt Handling - configure and service I2C interrupts
5. Customized Configuration - adjust default I2C communication parameters (timings, bit order, etc.)
6. Error Handling - how to recognize and handle driver configuration and communication errors
7. Delete Driver - release resources used by the I2C driver when communication ends
Configuration  To establish I2C communication, start by configuring the driver. This is done by setting the parameters of the structure `i2c_config_t`:

- Set I2C mode of operation - master or slave from `i2c_mode_t`
- Configure communication pins
  - Assign GPIO pins for SDA and SCL signals
  - Set whether to enable ESP32’s internal pull-ups
- `(Master only)` Set I2C clock speed
- `(Slave only)` Configure the following
  - Whether to enable 10 bit address mode
  - Define slave address

After that, initialize the configuration for a given I2C port. For this, call the function `i2c_param_config()` and pass to it the port number and the structure `i2c_config_t`.

Configuration example (master):

```c
int i2c_master_port = 0;
i2c_config_t conf = {
  .mode = I2C_MODE_MASTER,
  .sda_io_num = I2C_MASTER_SDA_IO, // select SDA GPIO specific to your...
  .project
    .sda_pullup_en = GPIO_PULLUP_ENABLE,
    .scl_io_num = I2C_MASTER_SCL_IO, // select SCL GPIO specific to your...
  .project
    .scl_pullup_en = GPIO_PULLUP_ENABLE,
    .master.clk_speed = I2C_MASTER_FREQ_HZ, // select frequency specific to your...
  .project
    .clk_flags = 0, // optional; you can use I2C_SCLK_SRC_*
    .FLAG_* flags to choose i2c source clock here
};
```

Configuration example (slave):

```c
int i2c_slave_port = I2C_SLAVE_NUM;
i2c_config_t conf_slave = {
  .sda_io_num = I2C_SLAVE_SDA_IO, // select SDA GPIO specific to your...
  .project
    .sda_pullup_en = GPIO_PULLUP_ENABLE,
    .scl_io_num = I2C_SLAVE_SCL_IO, // select SCL GPIO specific to your...
  .project
    .scl_pullup_en = GPIO_PULLUP_ENABLE,
    .mode = I2C_MODE_SLAVE,
    .slave.addr_10bit_en = 0,
    .slave.slave_addr = ESP_SLAVE_ADDR, // slave address of your project
    .slave.maximum_speed = I2C_SLAVE_MAX_SPEED // expected maximum clock speed
  .clk_flags = 0, // optional; you can use I2C_SCLK_SRC_*
  .FLAG_* flags to choose i2c source clock here
};
```

At this stage, `i2c_param_config()` also sets a few other I2C configuration parameters to default values that are defined by the I2C specification. For more details on the values and how to modify them, see Customized Configuration.

Source Clock Configuration  Clock sources allocator is added for supporting different clock sources. The clock allocator will choose one clock source that meets all the requirements of frequency and capability (as requested in `i2c_config_t::clk_flags`).

When `i2c_config_t::clk_flags` is 0, the clock allocator will select only according to the desired frequency. If no special capabilities are needed, such as APB, you can configure the clock allocator to select the source clock only according to the desired frequency. For this, set `i2c_config_t::clk_flags` to 0. For clock characteristics, see the table below.
Note: A clock is not a valid option, if it doesn’t meet the requested capabilities, i.e. any bit of requested capabilities (clk_flags) is 0 in the clock’s capabilities.

Table 3: Characteristics of ESP32 clock sources

<table>
<thead>
<tr>
<th>Clock name</th>
<th>Clock frequency</th>
<th>MAX freq for SCL</th>
<th>Clock capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>APB clock</td>
<td>80 MHz</td>
<td>4 MHz</td>
<td>/</td>
</tr>
</tbody>
</table>

Explanations for `i2c_config_t::clk_flags` are as follows:

1. `I2C_SCLK_SRC_FLAG_AWARE_DFS`: Clock’s baud rate will not change while APB clock is changing.
2. `I2C_SCLK_SRC_FLAG_LIGHT_SLEEP`: It supports Light-sleep mode, which APB clock cannot do.
3. Some flags may not be supported on ESP32, reading technical reference manual before using it.

Note: The clock frequency of SCL in master mode should not be larger than max frequency for SCL mentioned in the table above.

Note: The clock frequency of SCL will be influenced by the pull-up resistors and wire capacitance (or might slave capacitance) together. Therefore, users need to choose correct pull-up resistors by themselves to make the frequency accurate. It is recommended by I2C protocol that the pull-up resistors commonly range from 1KOhms to 10KOhms, but different frequencies need different resistors.

Generally speaking, the higher frequency is selected, the smaller resistor should be used (but not less than 1KOhms). This is because high resistor will decline the current, which will lengthen the rising time and reduce the frequency. Usually, range 2KOhms to 5KOhms is what we recommend, but users also might need to make some adjustment depends on their reality.

Install Driver  After the I2C driver is configured, install it by calling the function `i2c_driver_install()` with the following parameters:

- Port number, one of the two port numbers from `i2c_port_t`
- master or slave, selected from `i2c_mode_t`
- (Slave only) Size of buffers to allocate for sending and receiving data. As I2C is a master-centric bus, data can only go from the slave to the master at the master’s request. Therefore, the slave will usually have a send buffer where the slave application writes data. The data remains in the send buffer to be read by the master at the master’s own discretion.
- Flags for allocating the interrupt (see `ESP_INTR_FLAG_*` values in `esp_hw_support/include/esp_intr_alloc.h`)

Communication as Master  After installing the I2C driver, ESP32 is ready to communicate with other I2C devices. ESP32’s I2C controller operating as master is responsible for establishing communication with I2C slave devices and sending commands to trigger a slave to action, for example, to take a measurement and send the readings back to the master.

For better process organization, the driver provides a container, called a “command link”, that should be populated with a sequence of commands and then passed to the I2C controller for execution.
Master Write The example below shows how to build a command link for an I2C master to send \( n \) bytes to a slave.

The following describes how a command link for a “master write” is set up and what comes inside:

1. Create a command link with \texttt{i2c\_cmd\_link\_create()}. Then, populate it with the series of data to be sent to the slave:
   a) Start bit - \texttt{i2c\_master\_start()}
   b) Slave address - \texttt{i2c\_master\_write\_byte()} The single byte address is provided as an argument of this function call.
   c) Data - One or more bytes as an argument of \texttt{i2c\_master\_write()} 
   d) Stop bit - \texttt{i2c\_master\_stop()}

2. Trigger the execution of the command link by I2C controller by calling \texttt{i2c\_master\_cmd\_begin()}

3. After the commands are transmitted, release the resources used by the command link by calling \texttt{i2c\_cmd\_link\_delete()}

Master Read The example below shows how to build a command link for an I2C master to read \( n \) bytes from a slave.

Compared to writing data, the command link is populated in Step 4 not with \texttt{i2c\_master\_write...} functions but with \texttt{i2c\_master\_read\_byte()} and/or \texttt{i2c\_master\_read()}. Also, the last read in Step 5 is configured so that the master does not provide the ACK bit.

Indicating Write or Read After sending a slave address (see Step 3 on both diagrams above), the master either writes or reads from the slave.

The information on what the master will actually do is hidden in the least significant bit of the slave’s address.

For this reason, the command link sent by the master to write data to the slave contains the address \((\text{ESP\_SLAVE\_ADDR} << 1) \mid \text{I2C\_MASTER\_WRITE})\) and looks as follows:

\[
i2c\_master\_write\_byte(cmd, (\text{ESP\_SLAVE\_ADDR} << 1) \mid \text{I2C\_MASTER\_WRITE, ACK\_EN});
\]

Likewise, the command link to read from the slave looks as follows:
Fig. 9: I2C command link - master read example

```c
i2c_master_write_byte(cmd, (ESP_SLAVE_ADDR << 1) | I2C_MASTER_READ, ACK_EN);
```

**Communication as Slave** After installing the I2C driver, ESP32 is ready to communicate with other I2C devices.

The API provides the following functions for slaves:

- **`i2c_slave_read_buffer()`**
  Whenever the master writes data to the slave, the slave will automatically store it in the receive buffer. This allows the slave application to call the function `i2c_slave_read_buffer()` at its own discretion. This function also has a parameter to specify block time if no data is in the receive buffer. This will allow the slave application to wait with a specified timeout for data to arrive to the buffer.

- **`i2c_slave_write_buffer()`**
  The send buffer is used to store all the data that the slave wants to send to the master in FIFO order. The data stays there until the master requests for it. The function `i2c_slave_write_buffer()` has a parameter to specify block time if the send buffer is full. This will allow the slave application to wait with a specified timeout for the adequate amount of space to become available in the send buffer.

A code example showing how to use these functions can be found in `peripherals/i2c`.

**Interrupt Handling** During driver installation, an interrupt handler is installed by default.

**Customized Configuration** As mentioned at the end of Section **Configuration**, when the function `i2c_param_config()` initializes the driver configuration for an I2C port, it also sets several I2C communication parameters to default values defined in the I2C specification. Some other related parameters are pre-configured in registers of the I2C controller.

All these parameters can be changed to user-defined values by calling dedicated functions given in the table below. Please note that the timing values are defined in APB clock cycles.
Table 4: Other Configurable I2C Communication Parameters

<table>
<thead>
<tr>
<th>Parameters to Change</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>High time and low time for SCL pulses</td>
<td><code>i2c_set_period()</code></td>
</tr>
<tr>
<td>SCL and SDA signal timing used during generation of <strong>start</strong> signals</td>
<td><code>i2c_set_start_timing()</code></td>
</tr>
<tr>
<td>SCL and SDA signal timing used during generation of <strong>stop</strong> signals</td>
<td><code>i2c_set_stop_timing()</code></td>
</tr>
<tr>
<td>Timing relationship between SCL and SDA signals when slave samples, as well as when master toggles</td>
<td><code>i2c_set_data_timing()</code></td>
</tr>
<tr>
<td>I2C timeout</td>
<td><code>i2c_set_timeout()</code></td>
</tr>
<tr>
<td>Choice between transmitting / receiving the LSB or MSB first, choose one of the modes defined in <code>i2c_trans_mode_t</code></td>
<td><code>i2c_set_data_mode()</code></td>
</tr>
</tbody>
</table>

Each of the above functions has a _get_ counterpart to check the currently set value. For example, to check the I2C timeout value, call `i2c_get_timeout()`.

To check the default parameter values which are set during the driver configuration process, please refer to the file `driver/i2c/i2c.c` and look for defines with the suffix `_DEFAULT`.

You can also select different pins for SDA and SCL signals and alter the configuration of pull-ups with the function `i2c_set_pin()`. If you want to modify already entered values, use the function `i2c_param_config()`.

**Note:** ESP32’s internal pull-ups are in the range of tens of kOhm, which is, in most cases, insufficient for use as I2C pull-ups. Users are advised to use external pull-ups with values described in the I2C specification. For help with calculating the resistor values see TI Application Note

**Error Handling** The majority of I2C driver functions either return ESP_OK on successful completion or a specific error code on failure. It is a good practice to always check the returned values and implement error handling. The driver also prints out log messages that contain error details, e.g., when checking the validity of entered configuration. For details please refer to the file `driver/i2c/i2c.c` and look for defines with the suffix _ERR_STR.

Use dedicated interrupts to capture communication failures. For instance, if a slave stretches the clock for too long while preparing the data to send back to master, the interrupt I2C_TIME_OUT_INT will be triggered. For detailed information, see Interrupt Handling.

In case of a communication failure, you can reset the internal hardware buffers by calling the functions `i2c_reset_tx_fifo()` and `i2c_reset_rx_fifo()` for the send and receive buffers respectively.

**Delete Driver** When the I2C communication is established with the function `i2c_driver_install()` and is not required for some substantial amount of time, the driver may be deinitialized to release allocated resources by calling `i2c_driver_delete()`.

Before calling `i2c_driver_delete()` to remove i2c driver, please make sure that all threads have stopped using the driver in any way, because this function does not guarantee thread safety.

**Application Example**

I2C examples: `peripherals/i2c`.

**API Reference**

**Header File**

- components/driver/i2c/include/driver/i2c.h
Functions

`esp_err_t i2c_driver_install(i2c_port_t i2c_num, i2c_mode_t mode, size_t slv_rx_buf_len, size_t slv_tx_buf_len, int intr_alloc_flags)`

Install an I2C driver.

**Note:** Not all Espressif chips can support slave mode (e.g. ESP32C2)

**Note:** In master mode, if the cache is likely to be disabled (such as write flash) and the slave is time-sensitive, `ESP_INTR_FLAG_IRAM` is suggested to be used. In this case, please use the memory allocated from internal RAM in i2c read and write function, because we can not access the psram (if psram is enabled) in interrupt handle function when cache is disabled.

**Parameters**
- *i2c_num* - I2C port number
- *mode* - I2C mode (either master or slave).
- *slv_rx_buf_len* - Receiving buffer size. Only slave mode will use this value, it is ignored in master mode.
- *slv_tx_buf_len* - Sending buffer size. Only slave mode will use this value, it is ignored in master mode.
- *intr_alloc_flags* - Flags used to allocate the interrupt. One or multiple (ORred) `ESP_INTR_FLAG_*` values. See `esp_intr_alloc.h` for more info.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Driver installation error

`esp_err_t i2c_driver_delete(i2c_port_t i2c_num)`

Delete I2C driver.

**Note:** This function does not guarantee thread safety. Please make sure that no thread will continuously hold semaphores before calling the delete function.

**Parameters**
- *i2c_num* - I2C port to delete

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_param_config(i2c_port_t i2c_num, const i2c_config_t *i2c_conf)`

Configure an I2C bus with the given configuration.

**Parameters**
- *i2c_num* - I2C port to configure
- *i2c_conf* - Pointer to the I2C configuration

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_reset_tx_fifo(i2c_port_t i2c_num)`

Reset I2C tx hardware fifo

**Parameters**
- *i2c_num* - I2C port number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
Chapter 2. API Reference

```c
esp_err_t i2c_reset_rx_fifo(i2c_port_t i2c_num)
reset I2C rx fifo
```

**Parameters**
- `i2c_num` - I2C port number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_set_pin(i2c_port_t i2c_num, int sda_io_num, int scl_io_num, bool sda_pullup_en, bool scl_pullup_en, i2c_mode_t mode)
Configure GPIO pins for I2C SCK and SDA signals.
```

**Parameters**
- `i2c_num` - I2C port number
- `sda_io_num` - GPIO number for I2C SDA signal
- `scl_io_num` - GPIO number for I2C SCL signal
- `sda_pullup_en` - Enable the internal pullup for SDA pin
- `scl_pullup_en` - Enable the internal pullup for SCL pin
- `mode` - I2C mode

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_master_write_to_device(i2c_port_t i2c_num, uint8_t device_address, const uint8_t *write_buffer, size_t write_size, TickType_t ticks_to_wait)
Perform a write to a device connected to a particular I2C port. This function is a wrapper to i2c_master_start(), i2c_master_write(), i2c_master_read(), etc... It shall only be called in I2C master mode.
```

**Parameters**
- `i2c_num` - I2C port number to perform the transfer on
- `device_address` - I2C device’s 7-bit address
- `write_buffer` - Bytes to send on the bus
- `write_size` - Size, in bytes, of the write buffer
- `ticks_to_wait` - Maximum ticks to wait before issuing a timeout.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Sending command error, slave hasn’t ACK the transfer.
- ESP_ERR_INVALID_STATE I2C driver not installed or not in master mode.
- ESP_ERR_TIMEOUT Operation timeout because the bus is busy.

```c
esp_err_t i2c_master_read_from_device(i2c_port_t i2c_num, uint8_t device_address, uint8_t *read_buffer, size_t read_size, TickType_t ticks_to_wait)
Perform a read to a device connected to a particular I2C port. This function is a wrapper to i2c_master_start(), i2c_master_write(), i2c_master_read(), etc... It shall only be called in I2C master mode.
```

**Parameters**
- `i2c_num` - I2C port number to perform the transfer on
- `device_address` - I2C device’s 7-bit address
- `read_buffer` - Buffer to store the bytes received on the bus
- `read_size` - Size, in bytes, of the read buffer
- `ticks_to_wait` - Maximum ticks to wait before issuing a timeout.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Sending command error, slave hasn’t ACK the transfer.
- ESP_ERR_INVALID_STATE I2C driver not installed or not in master mode.
- ESP_ERR_TIMEOUT Operation timeout because the bus is busy.
**esp_err_t i2c_master_write_read_device** *(i2c_port_t i2c_num, uint8_t device_address, const uint8_t *write_buffer, size_t write_size, uint8_t *read_buffer, size_t read_size, TickType_t ticks_to_wait)*

Perform a write followed by a read to a device on the I2C bus. A repeated start signal is used between the write and read, thus, the bus is not released until the two transactions are finished. This function is a wrapper to `i2c_master_start()`, `i2c_master_write()`, `i2c_master_read()`, etc... It shall only be called in I2C master mode.

**Parameters**
- `i2c_num` - I2C port number to perform the transfer on
- `device_address` - I2C device’s 7-bit address
- `write_buffer` - Bytes to send on the bus
- `write_size` - Size, in bytes, of the write buffer
- `read_buffer` - Buffer to store the bytes received on the bus
- `read_size` - Size, in bytes, of the read buffer
- `ticks_to_wait` - Maximum ticks to wait before issuing a timeout.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Sending command error, slave hasn’t ACK the transfer.
- ESP_ERR_INVALID_STATE I2C driver not installed or not in master mode.
- ESP_ERR_TIMEOUT Operation timeout because the bus is busy.

**i2c_cmd_handle_t i2c_cmd_link_create_static** *(uint8_t *buffer, uint32_t size)*

Create and initialize an I2C commands list with a given buffer. All the allocations for data or signals (START, STOP, ACK, ...) will be performed within this buffer. This buffer must be valid during the whole transaction. After finishing the I2C transactions, it is required to call `i2c_cmd_link_delete_static()`.

**Note:** It is highly advised not to allocate this buffer on the stack. The size of the data used underneath may increase in the future, resulting in a possible stack overflow as the macro `I2C_LINK_RECOMMENDED_SIZE` would also return a bigger value. A better option is to use a buffer allocated statically or dynamically (with `malloc`).

**Parameters**
- `buffer` - Buffer to use for commands allocations
- `size` - Size in bytes of the buffer

**Returns** Handle to the I2C command link or NULL if the buffer provided is too small, please use `I2C_LINK_RECOMMENDED_SIZE` macro to get the recommended size for the buffer.

**i2c_cmd_handle_t i2c_cmd_link_create** *(void)*

Create and initialize an I2C commands list with a given buffer. After finishing the I2C transactions, it is required to call `i2c_cmd_link_delete()` to release and return the resources. The required bytes will be dynamically allocated.

**Returns** Handle to the I2C command link or NULL in case of insufficient dynamic memory.

**void i2c_cmd_link_delete_static** *(i2c_cmd_handle_t cmd_handle)*

Free the I2C commands list allocated statically with `i2c_cmd_link_create_static`.

**Parameters**
- `cmd_handle` - I2C commands list allocated statically. This handle should be created thanks to `i2c_cmd_link_create_static()` function

**void i2c_cmd_link_delete** *(i2c_cmd_handle_t cmd_handle)*

Free the I2C commands list.

**Parameters**
- `cmd_handle` - I2C commands list. This handle should be created thanks to `i2c_cmd_link_create()` function
**esp_err_t i2c_master_start (i2c_cmd_handle_t cmd_handle)**

Queue a “START signal” to the given commands list. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all the queued commands.

**Parameters**
- `cmd_handle` - I2C commands list

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM The static buffer used to create `cmd_handler` is too small
- ESP_FAIL No more memory left on the heap

**esp_err_t i2c_master_write_byte (i2c_cmd_handle_t cmd_handle, uint8_t data, bool ack_en)**

Queue a “write byte” command to the commands list. A single byte will be sent on the I2C port. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all queued commands.

**Parameters**
- `cmd_handle` - I2C commands list
- `data` - Byte to send on the port
- `ack_en` - Enable ACK signal

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM The static buffer used to create `cmd_handler` is too small
- ESP_FAIL No more memory left on the heap

**esp_err_t i2c_master_write (i2c_cmd_handle_t cmd_handle, const uint8_t *data, size_t data_len, bool ack_en)**

Queue a “write (multiple) bytes” command to the commands list. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all queued commands.

**Parameters**
- `cmd_handle` - I2C commands list
- `data` - Bytes to send. This buffer shall remain valid until the transaction is finished. If the PSRAM is enabled and `intr_flag` is set to ESP_INTR_FLAG_IRAM, `data` should be allocated from internal RAM.
- `data_len` - Length, in bytes, of the data buffer
- `ack_en` - Enable ACK signal

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM The static buffer used to create `cmd_handler` is too small
- ESP_FAIL No more memory left on the heap

**esp_err_t i2c_master_read_byte (i2c_cmd_handle_t cmd_handle, uint8_t *data, i2c_ack_type_t ack)**

Queue a “read byte” command to the commands list. A single byte will be read on the I2C bus. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all queued commands.

**Parameters**
- `cmd_handle` - I2C commands list
- `data` - Pointer where the received byte will be stored. This buffer shall remain valid until the transaction is finished.
- `ack` - ACK signal

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM The static buffer used to create `cmd_handler` is too small
- ESP_FAIL No more memory left on the heap

**esp_err_t i2c_master_read (i2c_cmd_handle_t cmd_handle, uint8_t *data, size_t data_len, i2c_ack_type_t ack)**

Queue a “read (multiple) bytes” command to the commands list. Multiple bytes will be read on the I2C bus.
bus. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all queued commands.

**Parameters**
- `cmd_handle` - I2C commands list
- `data` - Pointer where the received bytes will be stored. This buffer shall remain valid until the transaction is finished.
- `data_len` - Size, in bytes, of the data buffer
- `ack` - ACK signal

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM The static buffer used to create `cmd_handler` is too small
- ESP_FAIL No more memory left on the heap

```c
esp_err_t i2c_master_stop(i2c_cmd_handle_t cmd_handle)
```
Queue a “STOP signal” to the given commands list. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all the queued commands.

**Parameters**
- `cmd_handle` - I2C commands list

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM The static buffer used to create `cmd_handler` is too small
- ESP_FAIL No more memory left on the heap

```c
esp_err_t i2c_master_cmd_begin(i2c_port_t i2c_num, i2c_cmd_handle_t cmd_handle, TickType_t ticks_to_wait)
```
Send all the queued commands on the I2C bus, in master mode. The task will be blocked until all the commands have been sent out. The I2C port is protected by mutex, so this function is thread-safe. This function shall only be called in I2C master mode.

**Parameters**
- `i2c_num` - I2C port number
- `cmd_handle` - I2C commands list
- `ticks_to_wait` - Maximum ticks to wait before issuing a timeout.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Sending command error, slave hasn’t ACK the transfer.
- ESP_ERR_INVALID_STATE I2C driver not installed or not in master mode.
- ESP_ERR_TIMEOUT Operation timeout because the bus is busy.

```c
int i2c_slave_write_buffer(i2c_port_t i2c_num, const uint8_t *data, int size, TickType_t ticks_to_wait)
```
Write bytes to internal ringbuffer of the I2C slave data. When the TX fifo empty, the ISR will fill the hardware FIFO with the internal ringbuffer’s data.

**Note:** This function shall only be called in I2C slave mode.

**Parameters**
- `i2c_num` - I2C port number
- `data` - Bytes to write into internal buffer
- `size` - Size, in bytes, of data buffer
- `ticks_to_wait` - Maximum ticks to wait.

**Returns**
- ESP_FAIL (-1) Parameter error
- Other (>=0) The number of data bytes pushed to the I2C slave buffer.
Chapter 2. API Reference

```c
int i2c_slave_read_buffer(i2c_port_t i2c_num, uint8_t* data, size_t max_size, TickType_t ticks_to_wait)
```

Read bytes from I2C internal buffer. When the I2C bus receives data, the ISR will copy them from the hardware RX FIFO to the internal ringbuffer. Calling this function will then copy bytes from the internal ringbuffer to the data user buffer.

**Note:** This function shall only be called in I2C slave mode.

**Parameters**
- **i2c_num** – I2C port number
- **data** – Buffer to fill with ringbuffer’s bytes
- **max_size** – Maximum bytes to read
- **ticks_to_wait** – Maximum waiting ticks

**Returns**
- ESP_FAIL(-1) Parameter error
- Others(>=0) The number of data bytes read from I2C slave buffer.

```c
esp_err_t i2c_set_period(i2c_port_t i2c_num, int high_period, int low_period)
```

Set I2C master clock period.

**Parameters**
- **i2c_num** – I2C port number
- **high_period** – Clock cycle number during SCL is high level, high_period is a 14 bit value
- **low_period** – Clock cycle number during SCL is low level, low_period is a 14 bit value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_get_period(i2c_port_t i2c_num, int* high_period, int* low_period)
```

Get I2C master clock period.

**Parameters**
- **i2c_num** – I2C port number
- **high_period** – pointer to get clock cycle number during SCL is high level, will get a 14 bit value
- **low_period** – pointer to get clock cycle number during SCL is low level, will get a 14 bit value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_filter_enable(i2c_port_t i2c_num, uint8_t cyc_num)
```

Enable hardware filter on I2C bus. Sometimes the I2C bus is disturbed by high frequency noise (about 20ns), or the rising edge of the SCL clock is very slow, these may cause the master state machine to break. Enable hardware filter can filter out high frequency interference and make the master more stable.

**Note:** Enable filter will slow down the SCL clock.

**Parameters**
- **i2c_num** – I2C port number to filter
- **cyc_num** – the APB cycles need to be filtered (0<= cyc_num <=7). When the period of a pulse is less than cyc_num * APB_cycle, the I2C controller will ignore this pulse.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
`esp_err_t i2c_filter_disable(i2c_port_t i2c_num)`
Disable filter on I2C bus.

**Parameters**
- **i2c_num** — I2C port number

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_set_start_timing(i2c_port_t i2c_num, int setup_time, int hold_time)`
set I2C master start signal timing

**Parameters**
- **i2c_num** — I2C port number
- **setup_time** — clock number between the falling-edge of SDA and rising-edge of SCL for start mark, it’s a 10-bit value.
- **hold_time** — clock number between the falling-edge of SDA and falling-edge of SCL for start mark, it’s a 10-bit value.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_get_start_timing(i2c_port_t i2c_num, int *setup_time, int *hold_time)`
get I2C master start signal timing

**Parameters**
- **i2c_num** — I2C port number
- **setup_time** — pointer to get setup time
- **hold_time** — pointer to get hold time

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_set_stop_timing(i2c_port_t i2c_num, int setup_time, int hold_time)`
set I2C master stop signal timing

**Parameters**
- **i2c_num** — I2C port number
- **setup_time** — clock number between the rising-edge of SCL and the rising-edge of SDA, it’s a 10-bit value.
- **hold_time** — clock number after the STOP bit’s rising-edge, it’s a 14-bit value.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_get_stop_timing(i2c_port_t i2c_num, int *setup_time, int *hold_time)`
get I2C master stop signal timing

**Parameters**
- **i2c_num** — I2C port number
- **setup_time** — pointer to get setup.
- **hold_time** — pointer to get hold time.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t i2c_set_data_timing(i2c_port_t i2c_num, int sample_time, int hold_time)`
set I2C data signal timing

**Parameters**
- **i2c_num** — I2C port number
- **sample_time** — clock number I2C used to sample data on SDA after the rising-edge of SCL, it’s a 10-bit value.
Chapter 2. API Reference

- **hold_time** – clock number I2C used to hold the data after the falling-edge of SCL, it’s a 10-bit value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_get_data_timing(i2c_port_t i2c_num, int *sample_time, int *hold_time)
```

get I2C data signal timing

**Parameters**
- **i2c_num** – I2C port number
- **sample_time** – pointer to get sample time
- **hold_time** – pointer to get hold time

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_set_timeout(i2c_port_t i2c_num, int timeout)
```

set I2C timeout value

**Parameters**
- **i2c_num** – I2C port number
- **timeout** – timeout value for I2C bus (unit: APB 80Mhz clock cycle)

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_get_timeout(i2c_port_t i2c_num, int *timeout)
```

get I2C timeout value

**Parameters**
- **i2c_num** – I2C port number
- **timeout** – pointer to get timeout value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_set_data_mode(i2c_port_t i2c_num, i2c_trans_mode_t tx_trans_mode, i2c_trans_mode_t rx_trans_mode)
```

set I2C data transfer mode

**Parameters**
- **i2c_num** – I2C port number
- **tx_trans_mode** – I2C sending data mode
- **rx_trans_mode** – I2C receiving data mode

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2c_get_data_mode(i2c_port_t i2c_num, i2c_trans_mode_t *tx_trans_mode, i2c_trans_mode_t *rx_trans_mode)
```

get I2C data transfer mode

**Parameters**
- **i2c_num** – I2C port number
- **tx_trans_mode** – pointer to get I2C sending data mode
- **rx_trans_mode** – pointer to get I2C receiving data mode

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
Structures

struct i2c_config_t
I2C initialization parameters.

Public Members

i2c_mode_t mode
I2C mode

int sda_io_num
GPIO number for I2C sda signal

int scl_io_num
GPIO number for I2C scl signal

bool sda_pullup_en
Internal GPIO pull mode for I2C sda signal

bool scl_pullup_en
Internal GPIO pull mode for I2C scl signal

uint32_t clk_speed
I2C clock frequency for master mode, (no higher than 1MHz for now)

struct i2c_config_t::[anonymous]::[anonymous] master
I2C master config

uint8_t addr_10bit_en
I2C 10bit address mode enable for slave mode

uint16_t slave_addr
I2C address for slave mode

uint32_t maximum_speed
I2C expected clock speed from SCL.

struct i2c_config_t::[anonymous]::[anonymous] slave
I2C slave config

uint32_t clk_flags
Bitwise of I2C_SCLK_SRC_FLAG_*FOR_DFS* for clk source choice

Macros

I2C_APB_CLK_FREQ
I2C source clock is APB clock, 80MHz, deprecated

I2C_SCLK_SRC_FLAG_FOR_NOMAL
Any one clock source that is available for the specified frequency may be choosen
**I2C_SCLK_SRC_FLAG_AWARE_DFS**
For REF tick clock, it won’t change with APB.

**I2C_SCLK_SRC_FLAG_LIGHT_SLEEP**
For light sleep mode.

**I2C_INTERNAL_STRUCT_SIZE**
Minimum size, in bytes, of the internal private structure used to describe I2C commands link.

**I2C_LINK_RECOMMENDED_SIZE** (TRANSACTIONS)
The following macro is used to determine the recommended size of the buffer to pass to `i2c_cmd_link_create_static()` function. It requires one parameter, TRANSACTIONS, describing the number of transactions intended to be performed on the I2C port. For example, if one wants to perform a read on an I2C device register, TRANSACTIONS must be at least 2, because the commands required are the following:

- write device register
- read register content

Signals such as “(repeated) start”, “stop”, “nack”, “ack” shall not be counted.

**Type Definitions**

```c
typedef void *i2c_cmd_handle_t
I2C command handle
```

**Header File**

- `components/hal/include/hal/i2c_types.h`

**Structures**

```c
struct i2c_hal_clk_config_t
Data structure for calculating I2C bus timing.
```

**Public Members**

```c
uint16_t clkm_div
I2C core clock devider
```

```c
uint16_t scl_low
I2C scl low period
```

```c
uint16_t scl_high
I2C scl high period
```

```c
uint16_t scl_wait_high
I2C scl wait_high period
```
uint16_t \texttt{sda\_hold}
\quad I2C sda hold period

uint16_t \texttt{sda\_sample}
\quad I2C sda sample time

uint16_t \texttt{setup}
\quad I2C start and stop condition setup period

uint16_t \texttt{hold}
\quad I2C start and stop condition hold period

uint16_t \texttt{tout}
\quad I2C bus timeout period

\begin{Verbatim}
\textbf{struct} \texttt{i2c\_hal\_timing\_config\_t}
\end{Verbatim}
\quad Timing configuration structure. Used for I2C reset internally.

\section*{Public Members}

\begin{itemize}
\item \texttt{int high\_period}
\quad high\_period time
\item \texttt{int low\_period}
\quad low\_period time
\item \texttt{int wait\_high\_period}
\quad wait\_high\_period time
\item \texttt{int rstart\_setup}
\quad restart setup
\item \texttt{int start\_hold}
\quad start hold time
\item \texttt{int stop\_setup}
\quad stop setup
\item \texttt{int stop\_hold}
\quad stop hold time
\item \texttt{int sda\_sample}
\quad high\_period time
\item \texttt{int sda\_hold}
\quad sda hold time
\item \texttt{int timeout}
\quad timeout value
\end{itemize}
Type Definitions

typedef `soc_periph_i2c_clk_src_t` `i2c_clock_source_t`
I2C group clock source.

Enumerations

enum `i2c_port_t`
I2C port number, can be `I2C_NUM_0` ~ `I2C_NUM_MAX-1`.
Values:

enumerator `I2C_NUM_0`
I2C port 0

enumerator `I2C_NUM_1`
I2C port 1

enumerator `I2C_NUM_MAX`
I2C port max

enum `i2c_mode_t`
Values:

enumerator `I2C_MODE_SLAVE`
I2C slave mode

enumerator `I2C_MODE_MASTER`
I2C master mode

enumerator `I2C_MODE_MAX`

enum `i2c_rw_t`
Values:

enumerator `I2C_MASTER_WRITE`
I2C write data

enumerator `I2C_MASTER_READ`
I2C read data

enum `i2c_trans_mode_t`
Values:

enumerator `I2C_DATA_MODE_MSB_FIRST`
I2C data msb first

enumerator `I2C_DATA_MODE_LSB_FIRST`
I2C data lsb first

enumerator `I2C_DATA_MODE_MAX`
enum i2c_addr_mode_t

Values:

enumerator I2C_ADDR_BIT_7
I2C 7bit address for slave mode

enumerator I2C_ADDR_BIT_10
I2C 10bit address for slave mode

enumerator I2C_ADDR_BIT_MAX

enum i2c_ack_type_t

Values:

enumerator I2C_MASTER_ACK
I2C ack for each byte read

enumerator I2C_MASTER_NACK
I2C nack for each byte read

enumerator I2C_MASTER_LAST_NACK
I2C nack for the last byte

enumerator I2C_MASTER_ACK_MAX

2.6.9 Inter-IC Sound (I2S)

Introduction

I2S (Inter-IC Sound) is a synchronous serial communication protocol usually used for transmitting audio data between two digital audio devices.

ESP32 contains two I2S peripheral(s). These peripherals can be configured to input and output sample data via the I2S driver.

An I2S bus that communicates in standard or TDM mode consists of the following lines:

- MCLK: Master clock line. It is an optional signal depending on the slave side, mainly used for offering a reference clock to the I2S slave device.
- BCLK: Bit clock line. The bit clock for data line.
- WS: Word (Slot) select line. It is usually used to identify the vocal tract except PDM mode.
- DIN/DOUT: Serial data input/output line. Data will loopback internally if DIN and DOUT are set to a same GPIO.

An I2S bus that communicates in PDM mode consists of the following lines:

- CLK: PDM clock line.
- DIN/DOUT: Serial data input/output line.

Each I2S controller has the following features that can be configured by the I2S driver:

- Operation as system master or slave
- Capable of acting as transmitter or receiver
• DMA controller that allows stream sampling of data without requiring the CPU to copy each data sample. Each controller supports single RX or TX simplex communication. As RX and TX channels share a clock, they can only be combined with the same configuration to establish a full-duplex communication.

I2S File Structure

![I2S File Structure Diagram]

**Public headers that need to be included in the I2S application are as follows:**

- `i2s.h`: The header file that provides legacy I2S APIs (for apps using legacy driver).
- `i2s_std.h`: The header file that provides standard communication mode specific APIs (for apps using new driver with standard mode).
- `i2s_pdm.h`: The header file that provides PDM communication mode specific APIs (for apps using new driver with PDM mode).
- `i2s_tdm.h`: The header file that provides TDM communication mode specific APIs (for apps using new driver with TDM mode).

**Note:** The legacy driver cannot coexist with the new driver. Include `i2s.h` to use the legacy driver, or include the other three headers to use the new driver. The legacy driver might be removed in future.

**Public headers that have been included in the headers above are as follows:**

- `i2s_types_legacy.h`: The header file that provides legacy public types that are only used in the legacy driver.
- `i2s_types.h`: The header file that provides public types.
- `i2s_common.h`: The header file that provides common APIs for all communication modes.

I2S Clock

**Clock Source**

- `i2s_clock_src_t::I2S_CLK_SRC_DEFAULT`: Default PLL clock.
- `i2s_clock_src_t::I2S_CLK_SRC_PLL_160M`: 160 MHz PLL clock.
• **i2s_clock_src_t::I2S_CLK_SRC_APLL**: Audio PLL clock, which is more precise than I2S_CLK_SRC_PLL_160M in high sample rate applications. Its frequency is configurable according to the sample rate. However, if APLL has been occupied by EMAC or other channels, the APLL frequency cannot be changed, and the driver will try to work under this APLL frequency. If this frequency cannot meet the requirements of I2S, the clock configuration will fail.

### Clock Terminology

- **Sample rate**: The number of sampled data in one second per slot.
- **SCLK**: Source clock frequency. It is the frequency of the clock source.
- **MCLK**: Master clock frequency. BCLK is generated from this clock. The MCLK signal usually serves as a reference clock and is mostly needed to synchronize BCLK and WS between I2S master and slave roles.
- **BCLK**: Bit clock frequency. Every tick of this clock stands for one data bit on data pin. The slot bit width configured in `i2s_std_slot_config_t::slot_bit_width` is equal to the number of BCLK ticks, which means there will be 8/16/24/32 BCLK ticks in one slot.
- **LRCK / WS**: Left/right clock or word select clock. For non-PDM mode, its frequency is equal to the sample rate.

**Note:** Normally, MCLK should be the multiple of sample rate and BCLK at the same time. The field `i2s_std_clk_config_t::mclk_multiple` indicates the multiple of MCLK to the sample rate. In most cases, I2S_MCLK_MULTIPLE_256 should be enough. However, if `slot_bit_width` is set to I2S_SLOT_BIT_WIDTH_24BIT, to keep MCLK a multiple to the BCLK, `i2s_std_clk_config_t::mclk_multiple` should be set to multiples that are divisible by 3 such as I2S_MCLK_MULTIPLE_384. Otherwise, WS will be inaccurate.

### I2S Communication Mode

#### Overview of All Modes

<table>
<thead>
<tr>
<th>Target</th>
<th>Standard</th>
<th>PDM TX</th>
<th>PDM RX</th>
<th>TDM</th>
<th>ADC/DAC</th>
<th>LCD/Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32</td>
<td>I2S 0/1</td>
<td>I2S 0</td>
<td>I2S 0</td>
<td>none</td>
<td>I2S 0</td>
<td>I2S 0</td>
</tr>
<tr>
<td>ESP32-S2</td>
<td>I2S 0</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>I2S 0</td>
</tr>
<tr>
<td>ESP32-C3</td>
<td>I2S 0</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>ESP32-C6</td>
<td>I2S 0</td>
<td>none</td>
<td>none</td>
<td>I2S 0</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>ESP32-S3</td>
<td>I2S 0/1</td>
<td>I2S 0</td>
<td>I2S 0</td>
<td>I2S 0/1</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>ESP32-H2</td>
<td>I2S 0</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
</tbody>
</table>

**Standard Mode** In standard mode, there are always two sound channels, i.e., the left and right channels, which are called “slots”. These slots support 8/16/24/32-bit width sample data. The communication format for the slots mainly includes the followings:

- **Philips Format**: Data signal has one-bit shift comparing to the WS signal, and the duty of WS signal is 50%.
• **MSB Format**: Basically the same as Philips format, but without data shift.

![Standard MSB Timing Diagram](image)

• **PCM Short Format**: Data has one-bit shift and meanwhile the WS signal becomes a pulse lasting for one BCLK cycle.

![Standard PCM Timing Diagram](image)

**PDM Mode (TX)**  PDM (Pulse-density Modulation) mode for the TX channel can convert PCM data into PDM format which always has left and right slots. PDM TX is only supported on I2S0 and it only supports 16-bit width sample data. It needs at least a CLK pin for clock signal and a DOUT pin for data signal (i.e., the WS and SD signal in the following figure; the BCK signal is an internal bit sampling clock, which is not needed between PDM devices). This mode allows users to configure the up-sampling parameters `i2s_pdm_tx_clk_config_t::up_sample_fp` and `i2s_pdm_tx_clk_config_t::up_sample_fs`. The up-sampling rate can be calculated by $\text{up\_sample\_rate} = \frac{i2s_pdm_tx_clk_config_t::up\_sample\_fp}{i2s_pdm_tx_clk_config_t::up\_sample\_fs}$. There are two up-sampling modes in PDM TX:

- **Fixed Clock Frequency**: In this mode, the up-sampling rate changes according to the sample rate. Setting $fp = 960$ and $fs = \text{sample\_rate} / 100$, then the clock frequency (Fpdm) on CLK pin will be fixed to $128 \times 48 \text{ KHz} = 6.144 \text{ MHz}$. Note that this frequency is not equal to the sample rate (Fpcm).
- **Fixed Up-sampling Rate**: In this mode, the up-sampling rate is fixed to 2. Setting $fp = 960$ and $fs = 480$, then the clock frequency (Fpdm) on CLK pin will be $128 \times \text{sample\_rate}$.

![PDM Timing Diagram](image)

**PDM Mode (RX)**  PDM (Pulse-density Modulation) mode for RX channel can receive PDM-format data and convert the data into PCM format. PDM RX is only supported on I2S0, and it only supports 16-bit width sample data. PDM RX needs at least a CLK pin for clock signal and a DIN pin for data signal. This mode allows users to
Chapter 2.  API Reference

configure the down-sampling parameter `i2s_pdm_rx_clk_config_t::dn_sample_mode`. There are two down-sampling modes in PDM RX:

- `i2s_pdm_dsr_t::I2S_PDM_DSR_8S`: In this mode, the clock frequency (Fpdm) on the WS pin is `sample_rate (Fpcm) * 64`.
- `i2s_pdm_dsr_t::I2S_PDM_DSR_16S`: In this mode, the clock frequency (Fpdm) on the WS pin is `sample_rate (Fpcm) * 128`.

**LCD/Camera Mode**  
LCD/Camera mode is only supported on I2S0 over a parallel bus. For LCD mode, I2S0 should work at master TX mode. For camera mode, I2S0 should work at slave RX mode. These two modes are not implemented by the I2S driver. Please refer to `LCD` for details about the LCD implementation. For more information, see [ESP32 Technical Reference Manual > I2S Controller (I2S) > LCD Mode](https://esp32.com)

**ADC/DAC Mode**  
ADC and DAC modes only exist on ESP32 and are only supported on I2S0. Actually, they are two sub-modes of LCD/Camera mode. I2S0 can be routed directly to the internal analog-to-digital converter (ADC) and digital-to-analog converter (DAC). In other words, ADC and DAC peripherals can read or write continuously via I2S0 DMA. As they are not actual communication modes, the I2S driver does not implement them.

**Functional Overview**

The I2S driver offers the following services:

**Resource Management**  There are three levels of resources in the I2S driver:

- platform level: Resources of all I2S controllers in the current target.
- controller level: Resources in one I2S controller.
- channel level: Resources of TX or RX channel in one I2S controller.

The public APIs are all channel-level APIs. The channel handle `i2s_chan_handle_t` can help users to manage the resources under a specific channel without considering the other two levels. The other two upper levels’ resources are private and are managed by the driver automatically. Users can call `i2s_new_channel()` to allocate a channel handle and call `i2s_del_channel()` to delete it.

**Power Management**  When the power management is enabled (i.e., `CONFIG_PM_ENABLE` is on), the system will adjust or stop the source clock of I2S before entering Light-sleep, thus potentially changing the I2S signals and leading to transmitting or receiving invalid data.

The I2S driver can prevent the system from changing or stopping the source clock by acquiring a power management lock. When the source clock is generated from APB, the lock type will be set to `esp_pm_lock_type_t::ESP_PM_APB_FREQ_MAX` and when the source clock is APLL (if supported), it will be set to `esp_pm_lock_type_t::ESP_PM_NO_LIGHT_SLEEP`. Whenever the user is reading or writing via I2S (i.e., calling `i2s_channel_read()` or `i2s_channel_write()`), the driver will guarantee that the power management lock is acquired. Likewise, the driver releases the lock after the reading or writing finishes.

**Finite State Machine**  There are three states for an I2S channel, namely, registered, ready, and running. Their relationship is shown in the following diagram:

The `<mode>` in the diagram can be replaced by corresponding I2S communication modes, e.g., `std` for standard two-slot mode. For more information about communication modes, please refer to the I2S Communication Mode section.

**Data Transport**  The data transport of the I2S peripheral, including sending and receiving, is realized by DMA. Before transporting data, please call `i2s_channel_enable()` to enable the specific channel. When the sent or received data reaches the size of one DMA buffer, the `I2S_OUT_EOF` or `I2S_IN_SUC_EOF` interrupt will be triggered. Note that the DMA buffer size is not equal to `i2s_chan_config_t::dma_frame_num`. One frame here refers to all the sampled data in one WS circle. Therefore, `dma_buffer_size = dma_frame_num`.
Fig. 11: I2S Finite State Machine
* slot_num * slot_bit_width / 8. For the data transmitting, users can input the data by calling `i2s_channel_write()`. This function helps users to copy the data from the source buffer to the DMA TX buffer and wait for the transmission to finish. Then it will repeat until the sent bytes reach the given size. For the data receiving, the function `i2s_channel_read()` waits to receive the message queue which contains the DMA buffer address. It helps users copy the data from the DMA RX buffer to the destination buffer.

Both `i2s_channel_write()` and `i2s_channel_read()` are blocking functions. They keep waiting until the whole source buffer is sent or the whole destination buffer is loaded, unless they exceed the max blocking time, where the error code `ESP_ERR_TIMEOUT` returns. To send or receive data asynchronously, callbacks can be registered by `i2s_channel_register_event_callback()`. Users are able to access the DMA buffer directly in the callback function instead of transmitting or receiving by the two blocking functions. However, please be aware that it is an interrupt callback, so do not add complex logic, run floating operation, or call non-reentrant functions in the callback.

**Configuration** Users can initialize a channel by calling corresponding functions (i.e., `i2s_channel_init_std_mode()`, `i2s_channel_init_pdm_rx_mode()`, `i2s_channel_init_pdm_tx_mode()`, or `i2s_channel_init_tdm_mode()`) to a specific mode. If the configurations need to be updated after initialization, users have to first call `i2s_channel_disable()` to ensure that the channel has stopped, and then call corresponding ‘reconfig’ functions, like `i2s_channel_reconfig_std_slot()`, `i2s_channel_reconfig_std_clock()`, and `i2s_channel_reconfig_std_gpio()`.

**IRAM Safe** By default, the I2S interrupt will be deferred when the cache is disabled for reasons like writing/erasing flash. Thus the EOF interrupt will not get executed in time.

To avoid such case in real-time applications, you can enable the Kconfig option `CONFIG_I2S_ISR_IRAM_SAFE` that will:

1. Keep the interrupt being serviced even when the cache is disabled.
2. Place driver object into DRAM (in case it is linked to PSRAM by accident).

This will allow the interrupt to run while the cache is disabled, but will come at the cost of increased IRAM consumption.

**Thread Safety** All the public I2S APIs are guaranteed to be thread safe by the driver, which means users can call them from different RTOS tasks without protection by extra locks. Notice that the I2S driver uses mutex lock to ensure the thread safety, thus these APIs are not allowed to be used in ISR.

**Kconfig Options**

- `CONFIG_I2S_ISR_IRAM_SAFE` controls whether the default ISR handler can work when the cache is disabled. See `IRAM Safe` for more information.
- `CONFIG_I2S_SUPPRESS_DEPRECATE_WARN` controls whether to suppress the compiling warning message while using the legacy I2S driver.
- `CONFIG_I2S_ENABLE_DEBUG_LOG` is used to enable the debug log output. Enable this option will increase the firmware binary size.

**Application Example**

The examples of the I2S driver can be found in the directory `peripherals/i2s`. Here are some simple usages of each mode:

**Standard TX/RX Usage** Different slot communication formats can be generated by the following helper macros for standard mode. As described above, there are three formats in standard mode, and their helper macros are:

- `I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG`
- `I2S_STD_PCM_SLOT_DEFAULT_CONFIG`
**I2S_STD_MSB_SLOT_DEFAULT_CONFIG**

The clock config helper macro is:

**I2S_STD_CLK_DEFAULT_CONFIG**

Please refer to **Standard Mode** for information about STD API. And for more details, please refer to `driver/i2s/include/driver/i2s_std.h`.

**STD TX Mode**  Take 16-bit data width for example. When the data in a `uint16_t` writing buffer are:

<table>
<thead>
<tr>
<th>data 0</th>
<th>data 1</th>
<th>data 2</th>
<th>data 3</th>
<th>data 4</th>
<th>data 5</th>
<th>data 6</th>
<th>data 7</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0001</td>
<td>0x0002</td>
<td>0x0003</td>
<td>0x0004</td>
<td>0x0005</td>
<td>0x0006</td>
<td>0x0007</td>
<td>0x0008</td>
<td>...</td>
</tr>
</tbody>
</table>

Here is the table of the real data on the line with different `i2s_std_slot_config_t::slot_mode` and `i2s_std_slot_config_t::slot_mask`.

<table>
<thead>
<tr>
<th>data bit width</th>
<th>slot mode</th>
<th>slot mask</th>
<th>WS low</th>
<th>WS high</th>
<th>WS low</th>
<th>WS high</th>
<th>WS low</th>
<th>WS high</th>
<th>WS low</th>
<th>WS high</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 bit</td>
<td>mono</td>
<td>left</td>
<td>0x0002</td>
<td>0x0000</td>
<td>0x0001</td>
<td>0x0000</td>
<td>0x0004</td>
<td>0x0000</td>
<td>0x0003</td>
<td>0x0000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>right</td>
<td>0x0000</td>
<td>0x0002</td>
<td>0x0000</td>
<td>0x0001</td>
<td>0x0000</td>
<td>0x0004</td>
<td>0x0000</td>
<td>0x0003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>both</td>
<td>0x0002</td>
<td>0x0002</td>
<td>0x0001</td>
<td>0x0001</td>
<td>0x0004</td>
<td>0x0004</td>
<td>0x0003</td>
<td>0x0003</td>
</tr>
<tr>
<td></td>
<td>stereo</td>
<td>left</td>
<td>0x0001</td>
<td>0x0001</td>
<td>0x0003</td>
<td>0x0003</td>
<td>0x0005</td>
<td>0x0005</td>
<td>0x0007</td>
<td>0x0007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>right</td>
<td>0x0002</td>
<td>0x0002</td>
<td>0x0004</td>
<td>0x0004</td>
<td>0x0006</td>
<td>0x0006</td>
<td>0x0008</td>
<td>0x0008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>both</td>
<td>0x0001</td>
<td>0x0002</td>
<td>0x0003</td>
<td>0x0004</td>
<td>0x0005</td>
<td>0x0006</td>
<td>0x0007</td>
<td>0x0008</td>
</tr>
</tbody>
</table>

**Note:** It is similar when the data is 32-bit width, but take care when using 8-bit and 24-bit data width. For 8-bit width, the written buffer should still use `uint16_t` (i.e., align with 2 bytes), and only the high 8 bits are valid while the low 8 bits are dropped. For 24-bit width, the buffer is supposed to use `uint32_t` (i.e., align with 4 bytes), and only the high 24 bits are valid while the low 8 bits are dropped.

Besides, for 8-bit and 16-bit mono modes, the real data on the line is swapped. To get the correct data sequence, the writing buffer needs to swap the data every two bytes.

```c
#include "driver/i2s_std.h"
#include "driver/gpio.h"

i2s_chan_handle_t tx_handle;
/* Get the default channel configuration by the helper macro. */
/* This helper macro is defined in 'i2s_common.h' and shared by all the I2S communication modes. */
/* It can help to specify the I2S role and port ID */
i2s_chan_config_t chan_cfg = I2S_CHANNEL_DEFAULT_CONFIG(I2S_NUM_AUTO, I2S_ROLE_MASTER);
/* Allocate a new TX channel and get the handle of this channel */
i2s_new_channel(&chan_cfg, &tx_handle, NULL);

/* Setting the configurations, the slot configuration and clock configuration can be generated by the macros */
/* These two helper macros are defined in 'i2s_std.h' which can only be used in STD mode. */
/* They can help to specify the slot and clock configurations for initialization or updating */
i2s_std_config_t std_cfg = {
    .clk_cfg = I2S_STD_CLK_DEFAULT_CONFIG(48000),
    .slot_cfg = I2S_STD_MSB_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_32BIT, I2S_SLOT_MODE_STEREO),
    .gpio_cfg = {
        ...
    }
};
```

(continues on next page)
.mclk = I2S_GPIO_UNUSED,
.bclk = GPIO_NUM_4,
.ws = GPIO_NUM_5,
.dout = GPIO_NUM_18,
.din = I2S_GPIO_UNUSED,
.invert_flags = {
    .mclk_inv = false,
    .bclk_inv = false,
    .ws_inv = false,
},
};
/* Initialize the channel */
i2s_channel_init_std_mode(tx_handle, &std_cfg);

/* Before writing data, start the TX channel first */
if (
    i2s_channel_enable(tx_handle);
    write_buf,
    bytes_to_write,
    bytes_written,
    ticks_to_wait);

/* If the configurations of slot or clock need to be updated, */
/* stop the channel first and then update it */
if (
    i2s_channel_disable(tx_handle); // std_cfg.slot_cfg.slot_mode = I2S_SLOT_MODE_MONO; // Default is stereo
    i2s_channel_reconfig_std_slot(tx_handle, &std_cfg.slot_cfg);
    i2s_channel_reconfig_std_clock(tx_handle, &std_cfg.clk_cfg);
)
/* Have to stop the channel before deleting it */
i2s_channel_disable(tx_handle); /* If the handle is not needed any more, delete it to release the channel... */
i2s_del_channel(tx_handle);

STD RX Mode  Taking 16-bit data width for example, when the data on the line are:

<table>
<thead>
<tr>
<th>WS low</th>
<th>WS high</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0001</td>
<td>0x0002</td>
</tr>
<tr>
<td>0x0003</td>
<td>0x0004</td>
</tr>
<tr>
<td>0x0005</td>
<td>0x0006</td>
</tr>
<tr>
<td>0x0007</td>
<td>0x0008</td>
</tr>
</tbody>
</table>

Here is the table of the data received in the buffer with different i2s_std_slot_config_t::slot_mode and i2s_std_slot_config_t::slot_mask:

<table>
<thead>
<tr>
<th>data width</th>
<th>bit slot mode slot mask</th>
<th>data 0</th>
<th>data 1</th>
<th>data 2</th>
<th>data 3</th>
<th>data 4</th>
<th>data 5</th>
<th>data 6</th>
<th>data 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 bit</td>
<td>mono</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>left</td>
<td>0x0001</td>
<td>0x0000</td>
<td>0x0005</td>
<td>0x0003</td>
<td>0x0009</td>
<td>0x0007</td>
<td>0x0004</td>
<td>0x000b</td>
</tr>
<tr>
<td></td>
<td>right</td>
<td>0x0002</td>
<td>0x0000</td>
<td>0x0006</td>
<td>0x0004</td>
<td>0x000a</td>
<td>0x0008</td>
<td>0x0004</td>
<td>0x000c</td>
</tr>
<tr>
<td></td>
<td>stereo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>any</td>
<td>0x0001</td>
<td>0x0002</td>
<td>0x0003</td>
<td>0x0004</td>
<td>0x0005</td>
<td>0x0006</td>
<td>0x0007</td>
<td>0x0008</td>
</tr>
</tbody>
</table>

Note: The receive case is a little bit complicated on ESP32. Firstly, when the data width is 8-bit or 24-bit, the received data will still align with two bytes or four bytes, which means that the valid data are put in the high 8 bits in every two bytes and high 24 bits in every four bytes. For example, the received data will be 0x5A00 when the data on the line is 0x5A in 8-bit width, and 0x0000 5A00 if the data on the line is 0x00 005A. Secondly, for the 8-bit or 16-bit mono case, the data in buffer is swapped every two data, so it may be necessary to manually swap the data back to the correct order.
```c
#include "driver/i2s_std.h"
#include "driver/gpio.h"

i2s_chan_handle_t rx_handle;
/* Get the default channel configuration by helper macro.
 * This helper macro is defined in 'i2s_common.h' and shared by all the I2S
-communication modes.
 * It can help to specify the I2S role and port ID */

i2s_chan_config_t chan_cfg = I2S_CHANNEL_DEFAULT_CONFIG(I2S_NUM_AUTO, I2S_ROLE-
-MASTER);
/* Allocate a new RX channel and get the handle of this channel */

i2s_new_channel(&chan_cfg, NULL, &rx_handle);

/* Setting the configurations, the slot configuration and clock configuration can-
be generated by the macros.
 * These two helper macros are defined in 'i2s_std.h' which can only be used in-
-STD mode.
 * They can help to specify the slot and clock configurations for initialization-
or updating */

i2s_std_config_t std_cfg = {
    .clk_cfg = I2S_STD_CLK_DEFAULT_CONFIG(48000),
    .slot_cfg = I2S_STD_MSB_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_32BIT, I2S_SLOT-
-MODE_STEREO),
    .gpio_cfg = {
        .mclk = I2S_GPIO_UNUSED,
        .bclk = GPIO_NUM_4,
        .ws = GPIO_NUM_5,
        .dout = I2S_GPIO_UNUSED,
        .din = GPIO_NUM_19,
        .invert_flags = {
            .mclk_inv = false,
            .bclk_inv = false,
            .ws_inv = false,
        },
    },
};
/* Initialize the channel */

i2s_channel_init_std_mode(rx_handle, &std_cfg);

/* Before reading data, start the RX channel first */

i2s_channel_enable(rx_handle);

i2s_channel_read(rx_handle, desc_buf, bytes_to_read, bytes_read, ticks_to_wait);
/* Have to stop the channel before deleting it */

i2s_channel_disable(rx_handle);
/* If the handle is not needed any more, delete it to release the channel-
resources */

i2s_del_channel(rx_handle);
```

**PDM TX Usage**  For PDM mode in TX channel, the slot configuration helper macro is:

- `I2S_PDM_TX_SLOT_DEFAULT_CONFIG`

The clock configuration helper macro is:

- `I2S_PDM_TX_CLK_DEFAULT_CONFIG`

Please refer to [PDM Mode](#) for information about PDM TX API. And for more details, please refer to `driver/i2s/include/driver/i2s_pdm.h`.

The PDM data width is fixed to 16-bit. When the data in an `int16_t` writing buffer is:
Here is the table of the real data on the line with different `i2s_pdm_tx_slot_config_t::slot_mode` and `i2s_pdm_tx_slot_config_t::slot_mask` (The PDM format on the line is transferred to PCM format for better comprehension).

<table>
<thead>
<tr>
<th>slot mode</th>
<th>slot mask</th>
<th>left</th>
<th>right</th>
<th>left</th>
<th>right</th>
<th>left</th>
<th>right</th>
<th>left</th>
<th>right</th>
</tr>
</thead>
<tbody>
<tr>
<td>mono</td>
<td>left</td>
<td>0x0001</td>
<td>0x0000</td>
<td>0x0002</td>
<td>0x0000</td>
<td>0x0003</td>
<td>0x0000</td>
<td>0x0004</td>
<td>0x0000</td>
</tr>
<tr>
<td></td>
<td>right</td>
<td>0x0000</td>
<td>0x0001</td>
<td>0x0000</td>
<td>0x0002</td>
<td>0x0000</td>
<td>0x0003</td>
<td>0x0000</td>
<td>0x0004</td>
</tr>
<tr>
<td></td>
<td>both</td>
<td>0x0001</td>
<td>0x0001</td>
<td>0x0000</td>
<td>0x0002</td>
<td>0x0000</td>
<td>0x0003</td>
<td>0x0000</td>
<td>0x0004</td>
</tr>
<tr>
<td>stereo</td>
<td>left</td>
<td>0x0001</td>
<td>0x0001</td>
<td>0x0003</td>
<td>0x0000</td>
<td>0x0005</td>
<td>0x0000</td>
<td>0x0007</td>
<td>0x0000</td>
</tr>
<tr>
<td></td>
<td>right</td>
<td>0x0002</td>
<td>0x0002</td>
<td>0x0004</td>
<td>0x0000</td>
<td>0x0006</td>
<td>0x0000</td>
<td>0x0008</td>
<td>0x0000</td>
</tr>
<tr>
<td></td>
<td>both</td>
<td>0x0001</td>
<td>0x0002</td>
<td>0x0003</td>
<td>0x0004</td>
<td>0x0005</td>
<td>0x0006</td>
<td>0x0007</td>
<td>0x0008</td>
</tr>
</tbody>
</table>

```cpp
#include "driver/i2s_pdm.h"
#include "driver/gpio.h"

/* Allocate an I2S TX channel */
i2s_chan_config_t chan_cfg = I2S_CHANNEL_DEFAULT_CONFIG(I2S_NUM_0, I2S_ROLE_MASTER);
i2s_new_channel(&chan_cfg, &tx_handle, NULL);

/* Init the channel into PDM TX mode */
i2s_pdm_tx_config_t pdm_tx_cfg = {
  .clk_cfg = I2S_PDM_TX_CLK_DEFAULT_CONFIG(36000),
  .slot_cfg = I2S_PDM_TX_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_16BIT, I2S_SLOT_MODE_MONO),
  .gpio_cfg = {
    .clk = GPIO_NUM_5,
    .dout = GPIO_NUM_18,
    .invert_flags = {
      .clk_inv = false,
    },
  },
};
i2s_channel_init_pdm_tx_mode(tx_handle, &pdm_tx_cfg);
...
```

### PDM RX usage

For PDM mode in RX channel, the slot configuration helper macro is:

- `I2S_PDM_RX_SLOT_DEFAULT_CONFIG`

The clock configuration helper macro is:

- `I2S_PDM_RX_CLK_DEFAULT_CONFIG`

Please refer to [PDM Mode](#) for information about PDM RX API. And for more details, please refer to `driver/i2s/include/driver/i2s_pdm.h`.

The PDM data width is fixed to 16-bit. When the data on the line (The PDM format on the line is transferred to PCM format for easier comprehension) is:

<p>| | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>left</td>
<td>right</td>
<td>left</td>
<td>right</td>
<td>left</td>
<td>right</td>
<td>left</td>
<td>right</td>
<td></td>
</tr>
<tr>
<td>0x0001</td>
<td>0x0002</td>
<td>0x0003</td>
<td>0x0004</td>
<td>0x0005</td>
<td>0x0006</td>
<td>0x0007</td>
<td>0x0008</td>
<td></td>
</tr>
</tbody>
</table>

Here is the table of the data received in a `int16_t` buffer with different `i2s_pdm_rx_slot_config_t::slot_mode` and `i2s_pdm_rx_slot_config_t::slot_mask`. 
Chapter 2. API Reference

### slot mode

<table>
<thead>
<tr>
<th>mono</th>
<th>slot mask</th>
<th>data 0</th>
<th>data 1</th>
<th>data 2</th>
<th>data 3</th>
<th>data 4</th>
<th>data 5</th>
<th>data 6</th>
<th>data 7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>left</td>
<td>0x0001</td>
<td>0x0003</td>
<td>0x0005</td>
<td>0x0007</td>
<td>0x0009</td>
<td>0x000b</td>
<td>0x000d</td>
<td>0x000f</td>
</tr>
<tr>
<td></td>
<td>right</td>
<td>0x0002</td>
<td>0x0004</td>
<td>0x0006</td>
<td>0x0008</td>
<td>0x000a</td>
<td>0x000c</td>
<td>0x000e</td>
<td>0x0010</td>
</tr>
<tr>
<td>stereo</td>
<td>both</td>
<td>0x0001</td>
<td>0x0002</td>
<td>0x0003</td>
<td>0x0004</td>
<td>0x0005</td>
<td>0x0006</td>
<td>0x0007</td>
<td>0x0008</td>
</tr>
</tbody>
</table>

```c
#include "driver/i2s_pdm.h"
#include "driver/gpio.h"

i2s_chan_handle_t rx_handle;

/* Allocate an I2S RX channel */
i2s_chan_config_t chan_cfg = I2S_CHANNEL_DEFAULT_CONFIG(I2S_NUM_0, I2S_ROLE_MASTER);
i2s_new_channel(&chan_cfg, NULL, &rx_handle);

/* Init the channel into PDM RX mode */
i2s_pdm_rx_config_t pdm_rx_cfg = {
    .clk_cfg = I2S_PDM_RX_CLK_DEFAULT_CONFIG(36000),
    .slot_cfg = I2S_PDM_RX_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_16BIT, I2S_SLOT_MODE_MONO),
    .gpio_cfg = {
        .clk = GPIO_NUM_5,
        .din = GPIO_NUM_19,
        .invert_flags = {
            .clk_inv = false,
        },
    },
};
i2s_channel_init_pdm_rx_mode(rx_handle, &pdm_rx_cfg);
```

**Full-duplex**  Full-duplex mode registers TX and RX channel in an I2S port at the same time, and the channels share the BCLK and WS signals. Currently, STD and TDM communication modes supports full-duplex mode in the following way, but PDM full-duplex is not supported because due to different PDM TX and RX clocks.

Note that one handle can only stand for one channel. Therefore, it is still necessary to configure the slot and clock for both TX and RX channels one by one.

Here is an example of how to allocate a pair of full-duplex channels:

```c
#include "driver/i2s_std.h"
#include "driver/gpio.h"

i2s_chan_handle_t tx_handle;  
i2s_chan_handle_t rx_handle;

/* Allocate a pair of I2S channel */
i2s_chan_config_t chan_cfg = I2S_CHANNEL_DEFAULT_CONFIG(I2S_NUM_AUTO, I2S_ROLE_MASTER);
/* Allocate for TX and RX channel at the same time, then they will work in full-duplex mode */
i2s_new_channel(&chan_cfg, &tx_handle, &rx_handle);

/* Set the configurations for BOTH TWO channels, since TX and RX channel have to be same in full-duplex mode */
i2s_std_config_t std_cfg = {
    .clk_cfg = I2S_STD_CLK_DEFAULT_CONFIG(32000),
    .slot_cfg = I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_16BIT, I2S_SLOT_MODE_STEREO),
};
```

(continues on next page)
.gpio_cfg = {
    .mclk = I2S_GPIO_UNUSED,
    .bclk = GPIO_NUM_4,
    .ws = GPIO_NUM_5,
    .dout = GPIO_NUM_18,
    .din = GPIO_NUM_19,
    .invert_flags = {
        .mclk_inv = false,
        .bclk_inv = false,
        .ws_inv = false,
    },
},
};
i2s_channel_init_std_mode(tx_handle, &std_cfg);
i2s_channel_init_std_mode(rx_handle, &std_cfg);

```
i2s_new_channel(chan_cfg, NULL, &tx_handle);
i2s_std_config_t std_tx_cfg = {
    .clk_cfg = I2S_STD_CLK_DEFAULT_CONFIG(48000),
    .slot_cfg = I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_16BIT, I2S_SLOT_MODE_STEREO),
    .gpio_cfg = {
        .mclk = GPIO_NUM_0,
        .bclk = GPIO_NUM_4,
        .ws = GPIO_NUM_5,
        .dout = GPIO_NUM_18,
        .din = I2S_GPIO_UNUSED,
        .invert_flags = {
            .mclk_inv = false,
            .bclk_inv = false,
            .ws_inv = false,
        },
    },
};
/* Initialize the channel */
i2s_channel_init_std_mode(tx_handle, &std_tx_cfg);
i2s_channel_enable(tx_handle);
```

Simplex Mode  To allocate a channel handle in simplex mode, `i2s_new_channel()` should be called for each channel. The clock and GPIO pins of TX/RX channel on ESP32 are not independent, so the TX and RX channel cannot coexist on the same I2S port in simplex mode.
.clk_cfg = I2S_STD_CLK_DEFAULT_CONFIG(16000),
.slot_cfg = I2S_STD_MSB_SLOT_DEFAULT_CONFIG(I2S_DATA_BIT_WIDTH_32BIT, I2S_SLOT_MODE_STEREO),
.gpio_cfg = {
   .mclk = I2S_GPIO_UNUSED,  
   .bclk = GPIO_NUM_6,        
   .ws = GPIO_NUM_7,         
   .dout = I2S_GPIO_UNUSED,  
   .din = GPIO_NUM_19,       
   .invert_flags = {
      .mclk_inv = false,  
      .bclk_inv = false,  
      .ws_inv = false,   
   },
},

i2s_channel_init_std_mode(rx_handle, &std_rx_cfg);

i2s_channel_enable(rx_handle);

### Application Notes

#### How to Prevent Data Lost

For applications that need a high frequency sample rate, the massive data throughput may cause data lost. Users can receive data lost event by registering the ISR callback function to receive the event queue:

```c
static IRAM_ATTR bool i2s_rx_queue_overflow_callback_i2s_chan_handle_t handle, i2s_event_data_t *event, void *user_ctx)
{
   // handle RX queue overflow event ...
   return false;
}
```

i2s_event_callbacks_t cbs = {
   .on_recv = NULL,
   .on_recv_q_ovf = i2s_rx_queue_overflow_callback,
   .on_sent = NULL,
   .on_send_q_ovf = NULL,
};

TEST_ESP_OK(i2s_channel_register_event_callback(rx_handle, &cbs, NULL));

Please follow these steps to prevent data lost:

1. **Determine the interrupt interval.** Generally, when data lost happens, the bigger the interval, the better, which helps to reduce the interrupt times. This means `dma_frame_num` should be as big as possible while the DMA buffer size is below the maximum value of 4092. The relationships are:

   \[
   \text{interrupt\_interval}(\text{unit: sec}) = \frac{\text{dma\_frame\_num}}{\text{sample\_rate}} \\
   \text{dma\_buffer\_size} = \frac{\text{dma\_frame\_num} \times \text{slot\_num} \times \text{data\_bit\_width}}{8} \leq 4092
   \]

2. **Determine `dma_desc_num`.** `dma_desc_num` is decided by the maximum time of `i2s_channel_read` polling cycle. All the received data is supposed to be stored between two `i2s_channel_read`. This cycle can be measured by a timer or an outputting GPIO signal. The relationship is:

   \[
   \text{dma\_desc\_num} > \frac{\text{polling\_cycle}}{\text{interrupt\_interval}}
   \]

3. **Determine the receiving buffer size.** The receiving buffer offered by users in `i2s_channel_read` should be able to take all the data in all DMA buffers, which means that it should be larger than the total size of all the DMA buffers:

   \[
   \text{recv\_buffer\_size} > \text{dma\_desc\_num} \times \text{dma\_buffer\_size}
   \]
For example, if there is an I2S application, and the known values are:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample_rate</td>
<td>144000 Hz</td>
</tr>
<tr>
<td>data_bit_width</td>
<td>32 bits</td>
</tr>
<tr>
<td>slot_num</td>
<td>2</td>
</tr>
<tr>
<td>polling_cycle</td>
<td>10 ms</td>
</tr>
</tbody>
</table>

Then the parameters \( \text{dma\_frame\_num} \), \( \text{dma\_desc\_num} \), and \( \text{recv\_buf\_size} \) can be calculated as follows:

\[
\text{dma\_frame\_num} \times \text{slot\_num} \times \text{data\_bit\_width} \div 8 = \text{dma\_buffer\_size} \leq 4092 \\
\text{dma\_frame\_num} = 511 \\
\text{interrupt\_interval} = \text{dma\_frame\_num} \div \text{sample\_rate} = 511 \div 144000 = 0.003549 \text{ s} = 3.549 \text{ ms} \\
\text{dma\_desc\_num} > \text{polling\_cycle} \div \text{interrupt\_interval} = \text{cell}(10 \div 3.549) = \text{cell}(2.818) \geq 3 \\
\text{recv\_buffer\_size} > \text{dma\_desc\_num} \times \text{dma\_buffer\_size} = 3 \times 4092 = 12276 \text{ bytes}
\]

### API Reference

#### Standard Mode

**Header File**

- components/driver/i2s/include/driver/i2s_std.h

**Functions**

```c
esp_err_t i2s_channel_init_std_mode(i2s_chan_handle_t handle, const i2s_std_config_t *std_cfg)
```

Initialize I2S channel to standard mode.

**Note:** Only allowed to be called when the channel state is REGISTERED, i.e., channel has been allocated, but not initialized and the state will be updated to READY if initialization success, otherwise the state will return to REGISTERED.

#### Parameters

- **handle**  - [in] I2S channel handler
- **std_cfg** - [in] Configurations for standard mode, including clock, slot and gpio. The clock configuration can be generated by the helper macro `I2S_STD_CLK_DEFAULT_CONFIG` The slot configuration can be generated by the helper macro `I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG`, `I2S_STD_PCM_SLOT_DEFAULT_CONFIG`, or `I2S_STD_MSB_SLOT_DEFAULT_CONFIG`

#### Returns

- `ESP_OK` Initialize successfully
- `ESP_ERR_NO_MEM` No memory for storing the channel information
- `ESP_ERR_INVALID_ARG` NULL pointer or invalid configuration
- `ESP_ERR_INVALID_STATE` This channel is not registered

```c
esp_err_t i2s_channel_reconfig_std_clock(i2s_chan_handle_t handle, const i2s_std_clk_config_t *clk_cfg)
```

Reconfigure the I2S clock for standard mode.

**Note:** Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.
Chapter 2. API Reference

Note: The input channel handle has to be initialized to standard mode, i.e., ‘i2s_channel_init_std_mode’ has been called before reconfiguring

Parameters
• handle - [in] I2S channel handler
• clk_cfg - [in] Standard mode clock configuration, can be generated by
  I2S_STD_CLK_DEFAULT_CONFIG

Returns
• ESP_OK Set clock successfully
• ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not standard mode
• ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

\texttt{esp_err_t i2s_channel_reconfig_std_slot(i2s_chan_handle_t handle, const i2s_std_slot_config_t *slot_cfg)}

Reconfigure the I2S slot for standard mode.

Note: Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

Note: The input channel handle has to be initialized to standard mode, i.e., ‘i2s_channel_init_std_mode’ has been called before reconfiguring

Parameters
• handle - [in] I2S channel handler
• slot_cfg - [in] Standard mode slot configuration, can be generated by
  I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG,
  I2S_STD_PCM_SLOT_DEFAULT_CONFIG and I2S_STD_MSB_SLOT_DEFAULT_CONFIG.

Returns
• ESP_OK Set clock successfully
• ESP_ERR_NO_MEM No memory for DMA buffer
• ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not standard mode
• ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

\texttt{esp_err_t i2s_channel_reconfig_std_gpio(i2s_chan_handle_t handle, const i2s_std_gpio_config_t *gpio_cfg)}

Reconfigure the I2S gpio for standard mode.

Note: Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

Note: The input channel handle has to be initialized to standard mode, i.e., ‘i2s_channel_init_std_mode’ has been called before reconfiguring

Parameters
• handle - [in] I2S channel handler
• gpio_cfg - [in] Standard mode gpio configuration, specified by user

Returns
Chapter 2. API Reference

- ESP_OK Set clock successfully
- ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not standard mode
- ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

Structures

struct i2s_std_slot_config_t
I2S slot configuration for standard mode.

Public Members

i2s_data_bit_width_t data_bit_width
I2S sample data bit width (valid data bits per sample)

i2s_slot_bit_width_t slot_bit_width
I2S slot bit width (total bits per slot)

i2s_slot_mode_t slot_mode
Set mono or stereo mode with I2S_SLOT_MODE_MONO or I2S_SLOT_MODE_STEREO In TX direction, mono means the written buffer contains only one slot data and stereo means the written buffer contains both left and right data

i2s_std_slot_mask_t slot_mask
Select the left, right or both slot

uint32_t ws_width
WS signal width (i.e. the number of clock ticks that ws signal is high)

bool ws_pol
WS signal polarity, set true to enable high level first

bool bit_shift
Set to enable bit shift in Philips mode

bool msb_right
Set to place right channel data at the MSB in the FIFO

struct i2s_std_clk_config_t
I2S clock configuration for standard mode.

Public Members

uint32_t sample_rate_hz
I2S sample rate

i2s_clock_src_t clk_src
Choose clock source
Chapter 2. API Reference

\texttt{i2s\_mclk\_multiple} / \texttt{mclk\_multiple}

The multiple of mclk to the sample rate Default is 256 in the helper macro, it can satisfy most of cases, but please set this field a multiple of \texttt{3} (like 384) when using 24-bit data width, otherwise the sample rate might be inaccurate.

\texttt{struct i2s\_std\_gpio\_config\_t}

I2S standard mode GPIO pins configuration.

\textbf{Public Members}

\texttt{gpio\_num\_t mclk}

MCK pin, output

\texttt{gpio\_num\_t bclk}

BCK pin, input in slave role, output in master role

\texttt{gpio\_num\_t ws}

WS pin, input in slave role, output in master role

\texttt{gpio\_num\_t dout}

DATA pin, output

\texttt{gpio\_num\_t din}

DATA pin, input

\texttt{uint32\_t mclk\_inv}

Set 1 to invert the mclk output

\texttt{uint32\_t bclk\_inv}

Set 1 to invert the bclk input/output

\texttt{uint32\_t ws\_inv}

Set 1 to invert the ws input/output

\texttt{struct i2s\_std\_gpio\_config\_t:\[:anonymous\] invert\_flags}

GPIO pin invert flags

\texttt{struct i2s\_std\_config\_t}

I2S standard mode major configuration that including clock/slot/gpio configuration.

\textbf{Public Members}

\texttt{i2s\_std\_clk\_config\_t clk\_cfg}

Standard mode clock configuration, can be generated by macro \texttt{I2S\_STD\_CLK\_DEFAULT\_CONFIG}

\texttt{i2s\_std\_slot\_config\_t slot\_cfg}

Standard mode slot configuration, can be generated by macros \texttt{I2S\_STD\_[\texttt{mode}]\_SLOT\_DEFAULT\_CONFIG}, \texttt{[mode]} can be replaced with PHILIPS/MSB/PCM
i2s_std_gpio_config_t gpio_cfg

Standard mode gpio configuration, specified by user

Macros

I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG (bits_per_sample, mono_or_stereo)

Philips format in 2 slots.

This file is specified for I2S standard communication mode Features:

• Philips/MSB/PCM are supported in standard mode
• Fixed to 2 slots

Parameters

• bits_per_sample –i2s data bit width
• mono_or_stereo –I2S_SLOT_MODE_MONO or I2S_SLOT_MODE_STEREO

I2S_STD_PCM_SLOT_DEFAULT_CONFIG (bits_per_sample, mono_or_stereo)

PCM(short) format in 2 slots.

Note: PCM(long) is same as philips in 2 slots

Parameters

• bits_per_sample –i2s data bit width
• mono_or_stereo –I2S_SLOT_MODE_MONO or I2S_SLOT_MODE_STEREO

I2S_STD_MSB_SLOT_DEFAULT_CONFIG (bits_per_sample, mono_or_stereo)

MSB format in 2 slots.

Parameters

• bits_per_sample –i2s data bit width
• mono_or_stereo –I2S_SLOT_MODE_MONO or I2S_SLOT_MODE_STEREO

I2S_STD_CLK_DEFAULT_CONFIG (rate)

i2s default standard clock configuration

Note: Please set the mclk_multiple to I2S_MCLK_MULTIPLE_384 while using 24 bits data width Otherwise the sample rate might be imprecise since the bclk division is not a integer

Parameters

• rate –sample rate

PDM Mode

Header File

• components/driver/i2s/include/driver/i2s_pdm.h

Functions

esp_err_t i2s_channel_init_pdm_rx_mode (i2s_chan_handle_t handle, const i2s_pdm_rx_config_t *pdm_rx_cfg)
Initialize i2s channel to PDM RX mode.

**Note:** Only allowed to be called when the channel state is REGISTERED, (i.e., channel has been allocated, but not initialized) and the state will be updated to READY if initialization success, otherwise the state will return to REGISTERED.

**Parameters**
- **handle** - [in] I2S rx channel handler
- **pdm_rx_cfg** - [in] Configurations for PDM RX mode, including clock, slot and gpio. The clock configuration can be generated by the helper macro `I2S_PDM_RX_CLK_DEFAULT_CONFIG`. The slot configuration can be generated by the helper macro `I2S_PDM_RX_SLOT_DEFAULT_CONFIG`.

**Returns**
- ESP_OK: Initialize successfully
- ESP_ERR_NO_MEM: No memory for storing the channel information
- ESP_ERR_INVALID_ARG: NULL pointer or invalid configuration
- ESP_ERR_INVALID_STATE: This channel is not registered

```c
esp_err_t i2s_channel_reconfig_pdm_rx_clock(i2s_chan_handle_t handle, const i2s_pdm_rx_clk_config_t *clk_cfg)
```

Reconfigure the I2S clock for PDM RX mode.

**Note:** Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started. This function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

**Note:** The input channel handle has to be initialized to PDM RX mode, i.e., ‘i2s_channel_init_pdm_rx_mode’ has been called before reconfiguring.

**Parameters**
- **handle** - [in] I2S rx channel handler
- **clk_cfg** - [in] PDM RX mode clock configuration, can be generated by `I2S_PDM_RX_CLK_DEFAULT_CONFIG`.

**Returns**
- ESP_OK: Set clock successfully
- ESP_ERR_NO_MEM: NULL pointer, invalid configuration or not PDM mode
- ESP_ERR_INVALID_STATE: This channel is not initialized or not stopped

```c
esp_err_t i2s_channel_reconfig_pdm_rx_slot(i2s_chan_handle_t handle, const i2s_pdm_rx_slot_config_t *slot_cfg)
```

Reconfigure the I2S slot for PDM RX mode.

**Note:** Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started. This function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

**Note:** The input channel handle has to be initialized to PDM RX mode, i.e., ‘i2s_channel_init_pdm_rx_mode’ has been called before reconfiguring.

**Parameters**
Chapter 2. API Reference

- **handle** - [in] I2S rx channel handler
- **slot_cfg** - [in] PDM RX mode slot configuration, can be generated by `I2S_PDM_RX_SLOT_DEFAULT_CONFIG`

Returns
- ESP_OK Set clock successfully
- ESP_ERR_NO_MEM No memory for DMA buffer
- ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not PDM mode
- ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

```c
esp_err_t i2s_channel_reconfig_pdm_rx_gpio(i2s_chan_handle_t handle, const i2s_pdm_rx_gpio_config_t *gpio_cfg)
```

Reconfigure the I2S gpio for PDM RX mode.

**Note:** Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

**Parameters**
- **handle** - [in] I2S rx channel handler
- **gpio_cfg** - [in] PDM RX mode gpio configuration, specified by user

**Returns**
- ESP_OK Set clock successfully
- ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not PDM mode
- ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

```c
esp_err_t i2s_channel_init_pdm_tx_mode(i2s_chan_handle_t handle, const i2s_pdm_tx_config_t *pdm_tx_cfg)
```

Initialize i2s channel to PDM TX mode.

**Note:** Only allowed to be called when the channel state is REGISTERED, (i.e., channel has been allocated, but not initialized) and the state will be updated to READY if initialization success, otherwise the state will return to REGISTERED.

**Parameters**
- **handle** - [in] I2S tx channel handler
- **pdm_tx_cfg** - [in] Configurations for PDM TX mode, including clock, slot and gpio The clock configuration can be generated by the helper macro `I2S_PDM_TX_CLK_DEFAULT_CONFIG` The slot configuration can be generated by the helper macro `I2S_PDM_TX_SLOT_DEFAULT_CONFIG`

**Returns**
- ESP_OK Initialize successfully
- ESP_ERR_NO_MEM No memory for storing the channel information
- ESP_ERR_INVALID_ARG NULL pointer or invalid configuration
- ESP_ERR_INVALID_STATE This channel is not registered

```c
esp_err_t i2s_channel_reconfig_pdm_tx_clock(i2s_chan_handle_t handle, const i2s_pdm_tx_clk_config_t *clk_cfg)
```

Reconfigure the I2S clock for PDM TX mode.
Note: Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

Note: The input channel handle has to be initialized to PDM TX mode, i.e., ‘i2s_channel_init_pdm_tx_mode’ has been called before reconfiguring

Parameters
- **handle** [in] I2S tx channel handler
- **clk_cfg** [in] PDM TX mode clock configuration, can be generated by
  I2S_PDM_TX_CLK_DEFAULT_CONFIG

Returns
- ESP_OK Set clock successfully
- ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not PDM mode
- ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

```
esp_err_t i2s_channel_reconfig_pdm_tx_slot(i2s_chan_handle_t handle, const i2s_pdm_tx_slot_config_t *slot_cfg)
```

Reconfigure the I2S slot for PDM TX mode.

Note: Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.

Note: The input channel handle has to be initialized to PDM TX mode, i.e., ‘i2s_channel_init_pdm_tx_mode’ has been called before reconfiguring

Parameters
- **handle** [in] I2S tx channel handler
- **slot_cfg** [in] PDM TX mode slot configuration, can be generated by
  I2S_PDM_TX_SLOT_DEFAULT_CONFIG

Returns
- ESP_OK Set clock successfully
- ESP_ERR_NO_MEM No memory for DMA buffer
- ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not PDM mode
- ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

```
esp_err_t i2s_channel_reconfig_pdm_tx_gpio(i2s_chan_handle_t handle, const i2s_pdm_tx_gpio_config_t *gpio_cfg)
```

Reconfigure the I2S gpio for PDM TX mode.

Note: Only allowed to be called when the channel state is READY, i.e., channel has been initialized, but not started this function won’t change the state. ‘i2s_channel_disable’ should be called before calling this function if i2s has started.
Chapter 2. API Reference

Parameters

• `handle` - [in] I2S tx channel handler
• `gpio_cfg` - [in] PDM TX mode gpio configuration, specified by user

Returns

• ESP_OK Set clock successfully
• ESP_ERR_INVALID_ARG NULL pointer, invalid configuration or not PDM mode
• ESP_ERR_INVALID_STATE This channel is not initialized or not stopped

Structures

```c
struct i2s_pdm_rx_slot_config_t
I2S slot configuration for pdm rx mode.
```

Public Members

```c
i2s_data_bit_width_t data_bit_width
I2S sample data bit width (valid data bits per sample), only support 16 bits for PDM mode
```

```c
i2s_slot_bit_width_t slot_bit_width
I2S slot bit width (total bits per slot), only support 16 bits for PDM mode
```

```c
i2s_slot_mode_t slot_mode
Set mono or stereo mode with I2S_SLOT_MODE_MONO or I2S_SLOT_MODE_STEREO
```

```c
i2s_pdm_slot_mask_t slot_mask
Choose the slots to activate
```

```c
struct i2s_pdm_rx_clk_config_t
I2S clock configuration for pdm rx mode.
```

Public Members

```c
uint32_t sample_rate_hz
I2S sample rate
```

```c
i2s_clock_src_t clk_src
Choose clock source
```

```c
i2s_mclk_multiple_t mclk_multiple
The multiple of mclk to the sample rate
```

```c
i2s_pdm_dsr_t dn_sample_mode
Down-sampling rate mode
```

```c
struct i2s_pdm_rx_gpio_config_t
I2S PDM tx mode GPIO pins configuration.
```
Public Members

`gpio_num_t clk`
- PDM clk pin, output

`gpio_num_t din`
- DATA pin 0, input

`gpio_num_t dins[(1U)]`
- DATA pins, input, only take effect when corresponding I2S_PDM_RX_LINEx_SLOT_xxx is enabled in `i2s_pdm_rx_slot_config_t::slot_mask`

`uint32_t clk_inv`
- Set 1 to invert the clk output

`struct i2s_pdm_rx_gpio_config_t::[anonymous] invert_flags`
- GPIO pin invert flags

struct `i2s_pdm_rx_config_t`
- I2S PDM RX mode major configuration that including clock/slot/gpio configuration.

Public Members

`i2s_pdm_rx_clk_config_t clk_cfg`
- PDM RX clock configurations, can be generated by macro `I2S_PDM_RX_CLK_DEFAULT_CONFIG`

`i2s_pdm_rx_slot_config_t slot_cfg`
- PDM RX slot configurations, can be generated by macro `I2S_PDM_RX_SLOT_DEFAULT_CONFIG`

`i2s_pdm_rx_gpio_config_t gpio_cfg`
- PDM RX slot configurations, specified by user

struct `i2s_pdm_tx_slot_config_t`
- I2S slot configuration for pdm tx mode.

Public Members

`i2s_data_bit_width_t data_bit_width`
- I2S sample data bit width (valid data bits per sample), only support 16 bits for PDM mode

`i2s_slot_bit_width_t slot_bit_width`
- I2S slot bit width (total bits per slot), only support 16 bits for PDM mode

`i2s_slot_mode_t slot_mode`
- Set mono or stereo mode with `I2S_SLOT_MODE_MONO` or `I2S_SLOT_MODE_STEREO` For PDM TX mode, mono means the data buffer only contains one slot data, Stereo means the data buffer contains two slots data
i2s_pdm_slot_mask_t slot_mask
   Slot mask to choose left or right slot

uint32_t sd_prescale
   Sigma-delta filter prescale

i2s_pdm_sig_scale_t sd_scale
   Sigma-delta filter scaling value

i2s_pdm_sig_scale_t hp_scale
   High pass filter scaling value

i2s_pdm_sig_scale_t lp_scale
   Low pass filter scaling value

i2s_pdm_sig_scale_t sinc_scale
   Sinc filter scaling value

struct i2s_pdm_tx_clk_config_t
   I2S clock configuration for pdm tx mode.

Public Members

uint32_t sample_rate_hz
   I2S sample rate, not suggest to exceed 48000 Hz, otherwise more glitches and noise may appear

i2s_clock_src_t clk_src
   Choose clock source

i2s_mclk_multiple_t mclk_multiple
   The multiple of mclk to the sample rate

uint32_t up_sample_fp
   Up-sampling param fp

uint32_t up_sample_fs
   Up-sampling param fs, not allowed to be greater than 480

struct i2s_pdm_tx_gpio_config_t
   I2S PDM tx mode GPIO pins configuration.

Public Members

gpio_num_t clk
   PDM clk pin, output
**gpio_num_t dout**

DATA pin, output

uint32_t clk_inv

Set 1 to invert the clk output

struct i2s_pdm_tx_gpio_config_t::[anonymous] invert_flags

GPIO pin invert flags

struct i2s_pdm_tx_config_t

I2S PDM TX mode major configuration that including clock/slot/gpio configuration.

**Public Members**

i2s_pdm_tx_clk_config_t clk_cfg

PDM TX clock configurations, can be generated by macro I2S_PDM_TX_CLK_DEFAULT_CONFIG

i2s_pdm_tx_slot_config_t slot_cfg

PDM TX slot configurations, can be generated by macro I2S_PDM_TX_SLOT_DEFAULT_CONFIG

i2s_pdm_tx_gpio_config_t gpio_cfg

PDM TX gpio configurations, specified by user

**Macros**

I2S_PDM_RX_SLOT_DEFAULT_CONFIG (bits_per_sample, mono_or_stereo)

PDM format in 2 slots(RX)

This file is specified for I2S PDM communication mode Features:

- Only support PDM tx/rx mode
- Fixed to 2 slots
- Data bit width only support 16 bits

**Parameters**

- bits_per_sample - i2s data bit width, only support 16 bits for PDM mode
- mono_or_stereo - I2S_SLOT_MODE_MONO or I2S_SLOT_MODE_STEREO

I2S_PDM_RX_CLK_DEFAULT_CONFIG (rate)

d2s default pdm rx clock configuration

**Parameters**

- rate - sample rate

I2S_PDM_TX_SLOT_DEFAULT_CONFIG (bits_per_sample, mono_or_stereo)

PDM style in 2 slots(TX)

**Parameters**

- bits_per_sample - i2s data bit width, only support 16 bits for PDM mode
- mono_or_stereo - I2S_SLOT_MODE_MONO or I2S SLOT_MODE_STEREO

I2S_PDM_TX_CLK_DEFAULT_CONFIG (rate)

i2s default pdm tx clock configuration
Note: TX PDM can only be set to the following two up-sampling rate configurations: 1: fp = 960, fs = sample_rate_hz / 100, in this case, Fpdm = 128*48000 2: fp = 960, fs = 480, in this case, Fpdm = 128*Fpcm = 128*sample_rate_hz If the pdm receiver do not care the pdm serial clock, it’s recommended set Fpdm = 128*48000. Otherwise, the second configuration should be adopted.

Parameters
• **rate** - sample rate (not suggest to exceed 48000 Hz, otherwise more glitches and noise may appear)

I2S Driver

Header File
• components/driver/i2s/include/driver/i2s_common.h

Functions
```c
esp_err_t i2s_new_channel(const i2s_chan_config_t *chan_cfg, i2s_chan_handle_t *ret_tx_handle, i2s_chan_handle_t *ret_rx_handle)
```
Allocate new I2S channel(s)

Note: The new created I2S channel handle will be REGISTERED state after it is allocated successfully.

Note: When the port id in channel configuration is I2S_NUM_AUTO, driver will allocate I2S port automatically on one of the i2s controller, otherwise driver will try to allocate the new channel on the selected port.

Note: If both tx_handle and rx_handle are not NULL, it means this I2S controller will work at full-duplex mode, the rx and tx channels will be allocated on a same I2S port in this case. Note that some configurations of tx/rx channel are shared on ESP32 and ESP32S2, so please make sure they are working at same condition and under same status(start/stop). Currently, full-duplex mode can’t guarantee tx/rx channels write/read synchronously, they can only share the clock signals for now.

Note: If tx_handle OR rx_handle is NULL, it means this I2S controller will work at simplex mode. For ESP32 and ESP32S2, the whole I2S controller (i.e. both rx and tx channel) will be occupied, even if only one of rx or tx channel is registered. For the other targets, another channel on this controller will still available.

Parameters
• **chan_cfg** - [in] I2S controller channel configurations
• **ret_tx_handle** - [out] I2S channel handler used for managing the sending channel(optional)
• **ret_rx_handle** - [out] I2S channel handler used for managing the receiving channel(optional)

Returns
• ESP_OK Allocate new channel(s) success
• ESP_ERR_NOT_SUPPORTED The communication mode is not supported on the current chip
• ESP_ERR_INVALID_ARG NULL pointer or illegal parameter in i2s_chan_config_t
• ESP_ERR_NOT_FOUND No available I2S channel found
**esp_err_t i2s_del_channel(i2s_chan_handle_t handle)**

Delete the i2s channel.

**Note:** Only allowed to be called when the i2s channel is at REGISTERED or READY state (i.e., it should stop before deleting it).

**Note:** Resource will be free automatically if all channels in one port are deleted

**Parameters**
- **handle** – [in] I2S channel handler

**Returns**
- ESP_OK Delete successfully
- ESP_ERR_INVALID_ARG NULL pointer

**esp_err_t i2s_channel_get_info(i2s_chan_handle_t handle, i2s_chan_info_t *chan_info)**

Get I2S channel information.

**Parameters**
- **handle** – [in] I2S channel handler
- **chan_info** – [out] I2S channel basic information

**Returns**
- ESP_OK Get i2s channel information success
- ESP_ERR_NOT_FOUND The input handle doesn’t match any registered I2S channels, it may not an i2s channel handle or not available any more
- ESP_ERR_INVALID_ARG The input handle or chan_info pointer is NULL

**esp_err_t i2s_channel_enable(i2s_chan_handle_t handle)**

Enable the i2s channel.

**Note:** Only allowed to be called when the channel state is READY, (i.e., channel has been initialized, but not started) the channel will enter RUNNING state once it is enabled successfully.

**Note:** Enable the channel can start the I2S communication on hardware. It will start outputting bclk and ws signal. For mclksignal, it will start to output when initialization is finished

**Parameters**
- **handle** – [in] I2S channel handler

**Returns**
- ESP_OK Start successfully
- ESP_ERR_INVALID_ARG NULL pointer
- ESP_ERR_INVALID_STATE This channel has not initialized or already started

**esp_err_t i2s_channel_disable(i2s_chan_handle_t handle)**

Disable the i2s channel.

**Note:** Only allowed to be called when the channel state is RUNNING, (i.e., channel has been started) the channel will enter READY state once it is disabled successfully.

**Note:** Disable the channel can stop the I2S communication on hardware. It will stop bclk and ws signal but not mclk signal

**Parameters**
- **handle** – [in] I2S channel handler

**Returns**
i2s_channel_preload_data

Preload the data into TX DMA buffer.

**Note:** Only allowed to be called when the channel state is READY, (i.e., channel has been initialized, but not started)

**Note:** As the initial DMA buffer has no data inside, it will transmit the empty buffer after enabled the channel, this function is used to preload the data into the DMA buffer, so that the valid data can be transmitted immediately after the channel is enabled.

**Note:** This function can be called multiple times before enabling the channel, the buffer that loaded later will be concatenated behind the former loaded buffer. But when all the DMA buffers have been loaded, no more data can be preload then, please check the bytes_loaded parameter to see how many bytes are loaded successfully, when the bytes_loaded is smaller than the size, it means the DMA buffers are full.

**Parameters**

- `tx_handle` - [in] I2S TX channel handler
- `src` - [in] The pointer of the source buffer to be loaded
- `size` - [in] The source buffer size
- `bytes_loaded` - [out] The bytes that successfully been loaded into the TX DMA buffer

**Returns**

- `ESP_OK` Load data successful
- `ESP_ERR_INVALID_ARG` NULL pointer or not TX direction
- `ESP_ERR_INVALID_STATE` This channel has not stated

i2s_channel_write

I2S write data.

**Note:** Only allowed to be called when the channel state is RUNNING, (i.e., tx channel has been started and is not writing now) but the RUNNING only stands for the software state, it doesn’t mean there is no the signal transporting on line.

**Parameters**

- `handle` - [in] I2S channel handler
- `src` - [in] The pointer of sent data buffer
- `size` - [in] Max data buffer length
- `bytes_written` - [out] Byte number that actually be sent, can be NULL if not needed
- `timeout_ms` - [in] Max block time

**Returns**

- `ESP_OK` Write successfully
- `ESP_ERR_INVALID_ARG` NULL pointer or this handle is not tx handle
- `ESP_ERR_TIMEOUT` Writing timeout, no writing event received from ISR within ticks_to_wait
- `ESP_ERR_INVALID_STATE` I2S is not ready to write
**esp_err_t i2s_channel_read**

```c
i2s_channel_read(i2s_chan_handle_t handle, void *dest, size_t size, size_t *bytes_read, uint32_t timeout_ms)
```

I2S read data.

**Note:** Only allowed to be called when the channel state is RUNNING but the RUNNING only stands for the software state, it doesn’t mean there is no the signal transporting on line.

**Parameters**
- **handle** – ![in] I2S channel handler
- **dest** – ![in] The pointer of receiving data buffer
- **size** – ![in] Max data buffer length
- **bytes_read** – ![out] Byte number that actually be read, can be NULL if not needed
- **timeout_ms** – ![in] Max block time

**Returns**
- ESP_OK Read successfully
- ESP_ERR_INVALID_ARG NULL pointer or this handle is not rx handle
- ESP_ERR_TIMEOUT Reading timeout, no reading event received from ISR within ticks_to_wait
- ESP_ERR_INVALID_STATE I2S is not ready to read

**esp_err_t i2s_channel_register_event_callback**

```c
i2s_channel_register_event_callback(i2s_chan_handle_t handle, const i2s_event_callbacks_t *callbacks, void *user_data)
```

Set event callbacks for I2S channel.

**Note:** Only allowed to be called when the channel state is REGISTERED / READY, (i.e., before channel starts)

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the callbacks structure to NULL.

**Note:** When CONFIG_I2S_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well. The **user_data** should also reside in SRAM or internal RAM as well.

**Parameters**
- **handle** – ![in] I2S channel handler
- **callbacks** – ![in] Group of callback functions
- **user_data** – ![in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK Set event callbacks successfully
- ESP_ERR_INVALID_ARG Set event callbacks failed because of invalid argument
- ESP_ERR_INVALID_STATE Set event callbacks failed because the current channel state is not REGISTERED or READY

**Structures**

```c
struct i2s_event_callbacks_t
```

Group of I2S callbacks.
Note: The callbacks are all running under ISR environment.

Note: When CONFIG_I2S_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well.

Public Members

*i2s_isr_callback_t on_recv*

Callback of data received event, only for rx channel. The event data includes DMA buffer address and size that just finished receiving data.

*i2s_isr_callback_t on_recv_q_ovf*

Callback of receiving queue overflowed event, only for rx channel. The event data includes buffer size that has been overwritten.

*i2s_isr_callback_t on_sent*

Callback of data sent event, only for tx channel. The event data includes DMA buffer address and size that just finished sending data.

*i2s_isr_callback_t on_send_q_ovf*

Callback of sending queue overflowed event, only for tx channel. The event data includes buffer size that has been overwritten.

struct *i2s_chan_config_t*

I2S controller channel configuration.

Public Members

*i2s_port_t id*

I2S port id.

*i2s_role_t role*

I2S role, I2S_ROLE_MASTER or I2S_ROLE_SLAVE.

uint32_t dma_desc_num

I2S DMA buffer number, it is also the number of DMA descriptor.

uint32_t dma_frame_num

I2S frame number in one DMA buffer. One frame means one-time sample data in all slots, it should be the multiple of ‘3’ when the data bit width is 24.

bool auto_clear

Set to auto clear DMA TX buffer, i2s will always send zero automatically if no data to send.

struct *i2s_chan_info_t*

I2S channel information.
Public Members

*i2s_port_t* id
I2S port id

*i2s_role_t* role
I2S role, I2S_ROLE_MASTER or I2S_ROLE_SLAVE

*i2s_dir_t* dir
I2S channel direction

*i2s_comm_mode_t* mode
I2S channel communication mode

*i2s_chan_handle_t* pair_chan
I2S pair channel handle in duplex mode, always NULL in simplex mode

Macros

*I2S_CHANNEL_DEFAULT_CONFIG* (i2s_num, i2s_role)
get default I2S property

*I2S_GPIO_UNUSED*
Used in i2s_gpio_config_t for signals which are not used

I2S Types

Header File
- components/driver/i2s/include/driver/i2s_types.h

Structures

struct *i2s_event_data_t*
Event structure used in I2S event queue.

Public Members

void *data
The pointer of DMA buffer that just finished sending or receiving for on_recv and on_sent callback
NULL for on_recv_q_ovf and on_send_q_ovf callback

size_t size
The buffer size of DMA buffer when success to send or receive, also the buffer size that dropped when queue overflow. It is related to the dma_frame_num and data_bit_width, typically it is fixed when data_bit_width is not changed.
Type Definitions

typedef struct i2s_channel_obj_t *i2s_chan_handle_t
  i2s channel object handle, the control unit of the i2s driver

typedef bool (*i2s_isr_callback_t)(i2s_chan_handle_t handle, i2s_event_data_t *event, void *user_ctx)
  I2S event callback.

  Param handle [in] I2S channel handle, created from i2s_new_channel()
  Param event [in] I2S event data
  Param user_ctx [in] User registered context, passed from
  i2s_channel_register_event_callback()
  Return Whether a high priority task has been waken up by this callback function

Enumerations

enum i2s_port_t
  I2S controller port number, the max port number is (SOC_I2S_NUM -1).
  Values:

  enumerator I2S_NUM_0
    I2S controller port 0

  enumerator I2S_NUM_1
    I2S controller port 1

  enumerator I2S_NUM_AUTO
    Select whichever port is available

enum i2s_comm_mode_t
  I2S controller communication mode.
  Values:

  enumerator I2S_COMM_MODE_STD
    I2S controller using standard communication mode, support philips/MSB/PCM format

  enumerator I2S_COMM_MODE_PDM
    I2S controller using PDM communication mode, support PDM output or input

  enumerator I2S_COMM_MODE_NONE
    Unspecified I2S controller mode

enum i2s_mclk_multiple_t
  The multiple of mclk to sample rate.
  Values:

  enumerator I2S_MCLK_MULTIPLE_128
    mclk = sample_rate * 128

  enumerator I2S_MCLK_MULTIPLE_256
    mclk = sample_rate * 256
enumerator **I2S_MCLK_MULTIPLE_384**
\[ mclk = \text{sample_rate} \times 384 \]

enumerator **I2S_MCLK_MULTIPLE_512**
\[ mclk = \text{sample_rate} \times 512 \]

**Header File**
- components/hal/include/hal/i2s_types.h

**Type Definitions**

typedef `soc_periph_i2s_clk_src_t` **i2s_clock_src_t**

I2S clock source

**Enumerations**

enum **i2s_slot_mode_t**

I2S channel slot mode.

*Values:*

enumerator **I2S_SLOT_MODE_MONO**

I2S channel slot format mono, transmit same data in all slots for tx mode, only receive the data in the first slots for rx mode.

enumerator **I2S_SLOT_MODE_STEREO**

I2S channel slot format stereo, transmit different data in different slots for tx mode, receive the data in all slots for rx mode.

enum **i2s_dir_t**

I2S channel direction.

*Values:*

enumerator **I2S_DIR_RX**

I2S channel direction RX

enumerator **I2S_DIR_TX**

I2S channel direction TX

enum **i2s_role_t**

I2S controller role.

*Values:*

enumerator **I2S_ROLE_MASTER**

I2S controller master role, belk and ws signal will be set to output

enumerator **I2S_ROLE_SLAVE**

I2S controller slave role, belk and ws signal will be set to input
enum \texttt{i2s\_data\_bit\_width\_t}

Available data bit width in one slot.

\textit{Values:}

- \texttt{I2S\_DATA\_BIT\_WIDTH\_8BIT}
  - I2S channel data bit-width: 8

- \texttt{I2S\_DATA\_BIT\_WIDTH\_16BIT}
  - I2S channel data bit-width: 16

- \texttt{I2S\_DATA\_BIT\_WIDTH\_24BIT}
  - I2S channel data bit-width: 24

- \texttt{I2S\_DATA\_BIT\_WIDTH\_32BIT}
  - I2S channel data bit-width: 32

enum \texttt{i2s\_slot\_bit\_width\_t}

Total slot bit width in one slot.

\textit{Values:}

- \texttt{I2S\_SLOT\_BIT\_WIDTH\_AUTO}
  - I2S channel slot bit-width equals to data bit-width

- \texttt{I2S\_SLOT\_BIT\_WIDTH\_8BIT}
  - I2S channel slot bit-width: 8

- \texttt{I2S\_SLOT\_BIT\_WIDTH\_16BIT}
  - I2S channel slot bit-width: 16

- \texttt{I2S\_SLOT\_BIT\_WIDTH\_24BIT}
  - I2S channel slot bit-width: 24

- \texttt{I2S\_SLOT\_BIT\_WIDTH\_32BIT}
  - I2S channel slot bit-width: 32

enum \texttt{i2s\_pdm\_dsr\_t}

I2S PDM RX down-sampling mode.

\textit{Values:}

- \texttt{I2S\_PDM\_DSR\_8S}
  - downsampling number is 8 for PDM RX mode

- \texttt{I2S\_PDM\_DSR\_16S}
  - downsampling number is 16 for PDM RX mode

- \texttt{I2S\_PDM\_DSR\_MAX}
enum `i2s_pdm_sig_scale_t`

pdm tx signal scaling mode

**Values:**

enumerator `I2S_PDM_SIG_SCALING_DIV_2`

I2S TX PDM signal scaling: /2

enumerator `I2S_PDM_SIG_SCALING_MUL_1`

I2S TX PDM signal scaling: x1

enumerator `I2S_PDM_SIG_SCALING_MUL_2`

I2S TX PDM signal scaling: x2

enumerator `I2S_PDM_SIG_SCALING_MUL_4`

I2S TX PDM signal scaling: x4

---

enum `i2s_std_slot_mask_t`

I2S slot select in standard mode.

**Note:** It has different meanings in tx/rx/mono/stereo mode, and it may have different behaviors on different targets. For the details, please refer to the I2S API reference.

**Values:**

enumerator `I2S_STD_SLOT_LEFT`

I2S transmits or receives left slot

enumerator `I2S_STD_SLOT_RIGHT`

I2S transmits or receives right slot

enumerator `I2S_STD_SLOT_BOTH`

I2S transmits or receives both left and right slot

---

enum `i2s_pdm_slot_mask_t`

I2S slot select in PDM mode.

**Values:**

enumerator `I2S_PDM_SLOT_RIGHT`

I2S PDM only transmits or receives the PDM device whose ‘select’ pin is pulled up

enumerator `I2S_PDM_SLOT_LEFT`

I2S PDM only transmits or receives the PDM device whose ‘select’ pin is pulled down

enumerator `I2S_PDM_SLOT_BOTH`

I2S PDM transmits or receives both two slots
2.6.10 LCD

Introduction

ESP chips can generate various kinds of timings that needed by common LCDs on the market, like SPI LCD, I80 LCD (a.k.a Intel 8080 parallel LCD), RGB/SRGB LCD, I2C LCD, etc. The esp_lcd component is officially to support those LCDs with a group of universal APIs across chips.

Functional Overview

In esp_lcd, an LCD panel is represented by esp_lcd_panel_handle_t, which plays the role of an abstract frame buffer, regardless of the frame memory is allocated inside ESP chip or in external LCD controller. Based on the location of the frame buffer and the hardware connection interface, the LCD panel drivers are mainly grouped into the following categories:

- **Controller based LCD driver** involves multiple steps to get a panel handle, like bus allocation, IO device registration and controller driver install. The frame buffer is located in the controller’s internal GRAM (Graphical RAM). ESP-IDF provides only a limited number of LCD controller drivers out of the box (e.g. ST7789, SSD1306). More Controller Based LCD Drivers are maintained in the Espressif Component Registry [https://components.espressif.com/].
- **SPI Interfaced LCD** describes the steps to install the SPI LCD IO driver and then get the panel handle.
- **I2C Interfaced LCD** describes the steps to install the I2C LCD IO driver and then get the panel handle.
- **I80 Interfaced LCD** describes the steps to install the I80 LCD IO driver and then get the panel handle.
- **LCD Panel IO Operations** - provides a set of APIs to operate the LCD panel, like turning on/off the display, setting the orientation, etc. These operations are common for either controller-based LCD panel driver or RGB LCD panel driver.

**SPI Interfaced LCD**

1. Create an SPI bus. Please refer to *SPI Master API doc* for more details.

   ```c
   spi_bus_config_t buscfg = {
       .sclk_io_num = EXAMPLE_PIN_NUM_SCLK,
       .mosi_io_num = EXAMPLE_PIN_NUM_MOSI,
       .miso_io_num = EXAMPLE_PIN_NUM_MISO,
       .quadwp_io_num = -1, // Quad SPI LCD driver is not yet supported
       .quadhd_io_num = -1, // Quad SPI LCD driver is not yet supported
       .max_transfer_sz = EXAMPLE_LCD_H_RES * 80 * sizeof(uint16_t), //
                        // transfer 80 lines of pixels (assume pixel is RGB565) at most in one
                        // SPI transaction
   };                 
   ESP_ERROR_CHECK(spi_bus_initialize(LCD_HOST, &buscfg, SPI_DMA_CH_,
                                      AUTO)); // Enable the DMA feature
   ```

2. Allocate an LCD IO device handle from the SPI bus. In this step, you need to provide the following information:
   - **esp_lcd_panel_io_spi_config_t::dc_gpio_num** Sets the gpio number for the DC signal line (some LCD calls this RS line). The LCD driver will use this GPIO to switch between sending command and sending data.
   - **esp_lcd_panel_io_spi_config_t::cs_gpio_num** Sets the gpio number for the CS signal line. The LCD driver will use this GPIO to select the LCD chip. If the SPI bus only has one device attached (i.e. this LCD), you can set the gpio number to -1 to occupy the bus exclusively.
   - **esp_lcd_panel_io_spi_config_t::pclk_hz** sets the frequency of the pixel clock, in Hz. The value should not exceed the range recommended in the LCD spec.
   - **esp_lcd_panel_io_spi_config_t::spi_mode** sets the SPI mode. The LCD driver will use this mode to communicate with the LCD. For the meaning of the SPI mode, please refer to the *SPI Master API doc*. 

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Chapter 2. API Reference

- `esp_lcd_panel_io_spi_config_t::lcd_cmd_bits` and `esp_lcd_panel_io_spi_config_t::lcd_param_bits` set the bit width of the command and parameter that recognized by the LCD controller chip. This is chip specific, you should refer to your LCD spec in advance.

- `esp_lcd_panel_io_spi_config_t::trans_queue_depth` sets the depth of the SPI transaction queue. A bigger value means more transactions can be queued up, but it also consumes more memory.

```c
esp_lcd_panel_io_handle_t io_handle = NULL;
esp_lcd_panel_io_spi_config_t io_config = {
  .dc_gpio_num = EXAMPLE_PIN_NUM_LCD_DC,
  .cs_gpio_num = EXAMPLE_PIN_NUM_LCD_CS,
  .pclk_hz = EXAMPLE_LCD PIXEL_CLOCK_HZ,
  .lcd_cmd_bits = EXAMPLE_LCD_CMD_BITS,
  .lcd_param_bits = EXAMPLE_LCD PARAM_BITS,
  .spi_mode = 0,
  .trans_queue_depth = 10,
};
// Attach the LCD to the SPI bus
ESP_ERROR_CHECK(esp_lcd_new_panel_io_spi((esp_lcd_spi_bus_handle_t)LCD_~HOST, &io_config, &io_handle));
```

3. Install the LCD controller driver. The LCD controller driver is responsible for sending the commands and parameters to the LCD controller chip. In this step, you need to specify the SPI IO device handle that allocated in the last step, and some panel specific configurations:

- `esp_lcd_panel_dev_config_t::reset_gpio_num` sets the LCD’s hardware reset GPIO number. If the LCD does not have a hardware reset pin, set this to -1.
- `esp_lcd_panel_dev_config_t::rgb_ele_order` sets the R-G-B element order of each color data.
- `esp_lcd_panel_dev_config_t::bits_per_pixel` sets the bit width of the pixel color data. The LCD driver uses this value to calculate the number of bytes to send to the LCD controller chip.
- `esp_lcd_panel_dev_config_t::data_endian` specifies the data endian to be transmitted to the screen. No need to specify for color data within 1 byte, like RGB232.

For drivers that do not support specifying data endian, this field would be ignored.

```c
esp_lcd_panel_handle_t panel_handle = NULL;
esp_lcd_panel_dev_config_t panel_config = {
  .reset_gpio_num = EXAMPLE_PIN_NUM_RST,
  .rgb_ele_order = LCD_RGB_ELEMENT_ORDER_BGR,
  .bits_per_pixel = 16,
};
// Create LCD panel handle for ST7789, with the SPI IO device handle
ESP_ERROR_CHECK(esp_lcd_new_panel_st7789(io_handle, &panel_config, &panel_handle));
```

I2C Interfaced LCD

1. Create I2C bus. Please refer to I2C API doc for more details.

```c
i2c_config_t i2c_conf = {
  .mode = I2C_MODE_MASTER, // I2C LCD is a master node
  .sda_io_num = EXAMPLE_PIN_NUM_SDA,
  .scl_io_num = EXAMPLE_PIN_NUM_SCL,
  .sda_pullup_en = GPIO_PULLUP_ENABLE,
  .scl_pullup_en = GPIO_PULLUP_ENABLE,
  .master.clk_speed = EXAMPLE_LCD PIXEL_CLOCK_HZ,
};
ESP_ERROR_CHECK(i2c_param_config(I2C HOST, &i2c_conf));
ESP_ERROR_CHECK(i2c_driver_install(I2C HOST, I2C_MODE_MASTER, 0, 0, 0));
```
(continues on next page)
2. Allocate an LCD IO device handle from the I2C bus. In this step, you need to provide the following information:
   • `esp_lcd_panel_io_i2c_config_t::dev_addr` sets the I2C device address of the LCD controller chip. The LCD driver will use this address to communicate with the LCD controller chip.
   • `esp_lcd_panel_io_i2c_config_t::lcd_cmd_bits` and `esp_lcd_panel_io_i2c_config_t::lcd_param_bits` set the bit width of the command and parameter that recognized by the LCD controller chip. This is chip specific, you should refer to your LCD spec in advance.

```c
esp_lcd_panel_io_t io_handle = NULL;
esp_lcd_panel_io_i2c_config_t io_config = {
    .dev_addr = EXAMPLE_I2C_HW_ADDR,
    .control_phase_bytes = 1, // refer to LCD spec
    .dc_bit_offset = 6, // refer to LCD spec
    .lcd_cmd_bits = EXAMPLE_LCD_CMD_BITS,
    .lcd_param_bits = EXAMPLE_LCD_CMD_BITS,
};
ESP_ERROR_CHECK(esp_lcd_new_panel_io_i2c((esp_lcd_i2c_bus_handle_t)I2C_HOST, &io_config, &io_handle));
```

3. Install the LCD controller driver. The LCD controller driver is responsible for sending the commands and parameters to the LCD controller chip. In this step, you need to specify the I2C IO device handle that allocated in the last step, and some panel specific configurations:
   • `esp_lcd_panel_dev_config_t::reset_gpio_num` sets the LCD’s hardware reset GPIO number. If the LCD does not have a hardware reset pin, set this to -1.
   • `esp_lcd_panel_dev_config_t::bits_per_pixel` sets the bit width of the pixel color data. The LCD driver will use this value to calculate the number of bytes to send to the LCD controller chip.

```c
esp_lcd_panel_handle_t panel_handle = NULL;
esp_lcd_panel_dev_config_t panel_config = {
    .bits_per_pixel = 1,
    .reset_gpio_num = EXAMPLE_PIN_NUM_RST,
};
ESP_ERROR_CHECK(esp_lcd_new_panel_ssd1306(io_handle, &panel_config, &panel_handle));
```

### I80 Interfaced LCD

1. Create I80 bus by `esp_lcd_new_i80_bus()`. You need to set up the following parameters for an Intel 8080 parallel bus:
   • `esp_lcd_i80_bus_config_t::clk_src` sets the clock source of the I80 bus. Note, the default clock source may be different between ESP targets.
   • `esp_lcd_i80_bus_config_t::wr_gpio_num` sets the GPIO number of the pixel clock (also referred as WR in some LCD spec)
   • `esp_lcd_i80_bus_config_t::dc_gpio_num` sets the GPIO number of the data/command select pin (also referred as RS in some LCD spec)
   • `esp_lcd_i80_bus_config_t::bus_width` sets the bit width of the data bus (only support 8 or 16)
   • `esp_lcd_i80_bus_config_t::data_gpio_nums` is the array of the GPIO number of the data bus. The number of GPIOs should be equal to the `esp_lcd_i80_bus_config_t::bus_width` value.
   • `esp_lcd_i80_bus_config_t::max_transfer_bytes` sets the maximum number of bytes that can be transferred in one transaction.

```c
esp_lcd_i80_bus_handle_t i80_bus = NULL;
esp_lcd_i80_bus_config_t bus_config = {
```
2. Allocate an LCD IO device handle from the I80 bus. In this step, you need to provide the following information:
   - `esp_lcd_panel_io_i80_config_t::cs_gpio_num` sets the GPIO number of the chip select pin.
   - `esp_lcd_panel_io_i80_config_t::pclk_hz` sets the pixel clock frequency in Hz. Higher pixel clock frequency will result in higher refresh rate, but may cause flickering if the DMA bandwidth is not sufficient or the LCD controller chip does not support high pixel clock frequency.
   - `esp_lcd_panel_io_i80_config_t::trans_queue_depth` sets the maximum number of transactions that can be queued in the LCD IO device. A bigger value means more transactions can be queued up, but it also consumes more memory.

```c
esp_lcd_panel_io_i80_config_t io_config = {
    .cs_gpio_num = EXAMPLE_PIN_NUM_CS,
    .pclk_hz = EXAMPLE_LCD_PIXEL_CLOCK_HZ,
    .trans_queue_depth = 10,
    .dc_levels = {
        .dc_idle_level = 0,
        .dc_cmd_level = 0,
        .dc_dummy_level = 0,
        .dc_data_level = 1,
    },
    .lcd_cmd_bits = EXAMPLE_LCD_CMD_BITS,
    .lcd_param_bits = EXAMPLE_LCD_PARAM_BITS,
};
ESP_ERROR_CHECK(esp_lcd_new_panel_io_i80(i80_bus, &io_config, &io__handle));
```

3. Install the LCD controller driver. The LCD controller driver is responsible for sending the commands and parameters to the LCD controller chip. In this step, you need to specify the I80 IO device handle that allocated in the last step, and some panel specific configurations:
   - `esp_lcd_panel_dev_config_t::bits_per_pixel` sets the bit width of the pixel color data. The LCD driver will use this value to calculate the number of bytes to send to the LCD controller chip.
   - `esp_lcd_panel_dev_config_t::reset_gpio_num` sets the GPIO number of the

```c
.esp_lcd_panel_io_handle_t io_handle = NULL;
esp_lcd_panel_io_i80_config_t io_config = {
    .cs_gpio_num = EXAMPLE_PIN_NUM_CS,
    .pclk_hz = EXAMPLE_LCD_PIXEL_CLOCK_HZ,
    .trans_queue_depth = 10,
    .dc_levels = {
        .dc_idle_level = 0,
        .dc_cmd_level = 0,
        .dc_dummy_level = 0,
        .dc_data_level = 1,
    },
    .lcd_cmd_bits = EXAMPLE_LCD_CMD_BITS,
    .lcd_param_bits = EXAMPLE_LCD_PARAM_BITS,
};
ESP_ERROR_CHECK(esp_lcd_new_panel_io_i80(i80_bus, &io_config, &io__handle));
```
reset pin. If the LCD controller chip does not have a reset pin, you can set this value to \(-1\).

- `esp_lcd_panel_dev_config_t::rgb_ele_order` sets the color order the pixel color data.

```c
esp_lcd_panel_dev_config_t panel_config = {
    .reset_gpio_num = EXAMPLE_PIN_NUM_RST,
    .rgb_ele_order = LCD_RGB_ELEMENT_ORDER_RGB,
    .bits_per_pixel = 16,
};
ESP_ERROR_CHECK(esp_lcd_new_panel_st7789(io_handle, &panel_config, &panel_handle));
```

More Controller Based LCD Drivers

More LCD panel drivers and touch drivers are available in IDF Component Registry. The list of available and planned drivers with links is in this table.

LCD Panel IO Operations

- `esp_lcd_panel_reset()` can reset the LCD panel.
- Use `esp_lcd_panel_swap_xy()` and `esp_lcd_panel_mirror()`, you can rotate the LCD screen.
- `esp_lcd_panel_disp_on_off()` can turn on or off the LCD screen (different from LCD backlight).
- `esp_lcd_panel_draw_bitmap()` is the most significant function, that will do the magic to draw the user provided color buffer to the LCD screen, where the draw window is also configurable.

Application Example

LCD examples are located under: `peripherals/lcd`:

- Universal SPI LCD example with SPI touch - `peripherals/lcd/spi_lcd_touch`
- Jpeg decoding and LCD display - `peripherals/lcd/tjpgd`
- i80 controller based LCD and LVGL animation UI - `peripherals/lcd/i80_controller`
- I2C interfaced OLED display scrolling text - `peripherals/lcd/i2coled`

API Reference

Header File

- `components/hal/include/hal/lcd_types.h`

Macros

`LCD_RGB_ENDIAN_RGB`

`LCD_RGB_ENDIAN_BGR`

Type Definitions

typedef `soc_periph_lcd_clk_src_t` `lcd_clock_source_t`

LCD clock source.

typedef `lcd_rgb_element_order_t` `lcd_color_rgb_endian_t`

for backward compatible
Enumerations

enum **lcd_rgb_element_order_t**
  RGB color endian.
  
  Values:

  enumerator **LCD_RGB_ELEMENT_ORDER_RGB**
  RGB element order: RGB

  enumerator **LCD_RGB_ELEMENT_ORDER_BGR**
  RGB element order: BGR

enum **lcd_rgb_data_endian_t**
  RGB data endian.
  
  Values:

  enumerator **LCD_RGB_DATA_ENDIAN_BIG**
  RGB data endian: MSB first

  enumerator **LCD_RGB_DATA_ENDIAN_LITTLE**
  RGB data endian: LSB first

enum **lcd_color_space_t**
  LCD color space.
  
  Values:

  enumerator **LCD_COLOR_SPACE_RGB**
  Color space: RGB

  enumerator **LCD_COLOR_SPACE_YUV**
  Color space: YUV

enum **lcd_color_range_t**
  LCD color range.
  
  Values:

  enumerator **LCD_COLOR_RANGE_LIMIT**
  Limited color range

  enumerator **LCD_COLOR_RANGE_FULL**
  Full color range

enum **lcd_yuv_sample_t**
  YUV sampling method.
  
  Values:

  enumerator **LCD_YUV_SAMPLE_422**
  YUV 4:2:2 sampling
enumerator LCD_YUV_SAMPLE_420
   YUV 4:2:0 sampling

enumerator LCD_YUV_SAMPLE_411
   YUV 4:1:1 sampling

enum lcd_yuv_conv_std_t
   The standard used for conversion between RGB and YUV.
   Values:

enumerator LCD_YUV_CONV_STD_BT601
   YUV<->RGB conversion standard: BT.601

enumerator LCD_YUV_CONV_STD_BT709
   YUV<->RGB conversion standard: BT.709

Header File
   • components/esp_lcd/include/esp_lcd_types.h

Type Definitions

typedef struct esp_lcd_panel_io_t *esp_lcd_panel_io_handle_t
   Type of LCD panel IO handle

typedef struct esp_lcd_panel_t *esp_lcd_panel_handle_t
   Type of LCD panel handle

Header File
   • components/esp_lcd/include/esp_lcd_panel_io.h

Functions

esp_err_t esp_lcd_panel_io_rx_param(esp_lcd_panel_io_handle_t io, int lcd_cmd, void *param, size_t param_size)
   Transmit LCD command and receive corresponding parameters.

   Note: Commands sent by this function are short, so they are sent using polling transactions. The function does not return before the command transfer is completed. If any queued transactions sent by esp_lcd_panel_io_tx_color() are still pending when this function is called, this function will wait until they are finished and the queue is empty before sending the command(s).

Parameters
   • io  [in]  LCD panel IO handle, which is created by other factory API like esp_lcd_new_panel_io_spi()
   • lcd_cmd  [in]  The specific LCD command, set to -1 if no command needed
   • param  [out]  Buffer for the command data
   • param_size  [in]  Size of param buffer

Returns
   • ESP_ERR_INVALID_ARG if parameter is invalid
   • ESP_ERR_NOT_SUPPORTED if read is not supported by transport
• ESP_OK on success

```c
esp_err_t esp_lcd_panel_io_tx_param(esp_lcd_panel_io_handle_t io, int lcd_cmd, const void *param,
                                   size_t param_size)
```

Transmit LCD command and corresponding parameters.

**Note:** Commands sent by this function are short, so they are sent using polling transactions. The function does not return before the command transfer is completed. If any queued transactions sent by `esp_lcd_panel_io_tx_color()` are still pending when this function is called, this function will wait until they are finished and the queue is empty before sending the command(s).

**Parameters**

- **io** - [in] LCD panel IO handle, which is created by other factory API like `esp_lcd_new_panel_io_spi()`
- **lcd_cmd** - [in] The specific LCD command, set to -1 if no command needed
- **param** - [in] Buffer that holds the command specific parameters, set to NULL if no parameter is needed for the command
- **param_size** - [in] Size of param in memory, in bytes, set to zero if no parameter is needed for the command

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

```c
esp_err_t esp_lcd_panel_io_tx_color(esp_lcd_panel_io_handle_t io, int lcd_cmd, const void *color,
                                    size_t color_size)
```

Transmit LCD RGB data.

**Note:** This function will package the command and RGB data into a transaction, and push into a queue. The real transmission is performed in the background (DMA+interrupt). The caller should take care of the lifecycle of the `color` buffer. Recycling of color buffer should be done in the callback `on_color_trans_done()`.

**Parameters**

- **io** - [in] LCD panel IO handle, which is created by factory API like `esp_lcd_new_panel_io_spi()`
- **lcd_cmd** - [in] The specific LCD command, set to -1 if no command needed
- **color** - [in] Buffer that holds the RGB color data
- **color_size** - [in] Size of color in memory, in bytes

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

```c
esp_err_t esp_lcd_panel_io_del(esp_lcd_panel_io_handle_t io)
```

Destroy LCD panel IO handle (deinitialize panel and free all corresponding resource)

**Parameters**

- **io** - [in] LCD panel IO handle, which is created by factory API like `esp_lcd_new_panel_io_spi()`

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

```c
esp_err_t esp_lcd_panel_io_register_event_callbacks(esp_lcd_panel_io_handle_t io, const
                                                  esp_lcd_panel_io_callbacks_t *cbs, void
                                                  *user_ctx)
```

Register LCD panel IO callbacks.

**Parameters**
• **io** - [in] LCD panel IO handle, which is created by factory API like `esp_lcd_new_panel_io_spi()`  
• **cbs** - [in] structure with all LCD panel IO callbacks  
• **user_ctx** - [in] User private data, passed directly to callback’s user_ctx

**Returns**
- ESP_ERR_INVALID_ARG if parameter is invalid  
- ESP_OK on success

```c
esp_err_t esp_lcd_new_panel_io_spi(esp_lcd_spi_bus_handle_t bus, const esp_lcd_panel_io_spi_config_t *io_config, esp_lcd_panel_io_handle_t *ret_io)
```

Create LCD panel IO handle, for SPI interface.

**Parameters**
- **bus** - [in] SPI bus handle  
- **io_config** - [in] IO configuration, for SPI interface  
- **ret_io** - [out] Returned IO handle

**Returns**
- ESP_ERR_INVALID_ARG if parameter is invalid  
- ESP_ERR_NO_MEM if out of memory  
- ESP_OK on success

```c
esp_err_t esp_lcd_new_panel_io_i2c(esp_lcd_i2c_bus_handle_t bus, const esp_lcd_panel_io_i2c_config_t *io_config, esp_lcd_panel_io_handle_t *ret_io)
```

Create LCD panel IO handle, for I2C interface.

**Parameters**
- **bus** - [in] I2C bus handle  
- **io_config** - [in] IO configuration, for I2C interface  
- **ret_io** - [out] Returned IO handle

**Returns**
- ESP_ERR_INVALID_ARG if parameter is invalid  
- ESP_ERR_NO_MEM if out of memory  
- ESP_OK on success

```c
esp_err_t esp_lcd_new_i80_bus(const esp_lcd_i80_bus_config_t *bus_config, esp_lcd_i80_bus_handle_t *ret_bus)
```

Create Intel 8080 bus handle.

**Parameters**
- **bus_config** - [in] Bus configuration  
- **ret_bus** - [out] Returned bus handle

**Returns**
- ESP_ERR_INVALID_ARG if parameter is invalid  
- ESP_ERR_NO_MEM if out of memory  
- ESP_ERR_NOT_FOUND if no free bus is available  
- ESP_OK on success

```c
esp_err_t esp_lcd_del_i80_bus(esp_lcd_i80_bus_handle_t bus)
```

Destroy Intel 8080 bus handle.

**Parameters**
- **bus** - [in] Intel 8080 bus handle, created by `esp_lcd_new_i80_bus()`  

**Returns**
- ESP_ERR_INVALID_ARG if parameter is invalid  
- ESP_ERR_INVALID_STATE if there still be some device attached to the bus  
- ESP_OK on success

```c
esp_err_t esp_lcd_new_panel_io_i80(esp_lcd_i80_bus_handle_t bus, const esp_lcd_panel_io_i80_config_t *io_config, esp_lcd_panel_io_handle_t *ret_io)
```

Create LCD panel IO, for Intel 8080 interface.
Parameters

- **bus** [in] Intel 8080 bus handle, created by `esp_lcd_new_i80_bus()`
- **io_config** [in] IO configuration, for i80 interface
- **ret_io** [out] Returned panel IO handle

Returns

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_NOT_SUPPORTED if some configuration can’t be satisfied, e.g. pixel clock out of the range
- ESP_ERR_NO_MEM if out of memory
- ESP_OK on success

Structures

```c
struct esp_lcd_panel_io_event_data_t
    Type of LCD panel IO event data.
```

```c
struct esp_lcd_panel_io_callbacks_t
    Type of LCD panel IO callbacks.
```

Public Members

```c
esp_lcd_panel_io_color_trans_done_cb_t on_color_trans_done
    Callback invoked when color data transfer has finished
```

```c
struct esp_lcd_panel_io_spi_config_t
    Panel IO configuration structure, for SPI interface.
```

Public Members

```
int cs_gpio_num
    GPIO used for CS line
```

```
int dc_gpio_num
    GPIO used to select the D/C line, set this to -1 if the D/C line is not used
```

```
int spi_mode
    Traditional SPI mode (0~3)
```

```
unsigned int pclk_hz
    Frequency of pixel clock
```

```
size_t trans_queue_depth
    Size of internal transaction queue
```

```c
esp_lcd_panel_io_color_trans_done_cb_t on_color_trans_done
    Callback invoked when color data transfer has finished
```

```c
void *user_ctx
    User private data, passed directly to on_color_trans_done’ s user_ctx
```
int **lcd_cmd_bits**
Bit-width of LCD command

int **lcd_param_bits**
Bit-width of LCD parameter

unsigned int **dc_low_on_data**
If this flag is enabled, DC line = 0 means transfer data, DC line = 1 means transfer command; vice versa

unsigned int **octal_mode**
transmit with octal mode (8 data lines), this mode is used to simulate Intel 8080 timing

unsigned int **quad_mode**
transmit with quad mode (4 data lines), this mode is useful when transmitting LCD parameters (Only use one line for command)

unsigned int **sio_mode**
Read and write through a single data line (MOSI)

unsigned int **lsb_first**
transmit LSB bit first

unsigned int **cs_high_active**
CS line is high active

struct **esp_lcd_panel_io_spi_config_t::[anonymous]** flags
Extra flags to fine-tune the SPI device

struct **esp_lcd_panel_io_i2c_config_t**
Panel IO configuration structure, for I2C interface.

**Public Members**

uint32_t **dev_addr**
I2C device address

*esp_lcd_panel_io_color_trans_done_cb_t** on_color_trans_done
Callback invoked when color data transfer has finished

void **user_ctx**
User private data, passed directly to on_color_trans_done’s user_ctx

size_t **control_phase_bytes**
I2C LCD panel will encode control information (e.g. D/C selection) into control phase, in several bytes

unsigned int **dc_bit_offset**
Offset of the D/C selection bit in control phase
intlcd_cmd_bits
    Bit-width of LCD command

intlcd_param_bits
    Bit-width of LCD parameter

unsigned int dc_low_on_data
    If this flag is enabled, DC line = 0 means transfer data, DC line = 1 means transfer command; vice versa

unsigned int disable_control_phase
    If this flag is enabled, the control phase isn’t used

struct esp_lcd_panel_io_i2c_config_t::[anonymous] flags
    Extra flags to fine-tune the I2C device

struct esp_lcd_i80_bus_config_t
    LCD Intel 8080 bus configuration structure.

Public Members

int dc_gpio_num
    GPIO used for D/C line

int wr_gpio_num
    GPIO used for WR line

lcd_clock_source_t clk_src
    Clock source for the I80 LCD peripheral

int data_gpio_nums[(24)]
    GPIOs used for data lines

size_t bus_width
    Number of data lines, 8 or 16

size_t max_transfer_bytes
    Maximum transfer size, this determines the length of internal DMA link

size_t psram_trans_align
    DMA transfer alignment for data allocated from PSRAM

size_t sram_trans_align
    DMA transfer alignment for data allocated from SRAM

struct esp_lcd_panel_io_i80_config_t
    Panel IO configuration structure, for intel 8080 interface.
Public Members

int cs_gpio_num
    GPIO used for CS line, set to -1 will declaim exclusively use of I80 bus

uint32_t pclk_hz
    Frequency of pixel clock

size_t trans_queue_depth
    Transaction queue size, larger queue, higher throughput

esp_lcd_panel_io_color_trans_done_cb_t on_color_trans_done
    Callback invoked when color data was transferred done

void *user_ctx
    User private data, passed directly to on_color_trans_done’s user_ctx

int lcd_cmd_bits
    Bit-width of LCD command

int lcd_param_bits
    Bit-width of LCD parameter

unsigned int dc_idle_level
    Level of DC line in IDLE phase

unsigned int dc_cmd_level
    Level of DC line in CMD phase

unsigned int dc_dummy_level
    Level of DC line in DUMMY phase

unsigned int dc_data_level
    Level of DC line in DATA phase

struct esp_lcd_panel_io_i80_config_t::[anonymous] dc_levels
    Each i80 device might have its own D/C control logic

unsigned int cs_active_high
    If set, a high level of CS line will select the device, otherwise, CS line is low level active

unsigned int reverse_color_bits
    Reverse the data bits, D[N:0] -> D[0:N]

unsigned int swap_color_bytes
    Swap adjacent two color bytes

unsigned int pclk_active_neg
    The display will write data lines when there’s a falling edge on WR signal (a.k.a the PCLK)
unsigned int pclk_idle_low

The WR signal (a.k.a the PCLK) stays at low level in IDLE phase

struct esp_lcd_panel_io_i80_config_t::{anonymous} flags

Panel IO config flags

Type Definitions

typedef void *esp_lcd_spi_bus_handle_t

Type of LCD SPI bus handle

typedef void *esp_lcd_i2c_bus_handle_t

Type of LCD I2C bus handle

typedef struct esp_lcd_i80_bus_t *esp_lcd_i80_bus_handle_t

Type of LCD intel 8080 bus handle

typedef bool (*esp_lcd_panel_io_color_trans_done_cb_t)(esp_lcd_panel_io_handle_t panel_io, esp_lcd_panel_io_event_data_t *edata, void *user_ctx)

Declares the prototype of the function that will be invoked when panel IO finishes transferring color data.

Param panel_io [in] LCD panel IO handle, which is created by factory API like esp_lcd_new_panel_io_spi()

Param edata [in] Panel IO event data, fed by driver

Param user_ctx [in] User data, passed from esp_lcd_panel_io_xxx_config_t

Return Whether a high priority task has been waken up by this function

Header File

- components/esp_lcd/include/esp_lcd_panel_ops.h

Functions

esp_err_t esp_lcd_panel_reset (esp_lcd_panel_handle_t panel)

Reset LCD panel.

Note: Panel reset must be called before attempting to initialize the panel using esp_lcd_panel_init().

Parameters panel [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_io_st7789()

Returns

- ESP_OK on success

esp_err_t esp_lcd_panel_init (esp_lcd_panel_handle_t panel)

Initialize LCD panel.

Note: Before calling this function, make sure the LCD panel has finished the reset stage by esp_lcd_panel_reset().

Parameters panel [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_io_st7789()

Returns

- ESP_OK on success
esp_err_t esp_lcd_panel_del(esp_lcd_panel_handle_t panel)

Deinitialize the LCD panel.

**Parameters**
- panel – [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()

**Returns**
- ESP_OK on success

esp_err_t esp_lcd_panel_draw_bitmap(esp_lcd_panel_handle_t panel, int x_start, int y_start, int x_end, int y_end, const void *color_data)

Draw bitmap on LCD panel.

**Parameters**
- panel – [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- x_start – [in] Start index on x-axis (x_start included)
- y_start – [in] Start index on y-axis (y_start included)
- x_end – [in] End index on x-axis (x_end not included)
- y_end – [in] End index on y-axis (y_end not included)
- color_data – [in] RGB color data that will be dumped to the specific window range

**Returns**
- ESP_OK on success

esp_err_t esp_lcd_panel_mirror(esp_lcd_panel_handle_t panel, bool mirror_x, bool mirror_y)

Mirror the LCD panel on specific axis.

**Note:** Combined with esp_lcd_panel_swap_xy(), one can realize screen rotation

**Parameters**
- panel – [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- mirror_x – [in] Whether the panel will be mirrored about the x axis
- mirror_y – [in] Whether the panel will be mirrored about the y axis

**Returns**
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if this function is not supported by the panel

esp_err_t esp_lcd_panel_swap_xy(esp_lcd_panel_handle_t panel, bool swap_axes)

Swap/Exchange x and y axis.

**Note:** Combined with esp_lcd_panel_mirror(), one can realize screen rotation

**Parameters**
- panel – [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- swap_axes – [in] Whether to swap the x and y axis

**Returns**
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if this function is not supported by the panel

esp_err_t esp_lcd_panel_set_gap(esp_lcd_panel_handle_t panel, int x_gap, int y_gap)

Set extra gap in x and y axis.

The gap is the space (in pixels) between the left/top sides of the LCD panel and the first row/column respectively of the actual contents displayed.
Note: Setting a gap is useful when positioning or centering a frame that is smaller than the LCD.

Parameters
• **panel** - [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
• **x_gap** - [in] Extra gap on x axis, in pixels
• **y_gap** - [in] Extra gap on y axis, in pixels

Returns
• ESP_OK on success

```c
esp_err_t esp_lcd_panel_invert_color(esp_lcd_panel_handle_t panel, bool invert_color_data)
```
Invert the color (bit-wise invert the color data line)

Parameters
• **panel** - [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
• **invert_color_data** - [in] Whether to invert the color data

Returns
• ESP_OK on success

```c
esp_err_t esp_lcd_panel_disp_on_off(esp_lcd_panel_handle_t panel, bool on_off)
```
Turn on or off the display.

Parameters
• **panel** - [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
• **on_off** - [in] True to turns on display, False to turns off display

Returns
• ESP_OK on success
• ESP_ERR_NOT_SUPPORTED if this function is not supported by the panel

```c
esp_err_t esp_lcd_panel_disp_off(esp_lcd_panel_handle_t panel, bool off)
```
Turn off the display.

Parameters
• **panel** - [in] LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
• **off** - [in] Whether to turn off the screen

Returns
• ESP_OK on success
• ESP_ERR_NOT_SUPPORTED if this function is not supported by the panel

Header File
• components/esp_lcd/include/esp_lcd_panel_rgb.h

Header File
• components/esp_lcd/include/esp_lcd_panel_vendor.h

Functions
```c
esp_err_t esp_lcd_new_panel_st7789(const esp_lcd_panel_io_handle_t io, const esp_lcd_panel_dev_config_t *panel_dev_config, esp_lcd_panel_handle_t *ret_panel)
```
Create LCD panel for model ST7789.

Parameters
• io  [in] LCD panel IO handle
• panel_dev_config [in] general panel device configuration
• ret_panel  [out] Returned LCD panel handle

Returns
• ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_ERR_NO_MEM if out of memory
• ESP_OK on success

```
esp_err_t esp_lcd_new_panel_nt35510 (const esp_lcd_panel_io_handle_t io, const esp_lcd_panel_dev_config_t *panel_dev_config, esp_lcd_panel_handle_t *ret_panel)
```

Create LCD panel for model NT35510.

Parameters
• io  [in] LCD panel IO handle
• panel_dev_config [in] general panel device configuration
• ret_panel  [out] Returned LCD panel handle

Returns
• ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_ERR_NO_MEM if out of memory
• ESP_OK on success

```
esp_err_t esp_lcd_new_panel_ssd1306 (const esp_lcd_panel_io_handle_t io, const esp_lcd_panel_dev_config_t *panel_dev_config, esp_lcd_panel_handle_t *ret_panel)
```

Create LCD panel for model SSD1306.

Parameters
• io  [in] LCD panel IO handle
• panel_dev_config [in] general panel device configuration
• ret_panel  [out] Returned LCD panel handle

Returns
• ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_ERR_NO_MEM if out of memory
• ESP_OK on success

Structures

```
struct esp_lcd_panel_dev_config_t
```

Configuration structure for panel device.

Public Members

```

int reset_gpio_num
```

GPIO used to reset the LCD panel, set to -1 if it’s not used

```
lcd_rgb_element_order_t color_space
```

Deprecated:
Set RGB color space, please use rgb_ele_order instead

```
lcd_rgb_element_order_t rgb_endian
```

Deprecated:
Set RGB data endian, please use rgb_ele_order instead
### Chapter 2. API Reference

**lcd_rgb_element_order_t rgb_ele_order**
Set RGB element order, RGB or BGR

**lcd_rgb_data_endian_t data_endian**
Set the data endian for color data larger than 1 byte

unsigned int **bits_per_pixel**
Color depth, in bpp

unsigned int **reset_active_high**
Setting this if the panel reset is high level active

struct **esp_lcd_panel_dev_config_t::[anonymous]** \[flags\]
LCD panel config flags

void ***vendor_config**
vendor specific configuration, optional, left as NULL if not used

### 2.6.11 LED Control (LEDC)

#### Introduction

The LED control (LEDC) peripheral is primarily designed to control the intensity of LEDs, although it can also be used to generate PWM signals for other purposes. It has 8 channels which can generate independent waveforms that can be used, for example, to drive RGB LED devices.

LEDC channels are divided into two groups of 8 channels each. One group of LEDC channels operates in high speed mode. This mode is implemented in hardware and offers automatic and glitch-free changing of the PWM duty cycle. The other group of channels operate in low speed mode, the PWM duty cycle must be changed by the driver in software. Each group of channels is also able to use different clock sources.

The PWM controller can automatically increase or decrease the duty cycle gradually, allowing for fades without any processor interference.

#### Functionality Overview

Setting up a channel of the LEDC in either high or low speed mode is done in three steps:

1. **Timer Configuration** by specifying the PWM signal’s frequency and duty cycle resolution.
2. **Channel Configuration** by associating it with the timer and GPIO to output the PWM signal.
3. **Change PWM Signal** that drives the output in order to change LED’s intensity. This can be done under the full control of software or with hardware fading functions.

As an optional step, it is also possible to set up an interrupt on fade end.

**Note:** For an initial setup, it is recommended to configure for the timers first (by calling `ledc_timer_config()`), and then for the channels (by calling `ledc_channel_config()`). This ensures the PWM frequency is at the desired value since the appearance of the PWM signal from the IO pad.
Chapter 2. API Reference

**Fig. 12: Key Settings of LED PWM Controller’s API**

**Timer Configuration** Setting the timer is done by calling the function `ledc_timer_config()` and passing the data structure `ledc_timer_config_t` that contains the following configuration settings:

- Speed mode `ledc_mode_t`
- Timer number `ledc_timer_t`
- PWM signal frequency
- Resolution of PWM duty
- Source clock `ledc_clk_cfg_t`

The frequency and the duty resolution are interdependent. The higher the PWM frequency, the lower the duty resolution which is available, and vice versa. This relationship might be important if you are planning to use this API for purposes other than changing the intensity of LEDs. For more details, see Section Supported Range of Frequency and Duty Resolutions.

The source clock can also limit the PWM frequency. The higher the source clock frequency, the higher the maximum PWM frequency can be configured.

**Table 5: Characteristics of ESP32 LEDC source clocks**

<table>
<thead>
<tr>
<th>Clock name</th>
<th>Clock freq</th>
<th>Speed mode</th>
<th>Clock capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>APB_CLK</td>
<td>80 MHz</td>
<td>High/Low</td>
<td>/</td>
</tr>
<tr>
<td>REF_TICK</td>
<td>1 MHz</td>
<td>High/Low</td>
<td>Dynamic Frequency Scaling compatible</td>
</tr>
<tr>
<td>RC_FAST_CLK-8 MHz</td>
<td>8 MHz</td>
<td>Low</td>
<td>Dynamic Frequency Scaling compatible, Light sleep compatible</td>
</tr>
</tbody>
</table>

**Note:**
1. On ESP32, if RC_FAST_CLK is chosen as the LEDC clock source, an internal calibration will be performed to get the exact frequency of the clock. This ensures the accuracy of output PWM signal frequency.

**Channel Configuration** When the timer is set up, configure the desired channel (one out of `ledc_channel_t`). This is done by calling the function `ledc_channel_config()`.

---

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Similar to the timer configuration, the channel setup function should be passed a structure `ledc_channel_config_t` that contains the channel’s configuration parameters.

At this point, the channel should start operating and generating the PWM signal on the selected GPIO, as configured in `ledc_channel_config_t`, with the frequency specified in the timer settings and the given duty cycle. The channel operation (signal generation) can be suspended at any time by calling the function `ledc_stop()`.

**Change PWM Signal** Once the channel starts operating and generating the PWM signal with the constant duty cycle and frequency, there is a couple of ways to change this signal. When driving LEDs, primarily the duty cycle is changed to vary the light intensity.

The following two sections describe how to change the duty cycle using software and hardware fading. If required, the signal’s frequency can also be changed; it is covered in Section **Change PWM Frequency**.

**Change PWM Duty Cycle Using Software** To set the duty cycle, use the dedicated function `ledc_set_duty()`. After that, call `ledc_update_duty()` to activate the changes. To check the currently set value, use the corresponding get function `ledc_get_duty()`.

Another way to set the duty cycle, as well as some other channel parameters, is by calling `ledc_channel_config()` covered in Section **Channel Configuration**.

The range of the duty cycle values passed to functions depends on selected duty resolution and should be from 0 to \((2 ^ \text{duty_resolution}) - 1\). For example, if the selected duty resolution is 10, then the duty cycle values can range from 0 to 1023. This provides the resolution of ~0.1%.

**Change PWM Duty Cycle using Hardware** The LEDC hardware provides the means to gradually transition from one duty cycle value to another. To use this functionality, enable fading with `ledc_fade_func_install()` and then configure it by calling one of the available fading functions:

- `ledc_set_fade_with_time()`
- `ledc_set_fade_with_step()`
- `ledc_set_fade()`

Start fading with `ledc_fade_start()`. A fade can be operated in blocking or non-blocking mode, please check `ledc_fade_mode_t` for the difference between the two available fade modes. Note that with either fade mode, the next fade or fixed-duty update will not take effect until the last fade finishes. Due to hardware limitations, there is no way to stop a fade before it reaches its target duty.

To get a notification about the completion of a fade operation, a fade end callback function can be registered for each channel by calling `ledc_cb_register()` after the fade service being installed. The fade end callback prototype is defined in `ledc_cb_t`, where you should return a boolean value from the callback function, indicating whether a high priority task is woken up by this callback function. It is worth mentioning, the callback and the function invoked by itself should be placed in IRAM, as the interrupt service routine is in IRAM. `ledc_cb_register()` will print a warning message if it finds the addresses of callback and user context are incorrect.

If not required anymore, fading and an associated interrupt can be disabled with `ledc_fade_func_uninstall()`.

**Change PWM Frequency** The LEDC API provides several ways to change the PWM frequency “on the fly”:

- Set the frequency by calling `ledc_set_freq()`. There is a corresponding function `ledc_get_freq()` to check the current frequency.
- Change the frequency and the duty resolution by calling `ledc_bind_channel_timer()` to bind some other timer to the channel.
- Change the channel’s timer by calling `ledc_channel_config()`.

**More Control Over PWM** There are several lower level timer-specific functions that can be used to change PWM settings:

- `ledc_timer_set()`


- `ledc_timer_rst()`
- `ledc_timer_pause()`
- `ledc_timer_resume()`

The first two functions are called “behind the scenes” by `ledc_channel_config()` to provide a startup of a timer after it is configured.

**Use Interrupts** When configuring an LEDC channel, one of the parameters selected within `ledc_channel_config_t` is `ledc_intr_type_t` which triggers an interrupt on fade completion.

For registration of a handler to address this interrupt, call `ledc_isr_register()`.

**LEDC High and Low Speed Mode**

High speed mode enables a glitch-free changeover of timer settings. This means that if the timer settings are modified, the changes will be applied automatically on the next overflow interrupt of the timer. In contrast, when updating the low-speed timer, the change of settings should be explicitly triggered by software. The LEDC driver handles it in the background, e.g., when `ledc_timer_config()` or `ledc_timer_set()` is called.

For additional details regarding speed modes, see ESP32 Technical Reference Manual > LED PWM Controller (LEDC) [PDF].

**Supported Range of Frequency and Duty Resolutions**

The LED PWM Controller is designed primarily to drive LEDs. It provides a large flexibility of PWM duty cycle settings. For instance, the PWM frequency of 5 kHz can have the maximum duty resolution of 13 bits. This means that the duty can be set anywhere from 0 to 100% with a resolution of ~0.012% (2**13 = 8192 discrete levels of the LED intensity). Note, however, that these parameters depend on the clock signal clocking the LED PWM Controller timer which in turn clocks the channel (see timer configuration and the ESP32 Technical Reference Manual > LED PWM Controller (LEDC) [PDF]).

The LEDC can be used for generating signals at much higher frequencies that are sufficient enough to clock other devices, e.g., a digital camera module. In this case, the maximum available frequency is 40 MHz with duty resolution of 1 bit. This means that the duty cycle is fixed at 50% and cannot be adjusted.

The LEDC API is designed to report an error when trying to set a frequency and a duty resolution that exceed the range of LEDC’s hardware. For example, an attempt to set the frequency to 20 MHz and the duty resolution to 3 bits will result in the following error reported on a serial monitor:

```
E (196) ledc: requested frequency and duty resolution cannot be achieved, try reelection freq_hz or duty_resolution. div_param=128
```

In such a situation, either the duty resolution or the frequency must be reduced. For example, setting the duty resolution to 2 will resolve this issue and will make it possible to set the duty cycle at 25% steps, i.e., at 25%, 50% or 75%.

The LEDC driver will also capture and report attempts to configure frequency / duty resolution combinations that are below the supported minimum, e.g.:

```
E (196) ledc: requested frequency and duty resolution cannot be achieved, try reelection freq_hz or duty_resolution. div_param=128000000
```

The duty resolution is normally set using `ledc_timer_bit_t`. This enumeration covers the range from 10 to 15 bits. If a smaller duty resolution is required (from 10 down to 1), enter the equivalent numeric values directly.

**Application Example**

The LEDC basic example: `peripherals/ledc/ledc_basic`.

The LEDC change duty cycle and fading control example: `peripherals/ledc/ledc_fade`. 
Chapter 2. API Reference

API Reference

Header File

- components/driver/ledc/include/driver/ledc.h

Functions

`esp_err_t ledc_channel_config(const ledc_channel_config_t *ledc_conf)`

LEDC channel configuration Configure LEDC channel with the given channel/output gpio_num/interrupt/source timer/frequency(Hz)/LEDC duty resolution.

Parameters `ledc_conf` - Pointer of LEDC channel configure struct

Returns

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t ledc_timer_config(const ledc_timer_config_t *timer_conf)`

LEDC timer configuration Configure LEDC timer with the given source timer/frequency(Hz)/duty_resolution.

Parameters `timer_conf` - Pointer of LEDC timer configure struct

Returns

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Can not find a proper pre-divider number base on the given frequency and the current duty_resolution.

`esp_err_t ledc_update_duty(ledc_mode_t speed_mode, ledc_channel_t channel)`

LEDC update channel parameters.

Note: Call this function to activate the LEDC updated parameters. After ledc_set_duty, we need to call this function to update the settings. And the new LEDC parameters don’t take effect until the next PWM cycle.

Note: ledc_set_duty, ledc_set_duty_with_hpoint and ledc_update_duty are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is ledc_set_duty_and_update

Parameters

- `speed_mode` - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- `channel` - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from ledc_channel_t

Returns

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

`esp_err_t ledc_set_pin(int gpio_num, ledc_mode_t speed_mode, ledc_channel_t ledc_channel)`

Set LEDC output gpio.

Note: This function only routes the LEDC signal to GPIO through matrix, other LEDC resources initialization are not involved. Please use ledc_channel_config() instead to fully configure a LEDC channel.

Parameters

- `gpio_num` - The LEDC output gpio
- `speed_mode` - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
• **ledc_channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from ledc_channel_t

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t ledc_stop (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t idle_level)
```

LEDC stop. Disable LEDC output, and set idle level.

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from ledc_channel_t
- **idle_level** - Set output idle level after LEDC stops.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t ledc_set_freq (ledc_mode_t speed_mode, ledc_timer_t timer_num, uint32_t freq_hz)
```

LEDC set channel frequency (Hz)

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **timer_num** - LEDC timer index (0-3), select from ledc_timer_t
- **freq_hz** - Set the LEDC frequency

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Can not find a proper pre-divider number base on the given frequency and the current duty resolution.

```c
uint32_t ledc_get_freq (ledc_mode_t speed_mode, ledc_timer_t timer_num)
```

LEDC get channel frequency (Hz)

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **timer_num** - LEDC timer index (0-3), select from ledc_timer_t

**Returns**
- 0 error
- Others Current LEDC frequency

```c
esp_err_t ledc_set_duty_with_hpoint (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t duty, uint32_t hpoint)
```

LEDC set duty and hpoint value. Only after calling ledc_update_duty will the duty update.

**Note:** ledc_set_duty, ledc_set_duty_with_hpoint and ledc_update_duty are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is ledc_set_duty_and_update.

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

**Parameters**
**Chapter 2. API Reference**

- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from ledc_channel_t
- **duty** - Set the LEDC duty, the range of duty setting is \([0, (2^{duty\_resolution}) - 1]\)
- **hpoint** - Set the LEDC hpoint value (max: 0xfffff)

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```
int ledc_get_hpoint (ledc_mode_t speed_mode, ledc_channel_t channel)
```

LEDC get hpoint value, the counter value when the output is set high level.

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from ledc_channel_t

**Returns**
- LEDC_ERR_VAL if parameter error
- Others Current hpoint value of LEDC channel

```
esp_err_t ledc_set_duty (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t duty)
```

LEDC set duty This function do not change the hpoint value of this channel. If needed, please call ledc_set_duty_with_hpoint. Only after calling ledc_update_duty will the duty update.

**Note:** ledc_set_duty, ledc_set_duty_with_hpoint and ledc_update_duty are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is ledc_set_duty_and_update.

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

```
uint32_t ledc_get_duty (ledc_mode_t speed_mode, ledc_channel_t channel)
```

LEDC get duty This function returns the duty at the present PWM cycle. You shouldn’t expect the function to return the new duty in the same cycle of calling ledc_update_duty, because duty update doesn’t take effect until the next cycle.

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from ledc_channel_t

**Returns**
- LEDC_ERR_DUTY if parameter error
- Others Current LEDC duty
**Chapter 2. API Reference**

```
esp_err_t ledc_set_fade (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t duty,
                           ledc_duty_direction_t fade_direction, uint32_t step_num, uint32_t duty_cycle_num,
                           uint32_t duty_scale)
```

LEDC set gradient. Set LEDC gradient. After the function calls the `lede_update_duty` function, the function can take effect.

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- **duty** - Set the start of the gradient duty, the range of duty setting is \([0, (2^{**duty\_resolution}) - 1]\)
- **fade_direction** - Set the direction of the gradient
- **step_num** - Set the number of the gradient
- **duty_cycle_num** - Set how many LEDC tick each time the gradient lasts
- **duty_scale** - Set gradient change amplitude

**Returns**
- **ESP_OK** Success
- **ESP_ERR_INVALID_ARG** Parameter error

```
esp_err_t ledc_isr_register (void (*fn)(void*), void *arg, int intr_alloc_flags,
                            ledc_isr_handle_t *handle)
```

Register LEDC interrupt handler, the handler is an ISR. The handler will be attached to the same CPU core that this function is running on.

**Parameters**
- **fn** - Interrupt handler function.
- **arg** - User-supplied argument passed to the handler function.
- **intr_alloc_flags** - Flags used to allocate the interrupt. One or multiple (ORred) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info.
- **handle** - Pointer to return handle. If non-NULL, a handle for the interrupt will be returned here.

**Returns**
- **ESP_OK** Success
- **ESP_ERR_INVALID_ARG** Function pointer error.

```
esp_err_t ledc_timer_set (ledc_mode_t speed_mode, ledc_timer_t timer_sel, uint32_t clock_divider,
                          uint32_t duty_resolution, lede_clk_src_t clk_src)
```

Configure LEDC settings.

**Parameters**
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **timer_sel** - Timer index (0-3), there are 4 timers in LEDC module
- **clock_divider** - Timer clock divide value, the timer clock is divided from the selected clock source
- **duty_resolution** - Resolution of duty setting in number of bits. The range of duty values is \([0, (2^{**duty\_resolution})]\)
- **clk_src** - Select LEDC source clock.

**Returns**
- **(-1)** Parameter error
- **Other Current LEDC duty

```
esp_err_t ledc_timer_rst (ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Reset LEDC timer.
Chapter 2. API Reference

Parameters

• **speed_mode** – Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.

• **timer_sel** – LEDC timer index (0-3), select from `ledc_timer_t`

Returns

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

`esp_err_t ledc_timer_pause(ledc_mode_t speed_mode, ledc_timer_t timer_sel)`

Pause LEDC timer counter.

Parameters

• **speed_mode** – Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.

• **timer_sel** – LEDC timer index (0-3), select from `ledc_timer_t`

Returns

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

`esp_err_t ledc_timer_resume(ledc_mode_t speed_mode, ledc_timer_t timer_sel)`

Resume LEDC timer.

Parameters

• **speed_mode** – Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.

• **timer_sel** – LEDC timer index (0-3), select from `ledc_timer_t`

Returns

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

`esp_err_t ledc_bind_channel_timer(ledc_mode_t speed_mode, ledc_channel_t channel, ledc_timer_t timer_sel)`

Bind LEDC channel with the selected timer.

Parameters

• **speed_mode** – Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.

• **channel** – LEDC channel index (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`

• **timer_sel** – LEDC timer index (0-3), select from `ledc_timer_t`

Returns

• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

`esp_err_t ledc_set_fade_with_step(ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t scale, uint32_t cycle_num)`

Set LEDC fade function.

**Note:** Call `ledc_fade_func_install()` once before calling this function. Call `ledc_fade_start()` after this to start fading.

**Note:** `ledc_set_fade_with_step`, `ledc_set_fade_with_time` and `ledc_fade_start` are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is `ledc_set_fade_step_and_start`

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress.
on that channel. Other duty operations will have to wait until the fade operation has finished.

Parameters
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel index (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- **target_duty** - Target duty of fading \([0, (2^{\text{duty_resolution}}) - 1]\)
- **scale** - Controls the increase or decrease step scale.
- **cycle_num** - Increase or decrease the duty every `cycle_num` cycles

Returns
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

```c
esp_err_t ledc_set_fade_with_time(ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, int max_fade_time_ms)
```

Set LEDC fade function, with a limited time.

**Note:** Call `ledc_fade_func_install()` once before calling this function. Call `ledc_fade_start()` after this to start fading.

**Note:** `ledc_set_fade_with_step`, `ledc_set_fade_with_time` and `ledc_fade_start` are not thread-safe, do not call these functions to control one LEDC channel in different tasks at the same time. A thread-safe version of API is `ledc_set_fade_step_and_start`.

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

Parameters
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel index (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- **target_duty** - Target duty of fading \([0, (2^{\text{duty_resolution}}) - 1]\)
- **max_fade_time_ms** - The maximum time of the fading (ms).

Returns
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

```c
esp_err_t ledc_fade_func_install(int intr_alloc_flags)
```

Install LEDC fade function. This function will occupy interrupt of LEDC module.

**Parameters** `intr_alloc_flags` - Flags used to allocate the interrupt. One or multiple (ORred) `ESP_INTR_FLAG_*` values. See `esp_intr_alloc.h` for more info.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function already installed.
**void ledc_fade_func_uninstall (void)**

Uninstall LEDC fade function.

**esp_err_t ledc_fade_start (ledc_mode_t speed_mode, ledc_channel_t channel, ledc_fade_mode_t fade_mode)**

Start LEDC fading.

**Note:** Call `ledc_fade_func_install()` once before calling this function. Call this API right after `ledc_set_fade_with_time` or `ledc_set_fade_with_step` before to start fading.

**Note:** Starting fade operation with this API is not thread-safe, use with care.

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

**Parameters**

- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel number
- **fade_mode** - Whether to block until fading done. See `ledc_types.h ledc_fade_mode_t` for more info. Note that this function will not return until fading to the target duty if `LEDC_FADE_WAIT_DONE` mode is selected.

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_ERR_INVALID_ARG Parameter error.

**esp_err_t ledc_set_duty_and_update (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t duty, uint32_t hpoint)**

A thread-safe API to set duty for LEDC channel and return when duty updated.

**Note:** For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

**Parameters**

- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- **duty** - Set the LEDC duty, the range of duty setting is [0, (2**duty_resolution) - 1]
- **hpoint** - Set the LEDC hpoint value(max: 0xfffff)

**esp_err_t ledc_set_fade_time_and_start (ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t max_fade_time_ms, ledc_fade_mode_t fade_mode)**

A thread-safe API to set and start LEDC fade function, with a limited time.

**Note:** Call `ledc_fade_func_install()` once, before calling this function.
Note: For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

Parameters
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel index (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- **target_duty** - Target duty of fading [0, (2**duty_resolution) - 1]
- **max Fade time ms** - The maximum time of the fading (ms).
- **fade_mode** - Choose blocking or non-blocking mode

Returns
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

```c
esp_err_t ledc_set_fade_step_and_start(ledc_mode_t speed_mode, ledc_channel_t channel, uint32_t target_duty, uint32_t scale, uint32_t cycle_num, ledc_fade_mode_t fade_mode)
```

A thread-safe API to set and start LEDC fade function.

Note: Call `ledc_fade_func_install()` once before calling this function.

Note: For ESP32, hardware does not support any duty change while a fade operation is running in progress on that channel. Other duty operations will have to wait until the fade operation has finished.

Parameters
- **speed_mode** - Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.
- **channel** - LEDC channel index (0 - LEDC_CHANNEL_MAX-1), select from `ledc_channel_t`
- **target_duty** - Target duty of fading [0, (2**duty_resolution) - 1]
- **scale** - Controls the increase or decrease step scale.
- **cycle_num** - Increase or decrease the duty every cycle_num cycles
- **fade_mode** - Choose blocking or non-blocking mode

Returns
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

```c
esp_err_t ledc_cb_register(ledc_mode_t speed_mode, ledc_channel_t channel, ledc_cbs_t *cbs, void *user_arg)
```

LEDC callback registration function.

Note: The callback is called from an ISR, it must never attempt to block, and any FreeRTOS API called must be ISR capable.
• **speed_mode** – Select the LEDC channel group with specified speed mode. Note that not all targets support high speed mode.

• **channel** – LEDC channel index (0 - LEDC_CHANNEL_MAX-1), select from \texttt{ledc_channel_t}

• **cbs** – Group of LEDC callback functions

• **user_arg** – User registered data for the callback function

**Returns**

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

**Structures**

\texttt{struct ledc_channel_config_t}

Configuration parameters of LEDC channel for \texttt{ledc_channel_config} function.

**Public Members**

\begin{verbatim}
int gpio_num  
    the LEDC output gpio_num, if you want to use gpio16, gpio_num = 16

ledc_mode_t speed_mode  
    LEDC speed speed_mode, high-speed mode or low-speed mode

ledc_channel_t channel  
    LEDC channel (0 - LEDC_CHANNEL_MAX-1)

ledc_intr_type_t intr_type  
    configure interrupt, Fade interrupt enable or Fade interrupt disable

ledc_timer_t timer_sel  
    Select the timer source of channel (0 - LEDC_TIMER_MAX-1)

uint32_t duty  
    LEDC channel duty, the range of duty setting is [0, (2**duty_resolution)]

int hpoint  
    LEDC channel hpoint value, the max value is 0xffffffff

unsigned int output_invert  
    Enable (1) or disable (0) gpio output invert

struct ledc_channel_config_t::[anonymous] flags  
    LEDC flags
\end{verbatim}

\texttt{struct ledc_timer_config_t}

Configuration parameters of LEDC Timer timer for \texttt{ledc_timer_config} function.
Public Members

`ledc_mode_t speed_mode`
LEDC speed speed_mode, high-speed mode or low-speed mode

`ledc_timer_bit_t duty_resolution`
LEDC channel duty resolution

`ledc_timer_t timer_num`
The timer source of channel (0 - LEDC_TIMER_MAX-1)

`uint32_t freq_hz`
LEDC timer frequency (Hz)

`ledc_clk_cfg_t clk_cfg`
Configure LEDC source clock from ledc_clk_cfg_t. Note that LEDC_USE_RC_FAST_CLK and LEDC_USE_XTAL_CLK are non-timer-specific clock sources. You cannot have one LEDC timer uses RC_FAST_CLK as the clock source and have another LEDC timer uses XTAL_CLK as its clock source. All chips except esp32 and esp32s2 do not have timer-specific clock sources, which means clock source for all timers must be the same one.

struct `ledc_cb_param_t`
LEDC callback parameter.

Public Members

`ledc_cb_event_t event`
Event name

`uint32_t speed_mode`
Speed mode of the LEDC channel group

`uint32_t channel`
LEDC channel (0 - LEDC_CHANNEL_MAX-1)

`uint32_t duty`
LEDC current duty of the channel, the range of duty is [0, (2**duty_resolution) - 1]

struct `ledc_cbs_t`
Group of supported LEDC callbacks.

**Note:** The callbacks are all running under ISR environment

Public Members

`ledc_cb_t fade_cb`
LEDC fade_end callback function
Macros

**LEDC_APB_CLK_HZ**

Frequency of one of the LEDC peripheral clock sources, APB_CLK.

**Note:** This macro should have no use in your application, we keep it here only for backward compatible

**LEDC_REF_CLK_HZ**

Frequency of one of the LEDC peripheral clock sources, REF_TICK.

**Note:** This macro should have no use in your application, we keep it here only for backward compatible

**LEDC_ERR_DUTY**

**LEDC_ERR_VAL**

Type Definitions

typedef `intr_handle_t` **ledc_isr_handle_t**

typedef `bool (*)(ledc_cb_t *param, void *user_arg)` **ledc_isr_fn_t**

Type of LEDC event callback.

- **Param param** LEDC callback parameter
- **Param user_arg** User registered data
- **Return** Whether a high priority task has been waken up by this function

Enumerations

enum **ledc_cb_event_t**

LEDC callback event type.

**Values:**

- **enumerator LEDC_FADE_END_EVT**
  LEDC fade end event

Header File

- `components/hal/include/hal/ledc_types.h`

Type Definitions

typedef `soc_periph_ledc_clk_src_legacy_t` **ledc_clk_cfg_t**

LEDC clock source configuration struct.

In theory, the following enumeration shall be placed in LEDC driver’s header. However, as the next enumeration, `ledc_clk_src_t`, makes the use of some of these values and to avoid mutual inclusion of the headers, we must define it here.
Enumerations

enum ledc_mode_t

Values:

enumerator LEDC_HIGH_SPEED_MODE
LEDC high speed speed_mode

enumerator LEDC_LOW_SPEED_MODE
LEDC low speed speed_mode

enumerator LEDC_SPEED_MODE_MAX
LEDC speed limit

enum ledc_intr_type_t

Values:

enumerator LEDC_INTR_DISABLE
Disable LEDC interrupt

enumerator LEDC_INTR_FADE_END
Enable LEDC interrupt

enumerator LEDC_INTR_MAX

enum ledc_duty_direction_t

Values:

enumerator LEDC_DUTY_DIR_DECREASE
LEDC duty decrease direction

enumerator LEDC_DUTY_DIR_INCREASE
LEDC duty increase direction

enumerator LEDC_DUTY_DIR_MAX

enum ledc_slow_clk_sel_t

LEDC global clock sources.

Values:

enumerator LEDC_SLOW_CLK_RC_FAST
LEDC low speed timer clock source is RC_FAST clock

enumerator LEDC_SLOW_CLK_APB
LEDC low speed timer clock source is 80MHz APB clock

enumerator LEDC_SLOW_CLK_RTC8M
Alias of ‘LEDC_SLOW_CLK_RC_FAST’
enum ledc_clk_src_t
  LEDC timer-specific clock sources.
  
Note: Setting numeric values to match ledc_clk_cfg_t values are a hack to avoid collision with LEDC_AUTO_CLK in the driver, as these enums have very similar names and user may pass one of these by mistake.

Values:

enumerator LEDC_REF_TICK
  LEDC timer clock divided from reference tick (1Mhz)

enumerator LEDC_APB_CLK
  LEDC timer clock divided from APB clock (80Mhz)

enumerator LEDC_SCLK
  Selecting this value for LEDC_TICK_SEL_TIMER let the hardware take its source clock from LEDC_APB_CLK_SEL

enum ledc_timer_t
  Values:

enumerator LEDC_TIMER_0
  LEDC timer 0

enumerator LEDC_TIMER_1
  LEDC timer 1

enumerator LEDC_TIMER_2
  LEDC timer 2

enumerator LEDC_TIMER_3
  LEDC timer 3

enumerator LEDC_TIMER_MAX

enum ledc_channel_t
  Values:

enumerator LEDC_CHANNEL_0
  LEDC channel 0

enumerator LEDC_CHANNEL_1
  LEDC channel 1

enumerator LEDC_CHANNEL_2
  LEDC channel 2

enumerator LEDC_CHANNEL_3
  LEDC channel 3
enumerator LEDC_CHANNEL_4
   LEDC channel 4

enumerator LEDC_CHANNEL_5
   LEDC channel 5

enumerator LEDC_CHANNEL_6
   LEDC channel 6

enumerator LEDC_CHANNEL_7
   LEDC channel 7

enumerator LEDC_CHANNEL_MAX

enum ledc_timer_bit_t
   Values:

enumerator LEDC_TIMER_1_BIT
   LEDC PWM duty resolution of 1 bits

enumerator LEDC_TIMER_2_BIT
   LEDC PWM duty resolution of 2 bits

enumerator LEDC_TIMER_3_BIT
   LEDC PWM duty resolution of 3 bits

enumerator LEDC_TIMER_4_BIT
   LEDC PWM duty resolution of 4 bits

enumerator LEDC_TIMER_5_BIT
   LEDC PWM duty resolution of 5 bits

enumerator LEDC_TIMER_6_BIT
   LEDC PWM duty resolution of 6 bits

enumerator LEDC_TIMER_7_BIT
   LEDC PWM duty resolution of 7 bits

enumerator LEDC_TIMER_8_BIT
   LEDC PWM duty resolution of 8 bits

enumerator LEDC_TIMER_9_BIT
   LEDC PWM duty resolution of 9 bits

enumerator LEDC_TIMER_10_BIT
   LEDC PWM duty resolution of 10 bits

enumerator LEDC_TIMER_11_BIT
   LEDC PWM duty resolution of 11 bits
2.6.12 Motor Control Pulse Width Modulator (MCPWM)

The MCPWM peripheral is a versatile PWM generator, which contains various submodules to make it a key element in power electronic applications like motor control, digital power and so on. Typically, the MCPWM peripheral can be used in the following scenarios:

- Digital motor control, e.g. brushed/brushless DC motor, RC servo motor
- Switch mode based digital power conversion
- Power DAC, where the duty cycle is equivalent to a DAC analog value
- Calculate external pulse width, and convert it into other analog value like speed, distance
• Generate Space Vector PWM (SVPWM) signals for Field Oriented Control (FOC)

The main submodules are listed in the following diagram:

![MCPWM Overview Diagram]

- **MCPWM Timer**: The time base of the final PWM signal, it also determines the event timing of other submodules.
- **MCPWM Operator**: The key module that is responsible for generating the PWM waveforms. It consists of other submodules, like comparator, PWM generator, dead-time and carrier modulator.
- **MCPWM Comparator**: The compare module takes the time-base count value as input, and continuously compare to the threshold value that configured by user. When the time-base counter is equal to any of the threshold value, an compare event will be generated and the MCPWM generator can update its level accordingly.
- **MCPWM Generator**: One MCPWM generator can generate a pair of PWM waves, complementarily or independently, based on various events triggered from other submodules like MCPWM Timer, MCPWM Comparator.
- **MCPWM Fault**: The fault module is used to detect the fault condition from outside, mainly via GPIO matrix. Once the fault signal is active, MCPWM Operator will force all the generators into a predefined state, to protect the system from damage.
- **MCPWM Sync**: The sync module is used to synchronize the MCPWM timers, so that the final PWM signals generated by different MCPWM generators can have a fixed phase difference. The sync signal can be routed from GPIO matrix or from MCPWM Timer event.
- **Dead Time**: This submodule is used to insert extra delay to the existing PWM edges that generated in the previous steps.
- **Carrier Modulation**: The carrier submodule allows a high-frequency carrier signal to modulate the PWM waveforms generated by the generator and dead time submodules. This capability is mandatory if you need pulse transformer-based gate drivers to control the power switching elements.
- **Brake**: MCPWM operator can set how to brake the generators when particular fault is detected. We can shut down the PWM output immediately or regulate the PWM output cycle by cycle, depends on how critical the fault is.
- **MCPWM Capture**: This is a standalone submodule which can work even without the above MCPWM operators. The capture consists one dedicated timer and several independent channels. Each channel is connected to the GPIO, a pulse on the GPIO will trigger the capture timer to store the time-base count value and then notify the user by interrupt. Using this feature, we can measure a pulse width precisely. What’s more, the capture timer can also be synchronized by the MCPWM Sync submodule.

**Functional Overview**

Description of the MCPWM functionality is divided into the following sections:

- **Resource Allocation and Initialization** - covers how to allocate various MCPWM objects, like timers, operators, comparators, generators and so on. These objects are the basis of the following IO setting and control functions.
• **Timer Operations and Events** - describes control functions and event callbacks that supported by the MCPWM timer.

• **Comparator Operations and Events** - describes control functions and event callbacks that supported by the MCPWM comparator.

• **Generator Actions on Events** - describes how to set actions for MCPWM generators on particular events that generated by the MCPWM timer and comparators.

• **Classical PWM Waveforms and Generator Configurations** - demonstrates some classical PWM waveforms that can be achieved by configuring generator actions.

• **Dead Time** - describes how to set dead time for MCPWM generators.

• **Classical PWM Waveforms and Dead Time Configurations** - demonstrates some classical PWM waveforms that can be achieved by configuring dead time.

• **Carrier Modulation** - describes how to set modulate a high frequency onto the final PWM waveforms.

• **Faults and Brake Actions** - describes how to set brake actions for MCPWM operators on particular fault event.

• **Generator Force Actions** - describes how to control the generator output level asynchronously in a forceful way.

• **Synchronization** - describes how to synchronize the MCPWM timers and get a fixed phase difference between the generated PWM signals.

• **Capture** - describes how to use the MCPWM capture module to measure the pulse width of a signal.

• **Power Management** - describes how different source clock will affect power consumption.

• **IRAM Safe** - describes tips on how to make the RMT interrupt work better along with a disabled cache.

• **Thread Safety** - lists which APIs are guaranteed to be thread safe by the driver.

• **Kconfig Options** - lists the supported Kconfig options that can bring different effects to the driver.

**Resource Allocation and Initialization**  As displayed in the diagram above, the MCPWM peripheral consists of several submodules. Each submodule has its own resource allocation, which is described in the following sections.

**MCPWM Timers**  You can allocate a MCPWM timer object by calling `mcpwm_new_timer()` function, with a configuration structure `mcpwm_timer_config_t` as the parameter. The configuration structure is defined as:

```c
mcpwm_timer_config_t::group_id specifies the MCPWM group ID. The ID should belong to [0, SOC_MCPWM_GROUPS - 1] range. Please note, timers located in different groups are totally independent.

mcpwm_timer_config_t::intr_priority sets the priority of the interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.

mcpwm_timer_config_t::clk_src sets the clock source of the timer.

mcpwm_timer_config_t::resolution_hz set the expected resolution of the timer, the driver internally will set a proper divider based on the clock source and the resolution.

mcpwm_timer_config_t::count_mode sets the count mode of the timer.

mcpwm_timer_config_t::period_ticks sets the period of the timer, in ticks (the tick resolution is set in the `mcpwm_timer_config_t::resolution_hz`).

mcpwm_timer_config_t::update_period_on_empty sets whether to update the period value when the timer counts to zero.

mcpwm_timer_config_t::update_period_on_sync sets whether to update the period value when the timer takes a sync signal.
```

The `mcpwm_new_timer()` will return a pointer to the allocated timer object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no more free timers in the MCPWM group, this function will return `ESP_ERR_NOT_FOUND` error.  

On the contrary, calling `mcpwm_del_timer()` function will free the allocated timer object.

**MCPWM Operators**  You can allocate a MCPWM operator object by calling `mcpwm_new_operator()` function, with a configuration structure `mcpwm_operator_config_t` as the parameter. The configuration structure is defined as:

```c
Different ESP chip series might have different number of MCPWM resources (e.g. groups, timers, comparators, operators, generators and so on). Please refer to the [TRM] for details. The driver won’t forbids you from applying for more MCPWM resources, but it will return error when there’s no hardware resources available. Please always check the return value when doing Resource Allocation.
```
• `mcpwm_operator_config_t::group_id` specifies the MCPWM group ID. The ID should belong to \([0, \text{SOC\_MCPWM}\_\text{GROUPS} - 1]\) range. Please note, operators located in different groups are totally independent.

• `mcpwm_operator_config_t::intr_priority` sets the priority of the interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.

• `mcpwm_operator_config_t::update_gen_action_on_tez` sets whether to update the generator action when the timer counts to zero. Here and below, the timer refers to the one that is connected to the operator by `mcpwm_operator_connect_timer()`.

• `mcpwm_operator_config_t::update_gen_action_on_tep` sets whether to update the generator action when the timer counts to peak.

• `mcpwm_operator_config_t::update_gen_action_on_sync` sets whether to update the generator action when the timer takes a sync signal.

• `mcpwm_operator_config_t::update_dead_time_on_tez` sets whether to update the dead time when the timer counts to zero.

• `mcpwm_operator_config_t::update_dead_time_on_tep` sets whether to update the dead time when the timer counts to peak.

• `mcpwm_operator_config_t::update_dead_time_on_sync` sets whether to update the dead time when the timer takes a sync signal.

The `mcpwm_new_operator()` function will return a pointer to the allocated operator object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no more free operators in the MCPWM group, this function will return `ESP_ERR_NOT_FOUND` error.

On the contrary, calling `mcpwm_del_operator()` function will free the allocated operator object.

**MCPWM Comparators** You can allocate a MCPWM comparator object by calling `mcpwm_new_comparator()` function, with a MCPWM operator handle and configuration structure `mcpwm_comparator_config_t` as the parameter. The operator handle is created by `mcpwm_new_operator()`(). The configuration structure is defined as:

- `mcpwm_comparator_config_t::intr_priority` sets the priority of the interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.

- `mcpwm_comparator_config_t::update_cmp_on_tez` sets whether to update the compare threshold when the timer counts to zero.

- `mcpwm_comparator_config_t::update_cmp_on_tep` sets whether to update the compare threshold when the timer counts to peak.

- `mcpwm_comparator_config_t::update_cmp_on_sync` sets whether to update the compare threshold when the timer takes a sync signal.

The `mcpwm_new_comparator()` function will return a pointer to the allocated comparator object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no more free comparators in the MCPWM operator, this function will return `ESP_ERR_NOT_FOUND` error.

On the contrary, calling `mcpwm_del_comparator()` function will free the allocated comparator object.

**MCPWM Generators** You can allocate a MCPWM generator object by calling `mcpwm_new_generator()` function, with a MCPWM operator handle and configuration structure `mcpwm_generator_config_t` as the parameter. The operator handle is created by `mcpwm_new_operator()`(). The configuration structure is defined as:

- `mcpwm_generator_config_t::gen_gpio_num` sets the GPIO number used by the generator.

- `mcpwm_generator_config_t::invert_pwm` sets whether to invert the PWM signal.

- `mcpwm_generator_config_t::io_loop_back` sets whether to enable the Loop-back mode. It is for debugging purposes only. It enables both the GPIO’s input and output ability through the GPIO matrix peripheral.

- `mcpwm_generator_config_t::io_od_mode` configures the PWM GPIO as open-drain output.

- `mcpwm_generator_config_t::pull_up` and `mcpwm_generator_config_t::pull_down` controls whether to enable the internal pull-up and pull-down resistors accordingly.
The `mcpwm_new_generator()` function will return a pointer to the allocated generator object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no more free generators in the MCPWM operator, this function will return `ESP_ERR_NOT_FOUND` error. On the contrary, calling `mcpwm_del_generator()` function will free the allocated generator object.

**MCPWM Faults** There are two types of faults: A fault signal reflected from the GPIO and a fault generated by software. To allocate a GPIO fault object, you can call `mcpwm_new_gpio_fault()` function, with configuration structure `mcpwm_gpio_fault_config_t` as the parameter. The configuration structure is defined as:

To allocate a GPIO fault object, you can call the `mcpwm_new_gpio_fault()` function, with the configuration structure `mcpwm_gpio_fault_config_t` as the parameter. The configuration structure is defined as:

- `mcpwm_gpio_fault_config_t::group_id` sets the MCPWM group ID. The ID should belong to `[0, SOC_MCPWM_GROUPS - 1]` range. Please note, GPIO faults located in different groups are totally independent, i.e., GPIO faults in group 0 can not be detected by the operator in group 1.
- `mcpwm_gpio_fault_config_t::intr_priority` sets the priority of the interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.
- `mcpwm_gpio_fault_config_t::gpio_num` sets the GPIO number used by the fault.
- `mcpwm_gpio_fault_config_t::active_level` sets the active level of the fault signal.
- `mcpwm_gpio_fault_config_t::pull_up` and `mcpwm_gpio_fault_config_t::pull_down` set whether to pull up and/or pull down the GPIO internally.
- `mcpwm_gpio_fault_config_t::io_loop_back` sets whether to enable the loop back mode. It is for debugging purposes only. It enables both the GPIO’s input and output ability through the GPIO matrix peripheral.

The `mcpwm_new_gpio_fault()` will return a pointer to the allocated fault object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no more GPIO faults in the MCPWM group, this function will return `ESP_ERR_NOT_FOUND` error.

Software fault object can be used to trigger a fault by calling a function `mcpwm_soft_fault_activate()` instead of waiting for a real fault signal on the GPIO. A software fault object can be allocated by calling `mcpwm_new_soft_fault()` function, with configuration structure `mcpwm_soft_fault_config_t` as the parameter. Currently this configuration structure is left for future purpose. `mcpwm_new_soft_fault()` function will return a pointer to the allocated fault object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no memory left for the fault object, this function will return `ESP_ERR_NO_MEM` error. Although the software fault and GPIO fault are of different types, but the returned fault handle is of the same type.

On the contrary, calling `mcpwm_del_fault()` function will free the allocated fault object, this function works for both software and GPIO fault.

**MCPWM Sync Sources** The sync source is what can be used to synchronize the MCPWM timer and MCPWM capture timer. There’re three types of sync sources: A sync source reflected from the GPIO, a sync source generated by software and a sync source generated by MCPWM timer event.

To allocate a GPIO sync source, you can call `mcpwm_new_gpio_sync_src()` function, with configuration structure `mcpwm_gpio_sync_src_config_t` as the parameter. The configuration structure is defined as:

```c
mcpwm_gpio_sync_src_config_t::group_id` sets the MCPWM group ID. The ID should belong to `[0, SOC_MCPWM_GROUPS - 1]` range. Please note, GPIO sync source located in different groups are totally independent, i.e., GPIO sync source in group 0 can not be detected by the timers in group 1.
- `mcpwm_gpio_sync_src_config_t::gpio_num` sets the GPIO number used by the sync source.
- `mcpwm_gpio_sync_src_config_t::active_neg` sets whether the sync signal is active on falling edge.
- `mcpwm_gpio_sync_src_config_t::pull_up` and `mcpwm_gpio_sync_src_config_t::pull_down` set whether to pull up and/or pull down the GPIO internally.
- `mcpwm_gpio_sync_src_config_t::io_loop_back` sets whether to enable the loop back mode. It is for debugging purposes only. It enables both the GPIO’s input and output ability through the GPIO matrix peripheral.
```
Chapter 2.  API Reference

The `mcpwm_new_gpio_sync_src()` will return a pointer to the allocated sync source object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no more free GPIO sync sources in the MCPWM group, this function will return `ESP_ERR_NOT_FOUND` error.

To allocate a Timer event sync source, you can call `mcpwm_new_timer_sync_src()` function, with configuration structure `mcpwm_timer_sync_src_config_t` as the parameter. The configuration structure is defined as:

- `mcpwm_timer_sync_src_config_t::timer_event` specifies on what timer event to generate the sync signal.
- `mcpwm_timer_sync_src_config_t::propagate_input_sync` sets whether to propagate the input sync signal (i.e. the input sync signal will be routed to its sync output).

The `mcpwm_new_timer_sync_src()` will return a pointer to the allocated sync source object if the allocation succeeds. Otherwise, it will return error code. Specifically, if a sync source has been allocated from the same timer before, this function will return `ESP_ERR_INVALID_STATE` error.

Last but not least, to allocate a software sync source, you can call `mcpwm_new_soft_sync_src()` function, with configuration structure `mcpwm_soft_sync_config_t` as the parameter. Currently this configuration structure is left for future purpose. `mcpwm_new_soft_sync_src()` will return a pointer to the allocated sync source object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no memory left for the sync source object, this function will return `ESP_ERR_NO_MEM` error. Please note, to make a software sync source take effect, don’t forget to call `mcpwm_soft_sync_activate()`.

On the contrary, calling `mcpwm_del_sync_src()` function will free the allocated sync source object, this function works for all types of sync sources.

**MCPWM Capture Timer and Channels**  
The MCPWM group has a dedicated timer which is used to capture the timestamp when specific event occurred. The capture timer is connected with several independent channels, each channel is assigned with a GPIO.

To allocate a capture timer, you can call `mcpwm_new_capture_timer()` function, with configuration structure `mcpwm_capture_timer_config_t` as the parameter. The configuration structure is defined as:

- `mcpwm_capture_timer_config_t::group_id` sets the MCPWM group ID. The ID should belong to `[0, SOC_MCPWM_GROUPS - 1]` range.
- `mcpwm_capture_timer_config_t::clk_src` sets the clock source of the capture timer.
- `mcpwm_capture_timer_config_t::resolution_hz` The driver internally will set a proper divider based on the clock source and the resolution. If it is set to 0, the driver will pick an appropriate resolution on its own, and you can subsequently view the current timer resolution via `mcpwm_capture_timer_get_resolution()`.

**Note:** In ESP32, `mcpwm_capture_timer_config_t::resolution_hz` parameter is invalid, the capture timer resolution is always equal to the `MCPWM_CAPTURE_CLK_SRC_APB`.

The `mcpwm_new_capture_timer()` will return a pointer to the allocated capture timer object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no free capture timer left in the MCPWM group, this function will return `ESP_ERR_NOT_FOUND` error.

Next, to allocate a capture channel, you can call `mcpwm_new_capture_channel()` function, with a capture timer handle and configuration structure `mcpwm_capture_channel_config_t` as the parameter. The configuration structure is defined as:

- `mcpwm_capture_channel_config_t::intr_priority` sets the priority of the interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.
- `mcpwm_capture_channel_config_t::gpio_num` sets the GPIO number used by the capture channel.
- `mcpwm_capture_channel_config_t::prescale` sets the prescaler of the input signal.
- `mcpwm_capture_channel_config_t::pos_edge` and `mcpwm_capture_channel_config_t::neg_edge` set whether to capture on the positive and/or negative edge of the input signal.
• `mcpwm_capture_channel_config_t::pull_up` and `mcpwm_capture_channel_config_t::pull_down` set whether to pull up and/or pull down the GPIO internally.
• `mcpwm_capture_channel_config_t::invert_cap_signal` sets whether to invert the capture signal.
• `mcpwm_capture_channel_config_t::io_loop_back` sets whether to enable the loop back mode. It is for debugging purposes only. It enables both the GPIO’s input and output ability through the GPIO matrix peripheral.

The `mcpwm_new_capture_channel()` will return a pointer to the allocated capture channel object if the allocation succeeds. Otherwise, it will return error code. Specifically, when there are no free capture channel left in the capture timer, this function will return `ESP_ERR_NOT_FOUND` error.

On the contrary, calling `mcpwm_del_capture_channel()` and `mcpwm_del_capture_timer()` will free the allocated capture channel and timer object accordingly.

**MCPWM interrupt priority** MCPWM allows configuring interrupts separately for timer, operator, comparator, fault, and capture events. The interrupt priority is determined by the respective `config_t::intr_priority`. Additionally, events within the same MCPWM group share a common interrupt source. When registering multiple interrupt events, the interrupt priorities need to remain consistent.

**Note:** When registering multiple interrupt events within an MCPWM group, the driver will use the interrupt priority of the first registered event as the MCPWM group’s interrupt priority.

**Timer Operations and Events**

**Register Event Callbacks** The MCPWM timer can generate different events at runtime. If you have some function that should be called when particular event happens, you should hook your function to the interrupt service routine by calling `mcpwm_timer_register_event_callbacks()`. The callback function prototype is declared in `mcpwm_timer_event_cb_t`. All supported event callbacks are listed in the `mcpwm_timer_event_callbacks_t`:

• `mcpwm_timer_event_callbacks_t::on_full` sets callback function for timer when it counts to peak value.
• `mcpwm_timer_event_callbacks_t::on_empty` sets callback function for timer when it counts to zero.
• `mcpwm_timer_event_callbacks_t::on_stop` sets callback function for timer when it is stopped.

The callback functions above are called within the ISR context, so they should not attempt to block (e.g., make sure that only FreeRTOS APIs with ISR suffix is called within the function).

The parameter `user_data` of `mcpwm_timer_register_event_callbacks()` function is used to save user’s own context, it will be passed to each callback function directly.

This function will lazy install interrupt service for the MCPWM timer without enabling it. It is only allowed to be called before `mcpwm_timer_enable()`, otherwise the `ESP_ERR_INVALID_STATE` error will be returned. See also Enable and Disable timer for more information.

**Enable and Disable Timer** Before doing IO control to the timer, user needs to enable the timer first, by calling `mcpwm_timer_enable()`. Internally, this function will:

• switch the timer state from `init` to `enable`.
• enable the interrupt service if it has been lazy installed by `mcpwm_timer_register_event_callbacks()`.
• acquire a proper power management lock if a specific clock source (e.g. PLL_160M clock) is selected. See also Power management for more information.

On the contrary, calling `mcpwm_timer_disable()` will put the timer driver back to `init` state, disable the interrupts service and release the power management lock.
Start and Stop Timer  The basic IO operation of a timer is to start and stop. Calling `mcpwm_timer_start_stop()` with different `mcpwm_timer_start_stop_cmd_t` commands can start the timer immediately or stop the timer at a specific event. What’s more, you can even start the timer for only one round, that means, the timer will count to peak value or zero, and then stop itself.

Connect Timer with Operator  The allocated MCPWM Timer should be connected with a MCPWM operator by calling `mcpwm_operator_connect_timer()`, so that the operator can take that timer as its time base, and generate the required PWM waves. Make sure the MCPWM timer and operator are in the same group, otherwise, this function will return `ESP_ERR_INVALID_ARG` error.

Comparator Operations and Events

Register Event Callbacks  The MCPWM comparator can inform the user when the timer counter equals to the compare value. If you have some function that should be called when this event happens, you should hook your function to the interrupt service routine by calling `mcpwm_comparator_register_event_callbacks()`. The callback function prototype is declared in `mcpwm_compare_event_cb_t`. All supported event callbacks are listed in the `mcpwm_comparator_event_callbacks_t`:

- `mcpwm_comparator_event_callbacks_t::on_reach` sets callback function for comparator when the timer counter equals to the compare value.

The callback function will provide event specific data of type `mcpwm_compare_event_data_t` to the user. The callback function is called within the ISR context, so is should not attempt to block (e.g., make sure that only FreeRTOS APIs with ISR suffix is called within the function).

The parameter `user_data` of `mcpwm_comparator_register_event_callbacks()` function is used to save user’s own context, it will be passed to the callback function directly.

This function will lazy install interrupt service for the MCPWM comparator, whereas the service can only be removed in `mcpwm_del_comparator`.

Set Compare Value  You can set the compare value for the MCPWM comparator at runtime by calling `mcpwm_comparator_set_compare_value()`. There’re a few points to note:

- New compare value might won’t take effect immediately. The update time for the compare value is set by `mcpwm_comparator_config_t::update_cmp_on_tez` or `mcpwm_comparator_config_t::update_cmp_on_tep` or `mcpwm_comparator_config_t::update_cmp_on_sync`.
- Make sure the operator has connected to one MCPWM timer already by `mcpwm_operator_connect_timer()`. Otherwise, it will return error code `ESP_ERR_INVALID_STATE`.
- The compare value shouldn’t exceed timer’s count peak, otherwise, the compare event will never got triggered.

Generator Actions on Events

Set Generator Action on Timer Event  One generator can set multiple actions on different timer events, by calling `mcpwm_generator_set_actions_on_timer_event()` with variable number of action configurations. The action configuration is defined in `mcpwm_gen_timer_event_action_t`:

- `mcpwm_gen_timer_event_action_t::direction` specifies the timer direction. The supported directions are listed in `mcpwm_timer_direction_t`.
- `mcpwm_gen_timer_event_action_t::event` specifies the timer event. The supported timer events are listed in `mcpwm_timer_event_t`.
- `mcpwm_gen_timer_event_action_t::action` specifies the generator action to be taken. The supported actions are listed in `mcpwm_generator_action_t`.
There’s a helper macro `MCPWM_GEN_TIMER_EVENT_ACTION` to simplify the construction of a timer event action entry.

Please note, the argument list of `mcpwm_generator_set_actions_on_timer_event()` must be terminated by `MCPWM_GEN_TIMER_EVENT_ACTION_END`.

You can also set the timer action one by one by calling `mcpwm_generator_set_action_on_timer_event()` without varargs.

**Set Generator Action on Compare Event** One generator can set multiple actions on different compare events, by calling `mcpwm_generator_set_actions_on_compare_event()` with variable number of action configurations. The action configuration is defined in `mcpwm_gen_compare_event_action_t`:

- `mcpwm_gen_compare_event_action_t::direction` specifies the timer direction. The supported directions are listed in `mcpwm_timer_direction_t`.
- `mcpwm_gen_compare_event_action_t::comparator` specifies the comparator handle. See `MCPWM Comparators` for how to allocate a comparator.
- `mcpwm_gen_compare_event_action_t::action` specifies the generator action to be taken. The supported actions are listed in `mcpwm_generator_action_t`.

There’s a helper macro `MCPWM_GEN_COMPARE_EVENT_ACTION` to simplify the construction of a compare event action entry.

Please note, the argument list of `mcpwm_generator_set_actions_on_compare_event()` must be terminated by `MCPWM_GEN_COMPARE_EVENT_ACTION_END`.

You can also set the compare action one by one by calling `mcpwm_generator_set_action_on_compare_event()` without varargs.

**Classical PWM Waveforms and Generator Configurations** This section will demonstrate the classical PWM waveforms that can be generated by the pair of the generators. The code snippet that is used to generate the waveforms is also provided below the diagram. Some general summary:

- The Symmetric or Asymmetric of the waveforms are determined by the count mode of the MCPWM timer.
- The active level of the waveform pair is determined by the level of the PWM with a smaller duty cycle.
- The period of the PWM waveform is determined by the timer’s period and count mode.
- The duty cycle of the PWM waveform is determined by the generator’s various action combinations.

```c
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb, ...
    mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena,
    MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_
    TIMER_EVENT_EMPTY, MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
    MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,
    MCPWM_GEN_ACTION_LOW)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(genb,
    MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_
    TIMER_EVENT_EMPTY, MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(genb,
    MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpb,
    MCPWM_GEN_ACTION_LOW)));
}
```

Asymmetric Single Edge Active High
Asymmetric Single Edge Active Low

```c
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   --mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena,
        MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_
        --TIMER_EVENT_FULL, MCPWM_GEN_ACTION_LOW));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,--
        --MCPWM_GEN_ACTION_HIGH));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,--
        --MCPWM_GEN_ACTION_LOW));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpb,--
        --MCPWM_GEN_ACTION_HIGH)));
}
```

Asymmetric Pulse Placement

```c
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   --mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,--
        --MCPWM_GEN_ACTION_HIGH),
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpb,--
        --MCPWM_GEN_ACTION_LOW),
        MCPWM_GEN_COMPARE_EVENT_ACTION_END()));
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_timer_event(genb,
        MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_
        --TIMER_EVENT_EMPTY, MCPWM_GEN_ACTION_TOGGLE),
        MCPWM_GEN_TIMER_EVENT_ACTION_END()));
}
```

Asymmetric Dual Edge Active Low

```c
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   --mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,--
        --MCPWM_GEN_ACTION_HIGH),
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_DOWN,--
        --cmpb, MCPWM_GEN_ACTION_LOW),
        MCPWM_GEN_COMPARE_EVENT_ACTION_END()));
}
```
ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_timer_event(genb,
MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_-
->TIMER_EVENT_EMPTY, MCPWM_GEN_ACTION_LOW),
MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_DOWN, MCPWM_-
->TIMER_EVENT_FULL, MCPWM_GEN_ACTION_HIGH),
MCPWM_GEN_TIMER_EVENT_ACTION_END()));

Symmetric Dual Edge Active Low

\[\text{pwm}_A \quad \text{pwm}_B\]

static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,
        MCPWM_GEN_ACTION_HIGH),
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_DOWN,
        cmpa, MCPWM_GEN_ACTION_LOW),
        MCPWM_GEN_COMPARE_EVENT_ACTION_END()));
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_compare_event(genb,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpb,
        MCPWM_GEN_ACTION_HIGH),
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_DOWN,
        cmpb, MCPWM_GEN_ACTION_LOW),
        MCPWM_GEN_COMPARE_EVENT_ACTION_END()));
}

Symmetric Dual Edge Complementary

\[\text{pwm}_A \quad \text{pwm}_B\]

static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_compare_event(gena,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa,
        MCPWM_GEN_ACTION_HIGH),
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_DOWN,
        cmpa, MCPWM_GEN_ACTION_LOW),
        MCPWM_GEN_COMPARE_EVENT_ACTION_END()));
    ESP_ERROR_CHECK(mcpwm_generator_set_actions_on_compare_event(genb,
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpb,
        MCPWM_GEN_ACTION_LOW),
        MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_DOWN,
        cmpb, MCPWM_GEN_ACTION_HIGH),
        MCPWM_GEN_COMPARE_EVENT_ACTION_END()));
}
Dead Time In power electronics, the rectifier and inverter are commonly used. This requires the use of rectifier bridge and inverter bridge. Each bridge arm has two power electronic devices, such as MOSFET, IGBT, etc. The two MOSFETs on the same arm can’t conduct at the same time, otherwise there will be a short circuit. The fact is that, although the PWM wave shows it is turning off the switch, but the MOSFET still needs a small time window to make that happen. This requires an extra delay to be added to the existing PWM wave that generated by setting Generator Actions on Events.

The dead time driver works like a decorator. This is also reflected in the function parameters of mcpwm_generator_set_dead_time(), where it takes the primary generator handle (in_generator), and returns a new generator (out_generator) after applying the dead time. Please note, if the out_generator and in_generator are the same, it means we are adding the time delay to the PWM waveform in an “in-place” fashion. In turn, if the out_generator and in_generator are different, it means we’re deriving a new PWM waveform from the existing in_generator.

Dead-time specific configuration is listed in the mcpwm_dead_time_config_t structure:

- mcpwm_dead_time_config_t::posedge_delay_ticks and mcpwm_dead_time_config_t::negedge_delay_ticks set the number of ticks to delay the PWM waveform on the rising and falling edge. Specifically, setting both of them to zero means to bypass the dead-time module. The resolution of the dead-time tick is the same to the timer that is connected with the operator by mcpwm_operator_connect_timer().
- mcpwm_dead_time_config_t::invert_output: Whether to invert the signal after applying the dead-time, which can be used to control the delay edge polarity.

Warning: Due to the hardware limitation, one delay module (either posedge delay or negedge delay) can’t be applied to multiple MCPWM generators at the same time. e.g. the following configuration is invalid:

```c
mcpwm_dead_time_config_t dt_config = {
    .posedge_delay_ticks = 10,
};
// Set posedge delay to generator A
mcpwm_generator_set_dead_time(mcpwm_gen_a, mcpwm_gen_a, &dt_config);
// NOTE: This is invalid, you can't apply the posedge delay to another generator
mcpwm_generator_set_dead_time(mcpwm_gen_b, mcpwm_gen_b, &dt_config);
```

However, you can apply posedge delay to generator A and negedge delay to generator B. You can also set both posedge delay and negedge delay for generator A, while letting generator B bypass the dead time module.

Note: It is also possible to generate the required dead time by setting Generator Actions on Events, especially by controlling edge placement using different comparators. However, if the more classical edge delay-based dead time with polarity control is required, then the dead-time submodule should be used.

Classical PWM Waveforms and Dead Time Configurations This section will demonstrate the classical PWM waveforms that can be generated by the dead-time submodule. The code snippet that is used to generate the waveforms is also provided below the diagram.
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena,
       MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP,
       MCPWM_TIMER_EVENT_EMPTY,
       MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
       MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP,
       cmpa,
       MCPWM_GEN_ACTION_LOW)));
}

static void dead_time_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb)
{
    mcpwm_dead_time_config_t dead_time_config = {
       .posedge_delay_ticks = 50,
       .negedge_delay_ticks = 0
    };
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, gena, &dead_time_config));
    dead_time_config.posedge_delay_ticks = 0;
    dead_time_config.negedge_delay_ticks = 100;
    dead_time_config.flags.invert_output = true;
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, genb, &dead_time_config));
}

static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb,
   mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena,
       MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP,
       MCPWM_TIMER_EVENT_EMPTY,
       MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
       MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP,
       cmpa,
       MCPWM_GEN_ACTION_LOW)));
}

static void dead_time_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb)
{
    mcpwm_dead_time_config_t dead_time_config = {
       .posedge_delay_ticks = 50,
       .negedge_delay_ticks = 0,
       .flags.invert_output = true
    };
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, gena, &dead_time_config));
    dead_time_config.posedge_delay_ticks = 0;
    dead_time_config.negedge_delay_ticks = 100;
    dead_time_config.flags.invert_output = false;
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, genb, &dead_time_config));
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb, _mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb) {
   ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena, MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_TIMER_EVENT_EMPTY, MCPWM_gen_ACTION_HIGH)));
   ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena, MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa, MCPWM_GEN_ACTION_LOW)));
}

static void dead_time_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb) {
   mcpwm_dead_time_config_t dead_time_config = {
      .posedge_delay_ticks = 50,
      .negedge_delay_ticks = 0,
   };
   ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, gena, &dead_time_config));
   dead_time_config.posedge_delay_ticks = 0;
   dead_time_config.negedge_delay_ticks = 100;
   ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, genb, &dead_time_config));
}

(continues on next page)
dead_time_config.posedge_delay_ticks = 0;
dead_time_config.negedge_delay_ticks = 100;
ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, genb, &dead_time_config));
}

static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb, mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena,
                    MCPWM_TIMER_DIRECTION_UP, MCPWM_TIMER_EVENT_EMPTY,
                    MCPWM_GEN_ACTION_HIGH));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena,
                    MCPWM_TIMER_DIRECTION_UP, cmpa,
                    MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_GEN_ACTION_LOW)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(genb,
                    MCPWM_TIMER_DIRECTION_UP, MCPWM_TIMER_EVENT_EMPTY,
                    MCPWM_GEN_ACTION_HIGH));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(genb,
                    MCPWM_TIMER_DIRECTION_UP, cmpb,
                    MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_GEN_ACTION_LOW)));
}

static void dead_time_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb)
{
    mcpwm_dead_time_config_t dead_time_config = {
        .posedge_delay_ticks = 50,
        .negedge_delay_ticks = 0,
    };
    // apply deadtime to generator_a
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, gena, &dead_time_config));
    // bypass deadtime module for generator_b
    dead_time_config.posedge_delay_ticks = 0;
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, genb, &dead_time_config));
}
static void gen_action_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb, mcpwm_cmpr_handle_t cmpa, mcpwm_cmpr_handle_t cmpb)
{
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena, MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena, MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa, MCPWM_GEN_ACTION_LOW)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena, MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_TIMER_EVENT_EMPTY, MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena, MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa, MCPWM_GEN_ACTION_LOW)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_timer_event(gena, MCPWM_GEN_TIMER_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, MCPWM_TIMER_EVENT_EMPTY, MCPWM_GEN_ACTION_HIGH)));
    ESP_ERROR_CHECK(mcpwm_generator_set_action_on_compare_event(gena, MCPWM_GEN_COMPARE_EVENT_ACTION(MCPWM_TIMER_DIRECTION_UP, cmpa, MCPWM_GEN_ACTION_LOW)));
}

static void dead_time_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb)
{
    mcpwm_dead_time_config_t dead_time_config = {
        .posedge_delay_ticks = 0,
        .negedge_delay_ticks = 0,
    };
    // generator_a bypass the deadtime module (no delay)
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, gena, &dead_time_config));
    // apply dead time to generator_b
    dead_time_config.negedge_delay_ticks = 50;
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(genb, genb, &dead_time_config));
}
static void dead_time_config(mcpwm_gen_handle_t gena, mcpwm_gen_handle_t genb) {
    mcpwm_dead_time_config_t dead_time_config = {
        .posedge_delay_ticks = 0,
        .negedge_delay_ticks = 0,
    };
    // generator_a bypass the deadtime module (no delay)
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(gena, gena, &dead_time_config));
    // apply dead time on both edge for generator_b
    dead_time_config.negedge_delay_ticks = 50;
    dead_time_config.posedge_delay_ticks = 50;
    ESP_ERROR_CHECK(mcpwm_generator_set_dead_time(genb, genb, &dead_time_config));
}

Carrier Modulation  The MCPWM operator has a carrier submodule that can be used if galvanic isolation from the motor driver is required (e.g. isolated digital power application) by passing the PWM output signals through transformers. Any of PWM output signals may be at 100% duty and not changing whenever motor is required to run steady at the full load. Coupling of non alternating signals with a transformer is problematic, so the signals are modulated by the carrier submodule to create an AC waveform, to make the coupling possible.

To configure the carrier submodule, you can call `mcpwm_operator_applyCarrier()`, and provide configuration structure `mcpwm_carrier_config_t`:

- `mcpwm_carrier_config_t::clk_src` sets the clock source of the carrier.
- `mcpwm_carrier_config_t::frequency_hz` indicates carrier frequency in Hz.
- `mcpwm_carrier_config_t::duty_cycle` indicates the duty cycle of the carrier. Note that, the supported choices of the duty cycle are discrete, the driver will search for the nearest one based on your configuration.
- `mcpwm_carrier_config_t::first_pulse_duration_us` indicates the duration of the first pulse in microseconds. The resolution of the first pulse duration is determined by the carrier frequency you set in the `mcpwm_carrier_config_t::frequency_hz`. The first pulse duration can’t be zero, and it has to be at least one period of the carrier. A longer pulse width can help conduct the inductance quicker.
- `mcpwm_carrier_config_t::invert_before_modulate` and `mcpwm_carrier_config_t::invert_after_modulate` set whether to invert the carrier output before and after modulation.

Specifically, the carrier submodule can be disabled by calling `mcpwm_operator_applyCarrier()` with a NULL configuration.

Faults and Brake Actions  The MCPWM operator is able to sense external signals with information about failure of the motor, the power driver or any other device connected. These failure signals are encapsulated into `MCPWM fault objects`.

The user should determine possible failure modes of the motor and what action should be performed on detection of particular fault, e.g. drive all outputs low for a brushed motor, or lock current state for a stepper motor, etc. As result of this action the motor should be put into a safe state to reduce likelihood of a damage caused by the fault.

Set Operator Brake Mode on Fault  The way that MCPWM operator reacts to the fault is called Brake. The MCPWM operator can be configured to perform different brake modes for each fault object by calling `mcpwm_operator_set_brake_on_fault()`. Brake specific configuration is passed as a structure `mcpwm_brake_config_t`:

- `mcpwm_brake_config_t::fault` set which fault that the operator should react to.
- `mcpwm_brake_config_t::brake_mode` set the brake mode that should be used for the fault. The supported brake modes are listed in the `mcpwm_operator_brake_mode_t`. For `MCPWM_OPER BRAKE MODE_CBC` mode, the operator will recover itself automatically as long as the fault disappears. You can specify the recovery time in `mcpwm_brake_config_t::cbc_recover_on_tez` and `mcpwm_brake_config_t::cbc_recover_on_tep`. For `MCPWM_OPER BRAKE MODE_OST`
mode, the operator can’t recover even though the fault disappears. User has to call
`mcpwm_operator_recover_from_fault()` to manually recover it.

**Set Generator Action on Brake Event** One generator can set multiple actions on different brake events, by calling
`mcpwm_generator_set_actions_on_brake_event()` with variable number of action configurations. The action configuration is defined in `mcpwm_gen_brake_event_action_t`:

- `mcpwm_gen_brake_event_action_t::direction` specifies the timer direction. The supported directions are listed in `mcpwm_timer_direction_t`.
- `mcpwm_gen_brake_event_action_t::brake_mode` specifies the brake mode. The supported brake modes are listed in the `mcpwm_operator_brake_mode_t`.
- `mcpwm_gen_brake_event_action_t::action` specifies the generator action to be taken. The supported actions are listed in `mcpwm_generator_action_t`.

There’s a helper macro `MCPWM_GEN_BRAKE_EVENT_ACTION` to simplify the construction of a brake event action entry.

Please note, the argument list of `mcpwm_generator_set_actions_on_brake_event()` must be terminated by `MCPWM_GEN_BRAKE_EVENT_ACTION_END`.

You can also set the brake action one by one by calling `mcpwm_generator_set_action_on_brake_event()` without varargs.

**Register Fault Event Callbacks** The MCPWM fault detector can inform the user when it detects a valid fault or a fault signal disappears. If you have some function that should be called when such event happens, you should hook your function to the interrupt service routine by calling `mcpwm_fault_register_event_callbacks()`. The callback function prototype is declared in `mcpwm_fault_event_cb_t`. All supported event callbacks are listed in the `mcpwm_fault_event_callbacks_t`:

- `mcpwm_fault_event_callbacks_t::on_fault_enter` sets callback function that will be called when a fault is detected.
- `mcpwm_fault_event_callbacks_t::on_fault_exit` sets callback function that will be called when a fault is cleared.

The callback function is called within the ISR context, so it should not attempt to block (e.g., make sure that only FreeRTOS APIs with `ISR` suffix is called within the function).

The parameter `user_data` of `mcpwm_fault_register_event_callbacks()` function is used to save user’s own context, it will be passed to the callback function directly.

This function will lazy install interrupt service for the MCPWM fault, whereas the service can only be removed in `mcpwm_del_fault`.

**Register Brake Event Callbacks** The MCPWM operator can inform the user when it going to take a brake action. If you have some function that should be called when this event happens, you should hook your function to the interrupt service routine by calling `mcpwm_operator_register_event_callbacks()`. The callback function prototype is declared in `mcpwm_brake_event_cb_t`. All supported event callbacks are listed in the `mcpwm_operator_event_callbacks_t`:

- `mcpwm_operator_event_callbacks_t::on_brake_cbc` sets callback function that will be called when the operator is going to take a `CBC` action.
- `mcpwm_operator_event_callbacks_t::on_brake_ost` sets callback function that will be called when the operator is going to take an `OST` action.

The callback function is called within the ISR context, so it should not attempt to block (e.g., make sure that only FreeRTOS APIs with `ISR` suffix is called within the function).

The parameter `user_data` of `mcpwm_operator_register_event_callbacks()` function is used to save user’s own context, it will be passed to the callback function directly.

This function will lazy install interrupt service for the MCPWM operator, whereas the service can only be removed in `mcpwm_del_operator`.
Generator Force Actions  Software can override generator output level at runtime, by calling `mcpwm_generator_set_force_level()`. The software force level always has a higher priority than other event actions set in e.g. `mcpwm_generator_set_actions_on_timer_event()`.

- Set the `level` to -1 means to disable the force action, and the generator’s output level will be controlled by the event actions again.
- Set the `hold_on` to true, the force output level will keep alive, until it’s removed by assigning `level` to -1.
- Set the `hole_on` to false, the force output level will only be active for a short time, any upcoming event can override it.

Synchronization  When a sync signal is taken by the MCPWM timer, the timer will be forced into a predefined phase, where the phase is determined by count value and count direction. You can set the sync phase by calling `mcpwm_timer_set_phase_on_sync()`.

The sync phase configuration is defined in `mcpwm_timer_sync_phase_config_t` structure:

- `mcpwm_timer_sync_phase_config_t::sync_src` sets the sync signal source. See `MCPWM Sync Sources` for how to create a sync source object. Specifically, if this is set to NULL, the driver will disable the sync feature for the MCPWM timer.
- `mcpwm_timer_sync_phase_config_t::count_value` sets the count value to load when the sync signal is taken.
- `mcpwm_timer_sync_phase_config_t::direction` sets the count direction when the sync signal is taken.

Likewise, the MCPWM capture timer `MCPWM Capture Timer` can be synced as well. You can set the sync phase for the capture timer by calling `mcpwm_capture_timer_set_phase_on_sync()`. The sync phase configuration is defined in `mcpwm_capture_timer_sync_phase_config_t` structure:

- `mcpwm_capture_timerSyncPhaseConfig_t::sync_src` sets the sync signal source. See `MCPWM Sync Sources` for how to create a sync source object. Specifically, if this is set to NULL, the driver will disable the sync feature for the MCPWM capture timer.
- `mcpwm_capture_timerSyncPhaseConfig_t::count_value` sets the count value to load when the sync signal is taken.
- `mcpwm_capture_timerSyncPhaseConfig_t::direction` sets the count direction when the sync signal is taken. Note that, different from MCPWM Timer, the capture timer can only support one count direction: `MCPWM_TIMER_DIRECTION_UP`.

Sync Timers by GPIO

```c
static void example_setup_sync_strategy(mcpwm_timer_handle_t timers[]) {
    mcpwm_sync_handle_t gpio_sync_source = NULL;
    mcpwm_gpio_sync_src_config_t gpio_sync_config = {
        .group_id = 0, // GPIO fault should be in the same group of
        .gpio_num = EXAMPLE_SYNC_GPIO,
        .flags.pull_down = true,
        .flags.active_neg = false, // by default, a posedge pulse can trigger a
        .sync_src
    };
    ESP_ERROR_CHECK(mcpwm_new_gpio_sync_src(&gpio_sync_config, &gpio_sync_source));

    mcpwm_timer_sync_phase_config_t sync_phase_config = {
        .count_value = 0, // sync phase: target count value
        .direction = MCPWM_TIMER_DIRECTION_UP, // sync phase: count direction
        .sync_src = gpio_sync_source,
    };
    for (int i = 0; i < 3; i++) {
        ESP_ERROR_CHECK(mcpwm_timer_set_phase_on_sync(timers[i], &sync_phase_config));
    }
}
```
Capture The basic functionality of MCPWM capture is to record the time when any pulse edge of the capture signal turns active. Then you can get the pulse width and convert it into other physical quantity like distance or speed in the capture callback function. For example, in the BLDC (Brushless DC, see figure below) scenario, we can use the capture submodule to sense the rotor position from Hall sensor.

The capture timer is usually connected with several capture channels, please refer to MCPWM Capture Timer and Channels for resource allocation.

Register Event Callbacks The MCPWM capture channel can inform the user when there’s a valid edge detected on the signal. You have to register a callback function to get the timer count value of the capture moment, by calling mcpwm_capture_channel_register_event_callbacks(). The callback function prototype is declared in mcpwm_capture_event_cb_t. All supported capture callbacks are listed in the mcpwm_capture_event_callbacks_t:

- mcpwm_capture_event_callbacks_t::on_cap sets callback function for the capture channel when a valid edge is detected.

The callback function will provide event specific data of type mcpwm_capture_event_data_t, so that you can get the edge of the capture signal in mcpwm_capture_event_data_t::cap_edge and the count value of that moment in mcpwm_capture_event_data_t::cap_value. To convert the capture count into timestamp, you need to know the resolution of the capture timer by calling mcpwm_capture_timer_get_resolution().

The callback function is called within the ISR context, so is should not attempt to block (e.g., make sure that only FreeRTOS APIs with ISR suffix is called within the function).

The parameter user_data of mcpwm_capture_channel_register_event_callbacks() function is used to save user’s own context, it will be passed to the callback function directly.

This function will lazy install interrupt service for the MCPWM capture channel, whereas the service can only be removed in mcpwm_del_capture_channel.
Enable and Disable Capture Channel The capture channel is not enabled after allocation by `mcpwm_new_capture_channel()`. You should call `mcpwm_capture_channel_enable()` and `mcpwm_capture_channel_disable()` accordingly to enable or disable the channel. If the interrupt service is lazy installed during registering event callbacks for the channel in `mcpwm_capture_channel_register_event_callbacks()`, `mcpwm_capture_channel_enable()` will enable the interrupt service as well.

Enable and Disable Capture Timer Before doing IO control to the capture timer, user needs to enable the timer first, by calling `mcpwm_capture_timer_enable()`. Internally, this function will:

- switch the capture timer state from `init` to `enable`.
- acquire a proper power management lock if a specific clock source (e.g. APB clock) is selected. See also Power management for more information.

On the contrary, calling `mcpwm_capture_timer_disable()` will put the timer driver back to `init` state, and release the power management lock.

Start and Stop Capture Timer The basic IO operation of a capture timer is to start and stop. Calling `mcpwm_capture_timer_start()` can start the timer and calling `mcpwm_capture_timer_stop()` can stop the timer immediately.

Trigger a Software Capture Event Sometime, the software also wants to trigger a “fake” capture event. The `mcpwm_capture_channel_trigger_soft_catch()` is provided for that purpose. Please note that, even though it’s a “fake” capture event, it can still cause an interrupt, thus your capture event callback function will get invoked as well.

Power Management When power management is enabled (i.e. `CONFIG_PM_ENABLE` is on), the system will adjust the PLL, APB frequency before going into light sleep, thus potentially changing the period of a MCPWM timers’ counting step and leading to inaccurate time keeping.

Fig. 15: MCPWM BLDC with Hall Sensor
However, the driver can prevent the system from changing APB frequency by acquiring a power management lock of type `ESP_PM_APB_FREQ_MAX`. Whenever the driver creates a MCPWM timer instance that has selected `MCPWM_TIMER_CLK_SRC_PLL160M` as its clock source, the driver will guarantee that the power management lock is acquired when enable the timer by `mcpwm_timer_enable()`. Likewise, the driver releases the lock when `mcpwm_timer_disable()` is called for that timer.

Likewise, Whenever the driver creates a MCPWM capture timer instance that has selected `MCPWM_CAPTURE_CLK_SRC_APB` as its clock source, the driver will guarantee that the power management lock is acquired when enable the timer by `mcpwm_capture_timer_enable()`. And will release the lock in `mcpwm_capture_timer_disable()`.

**IRAM Safe**  By default, the MCPWM interrupt will be deferred when the Cache is disabled for reasons like writing/erasing Flash. Thus the event callback functions will not get executed in time, which is not expected in a real-time application.

There’s a Kconfig option `CONFIG_MCPWM_ISR_IRAM_SAFE` that will:

1. Enable the interrupt being serviced even when cache is disabled
2. Place all functions that used by the ISR into IRAM
3. Place driver object into DRAM (in case it’s mapped to PSRAM by accident)

This will allow the interrupt to run while the cache is disabled but will come at the cost of increased IRAM consumption.

There is another Kconfig option `CONFIG_MCPWM_CTRL_FUNC_IN_IRAM` that can put commonly used IO control functions into IRAM as well. So, these functions can also be executable when the cache is disabled. These IO control functions are as follows:

- `mcpwm_comparator_set_compare_value()`

**Thread Safety**  The factory functions like `mcpwm_new_timer()` are guaranteed to be thread safe by the driver, which means, you can call it from different RTOS tasks without protection by extra locks.

The following functions are allowed to run under ISR context, as the driver uses a critical section to prevent them being called concurrently in the task and ISR.

- `mcpwm_comparator_set_compare_value()`

Other functions that are not related to **Resource Allocation**, are not thread safe. Thus, you should avoid calling them in different tasks without mutex protection.

**Kconfig Options**

- `CONFIG_MCPWM_ISR_IRAM_SAFE` controls whether the default ISR handler can work when cache is disabled, see IRAM Safe for more information.
- `CONFIG_MCPWM_CTRL_FUNC_IN_IRAM` controls where to place the MCPWM control functions (IRAM or flash), see IRAM Safe for more information.
- `CONFIG_MCPWM_ENABLE_DEBUG_LOG` is used to enabled the debug log output. Enable this option will increase the firmware binary size.

**Application Examples**

- Brushed DC motor speed control by PID algorithm: peripherals/mcpwm/mcpwm_bdc_speed_control
- BLDC motor control with hall sensor feedback: peripherals/mcpwm/mcpwm_blde_hall_control
- Ultrasonic sensor (HC-SR04) distance measurement: peripherals/mcpwm/mcpwm_capture_hc_sr04
- Servo motor angle control: peripherals/mcpwm/mcpwm_servo_control
- MCPWM synchronization between timers: peripherals/mcpwm/mcpwm_sync

---

2 Callback function and the sub-functions invoked by itself should also be placed in IRAM, users need to take care of this by themselves.
API Reference

Header File

- components/driver/mcpwm/include/driver/mcpwm_timer.h

Functions

**esp_err_t mcpwm_new_timer** (const mcpwm_timer_config_t *config, mcpwm_timer_handle_t *ret_timer)

Create MCPWM timer.

Parameters

- `config` [in] MCPWM timer configuration
- `ret_timer` [out] Returned MCPWM timer handle

Returns

- ESP_OK: Create MCPWM timer successfully
- ESP_ERR_INVALID_ARG: Create MCPWM timer failed because of invalid argument
- ESP_ERR_NO_MEM: Create MCPWM timer failed because out of memory
- ESP_ERR_NOT_FOUND: Create MCPWM timer failed because all hardware timers are used up and no more free one
- ESP_FAIL: Create MCPWM timer failed because of other error

**esp_err_t mcpwm_del_timer** (mcpwm_timer_handle_t timer)

Delete MCPWM timer.

Parameters

- `timer` [in] MCPWM timer handle, allocated by `mcpwm_new_timer()`

Returns

- ESP_OK: Delete MCPWM timer successfully
- ESP_ERR_INVALID_ARG: Delete MCPWM timer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Delete MCPWM timer failed because timer is not in init state
- ESP_FAIL: Delete MCPWM timer failed because of other error

**esp_err_t mcpwm_timer_enable** (mcpwm_timer_handle_t timer)

Enable MCPWM timer.

Parameters

- `timer` [in] MCPWM timer handle, allocated by `mcpwm_new_timer()`

Returns

- ESP_OK: Enable MCPWM timer successfully
- ESP_ERR_INVALID_ARG: Enable MCPWM timer failed because of invalid argument
- ESP_ERR_INVALID_STATE: Enable MCPWM timer failed because timer is enabled already
- ESP_FAIL: Enable MCPWM timer failed because of other error

**esp_err_t mcpwm_timer_disable** (mcpwm_timer_handle_t timer)

Disable MCPWM timer.

Parameters

- `timer` [in] MCPWM timer handle, allocated by `mcpwm_new_timer()`

Returns

- ESP_OK: Disable MCPWM timer successfully
- ESP_ERR_INVALID_ARG: Disable MCPWM timer failed because of invalid argument
- ESP_ERR_INVALID_STATE:Disable MCPWM timer failed because timer is disabled already
- ESP_FAIL: Disable MCPWM timer failed because of other error

**esp_err_t mcpwm_timer_start_stop** (mcpwm_timer_handle_t timer, mcpwm_timer_start_stop_cmd_t command)

Send specific start/stop commands to MCPWM timer.

Parameters

- `timer` [in] MCPWM timer handle, allocated by `mcpwm_new_timer()`
- `command` [in] Supported command list for MCPWM timer

Returns

- ESP_OK
- ESP_ERR_INVALID_ARG
- ESP_ERR_INVALID_STATE
- ESP_FAIL

---

Espressif Systems 1225

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Release v5.1.2
• ESP_OK: Start or stop MCPWM timer successfully
• ESP_ERR_INVALID_ARG: Start or stop MCPWM timer failed because of invalid argument
• ESP_ERR_INVALID_STATE: Start or stop MCPWM timer failed because timer is not enabled
• ESP_FAIL: Start or stop MCPWM timer failed because of other error

\begin{verbatim}
esp_err_t mcpwm_timer_register_event_callbacks(mcpwm_timer_handle_t timer, const mcpwm_timer_event_callbacks_t *cbs, void *user_data)
\end{verbatim}

Set event callbacks for MCPWM timer.

**Note:** The first call to this function needs to be before the call to `mcpwm_timer_enable`

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the `cbs` structure to NULL.

**Parameters**
- `timer` [in] MCPWM timer handle, allocated by `mcpwm_new_timer()`
- `cbs` [in] Group of callback functions
- `user_data` [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set event callbacks failed because timer is not in init state
- ESP_FAIL: Set event callbacks failed because of other error

\begin{verbatim}
esp_err_t mcpwm_timer_set_phase_on_sync(mcpwm_timer_handle_t timer, const mcpwm_timer_sync_phase_config_t *config)
\end{verbatim}

Set sync phase for MCPWM timer.

**Parameters**
- `timer` [in] MCPWM timer handle, allocated by `mcpwm_new_timer()`
- `config` [in] MCPWM timer sync phase configuration

**Returns**
- ESP_OK: Set sync phase for MCPWM timer successfully
- ESP_ERR_INVALID_ARG: Set sync phase for MCPWM timer failed because of invalid argument
- ESP_FAIL: Set sync phase for MCPWM timer failed because of other error

**Structures**

\begin{verbatim}
struct mcpwm_timer_event_callbacks_t
\end{verbatim}

Group of supported MCPWM timer event callbacks.

**Note:** The callbacks are all running under ISR environment

**Public Members**

\begin{verbatim}
mcpwm_timer_event_cb_t on_full
\end{verbatim}

callback function when MCPWM timer counts to peak value
Chapter 2. API Reference

```c
mcpwm_timer_event_cb_t on_empty
    callback function when MCPWM timer counts to zero

mcpwm_timer_event_cb_t on_stop
    callback function when MCPWM timer stops
```

```c
struct mcpwm_timer_config_t
    MCPWM timer configuration.
```

**Public Members**

```c
int group_id
    Specify from which group to allocate the MCPWM timer
```

```c
mcpwm_timer_clock_source_t clk_src
    MCPWM timer clock source
```

```c
uint32_t resolution_hz
    Counter resolution in Hz The step size of each count tick equals to (1 / resolution_hz) seconds
```

```c
mcpwm_timer_count_mode_t count_mode
    Count mode
```

```c
uint32_t period_ticks
    Number of count ticks within a period
```

```c
int intr_priority
    MCPWM timer interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1, 2, 3)
```

```c
uint32_t update_period_on_empty
    Whether to update period when timer counts to zero
```

```c
uint32_t update_period_on_sync
    Whether to update period on sync event
```

```c
struct mcpwm_timer_config_t::[anonymous] flags
    Extra configuration flags for timer
```

```c
struct mcpwm_timer_sync_phase_config_t
    MCPWM Timer sync phase configuration.
```

**Public Members**

```c
mcpwm_sync_handle_t sync_src
    The sync event source. Set to NULL will disable the timer being synced by others
```
**count_value**

The count value that should lock to upon sync event

**direction**

The count direction that should lock to upon sync event

**Header File**

- components/driver/mcpwm/include/driver/mcpwm_oper.h

**Functions**

- **esp_err_t mcpwm_new_operator** (const mcpwm_operator_config_t *config, mcpwm_oper_handle_t *ret_oper)
  
  Create MCPWM operator.

  **Parameters**
  
  - config - [in] MCPWM operator configuration
  - ret_oper - [out] Returned MCPWM operator handle

  **Returns**
  
  - ESP_OK: Create MCPWM operator successfully
  - ESP_ERR_INVALID_ARG: Create MCPWM operator failed because of invalid argument
  - ESP_ERR_NO_MEM: Create MCPWM operator failed because out of memory
  - ESP_ERR_NOT_FOUND: Create MCPWM operator failed because can’t find free resource
  - ESP_FAIL: Create MCPWM operator failed because of other error

- **esp_err_t mcpwm_del_operator** (mcpwm_oper_handle_t oper)
  
  Delete MCPWM operator.

  **Parameters**
  
  - oper - [in] MCPWM operator, allocated by mcpwm_new_operator()

  **Returns**
  
  - ESP_OK: Delete MCPWM operator successfully
  - ESP_ERR_INVALID_ARG: Delete MCPWM operator failed because of invalid argument
  - ESP_FAIL: Delete MCPWM operator failed because of other error

- **esp_err_t mcpwm_operator_connect_timer** (mcpwm_oper_handle_t oper, mcpwm_timer_handle_t timer)
  
  Connect MCPWM operator and timer, so that the operator can be driven by the timer.

  **Parameters**
  
  - oper - [in] MCPWM operator handle, allocated by mcpwm_new_operator()
  - timer - [in] MCPWM timer handle, allocated by mcpwm_new_timer()

  **Returns**
  
  - ESP_OK: Connect MCPWM operator and timer successfully
  - ESP_ERR_INVALID_ARG: Connect MCPWM operator and timer failed because of invalid argument
  - ESP_FAIL: Connect MCPWM operator and timer failed because of other error

- **esp_err_t mcpwm_operator_set_brake_on_fault** (mcpwm_oper_handle_t oper, const mcpwm_brake_config_t *config)
  
  Set brake method for MCPWM operator.

  **Parameters**
  
  - oper - [in] MCPWM operator, allocated by mcpwm_new_operator()
  - config - [in] MCPWM brake configuration

  **Returns**
  
  - ESP_OK: Set trip for operator successfully
  - ESP_ERR_INVALID_ARG: Set trip for operator failed because of invalid argument
  - ESP_FAIL: Set trip for operator failed because of other error
**esp_err_t** mcpwm_operator_recover_from_fault(
  mcpwm_oper_handle_t oper,
  mcpwm_fault_handle_t fault
)

Try to make the operator recover from fault.

**Note:** To recover from fault or escape from trip, you make sure the fault signal has dissapeared already. Otherwise the recovery can’t succeed.

**Parameters**

- `oper` - [in] MCPWM operator, allocated by `mcpwm_new_operator()`
- `fault` - [in] MCPWM fault handle

**Returns**

- ESP_OK: Recover from fault successfully
- ESP_ERR_INVALID_ARG: Recover from fault failed because of invalid argument
- ESP_ERR_INVALID_STATE: Recover from fault failed because the fault source is still active
- ESP_FAIL: Recover from fault failed because of other error

**esp_err_t** mcpwm_operator_register_event_callbacks(
  mcpwm_oper_handle_t oper,
  const mcpwm_operator_event_callbacks_t *cbs,
  void *user_data
)

Set event callbacks for MCPWM operator.

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the `cbs` structure to NULL.

**Parameters**

- `oper` - [in] MCPWM operator handle, allocated by `mcpwm_new_operator()`
- `cbs` - [in] Group of callback functions
- `user_data` - [in] User data, which will be passed to callback functions directly

**Returns**

- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_FAIL: Set event callbacks failed because of other error

**esp_err_t** mcpwm_operator_apply_carrier(
  mcpwm_oper_handle_t oper,
  const mcpwm_carrier_config_t *config
)

Apply carrier feature for MCPWM operator.

**Parameters**

- `oper` - [in] MCPWM operator, allocated by `mcpwm_new_operator()`
- `config` - [in] MCPWM carrier specific configuration

**Returns**

- ESP_OK: Set carrier for operator successfully
- ESP_ERR_INVALID_ARG: Set carrier for operator failed because of invalid argument
- ESP_FAIL: Set carrier for operator failed because of other error

**Structures**

`struct mcpwm_operator_config_t`

MCPWM operator configuration.

**Public Members**
int group_id
    Specify from which group to allocate the MCPWM operator

int intr_priority
    MCPWM operator interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1,2,3)

uint32_t update_gen_action_on_tez
    Whether to update generator action when timer counts to zero

uint32_t update_gen_action_on_tep
    Whether to update generator action when timer counts to peak

uint32_t update_gen_action_on_sync
    Whether to update generator action on sync event

uint32_t update_dead_time_on_tez
    Whether to update dead time when timer counts to zero

uint32_t update_dead_time_on_tep
    Whether to update dead time when timer counts to peak

uint32_t update_dead_time_on_sync
    Whether to update dead time on sync event

struct mcpwm_operator_config_t::[anonymous] flags
    Extra configuration flags for operator

struct mcpwm_brake_config_t
    MCPWM brake configuration structure.

Public Members

mcpwm_fault_handle_t fault
    Which fault causes the operator to brake

mcpwm_operator_brake_mode_t brake_mode
    Brake mode

uint32_t cbc_recover_on_tez
    Recovery CBC brake state on tez event

uint32_t cbc_recover_on_tep
    Recovery CBC brake state on tep event

struct mcpwm_brake_config_t::[anonymous] flags
    Extra flags for brake configuration
struct mcpwm_operator_event_callbacks_t

Group of supported MCPWM operator event callbacks.

**Note:** The callbacks are all running under ISR environment

### Public Members

```
mcpwm_brake_event_cb_t on_brake_cbc
```

callback function when mcpwm operator brakes in CBC

```
mcpwm_brake_event_cb_t on_brake_ost
```

callback function when mcpwm operator brakes in OST

### Public Members

```
mcpwm_carrier_config_t
```

MCPWM carrier configuration structure.

### Public Members

```
mcpwm_carrier_clock_source_t clk_src
```

MCPWM carrier clock source

```
uint32_t frequency_hz
```

Carrier frequency in Hz

```
uint32_t first_pulse_duration_us
```

The duration of the first PWM pulse, in us

```
float duty_cycle
```

Carrier duty cycle

```
uint32_t invert_before_modulate
```

Invert the raw signal

```
uint32_t invert_after_modulate
```

Invert the modulated signal

```
struct mcpwm_carrier_config_t::[anonymous] flags
```

Extra flags for carrier configuration

### Header File

- components/driver/mcpwm/include/driver/mcpwm_cmpr.h
### Functions

#### esp_err_t mcpwm_new_comparator
```c
mcpwm_oper_handle_t oper,
const mcpwm_comparator_config_t *config,
*ret_cmpr)
```

Create MCPWM comparator.

**Parameters**
- `oper` - [in] MCPWM operator, allocated by `mcpwm_new_operator()`, the new comparator will be allocated from this operator
- `config` - [in] MCPWM comparator configuration
- `ret_cmpr` - [out] Returned MCPWM comparator

**Returns**
- ESP_OK: Create MCPWM comparator successfully
- ESP_ERR_INVALID_ARG: Create MCPWM comparator failed because of invalid argument
- ESP_ERR_NO_MEM: Create MCPWM comparator failed because out of memory
- ESP_ERR_NOT_FOUND: Create MCPWM comparator failed because can’t find free resource
- ESP_FAIL: Create MCPWM comparator failed because of other error

#### esp_err_t mcpwm_del_comparator
```c
mcpwm_cmpr_handle_t cmpr)
```

Delete MCPWM comparator.

**Parameters**
- `cmpr` - [in] MCPWM comparator handle, allocated by `mcpwm_new_comparator()`

**Returns**
- ESP_OK: Delete MCPWM comparator successfully
- ESP_ERR_INVALID_ARG: Delete MCPWM comparator failed because of invalid argument
- ESP_FAIL: Delete MCPWM comparator failed because of other error

#### esp_err_t mcpwm_comparator_register_event_callbacks
```c
const mcpwm_comparator_event_callbacks_t *cbs,
void *user_data
```

Set event callbacks for MCPWM comparator.

**Parameters**
- `cmpr` - [in] MCPWM comparator handle, allocated by `mcpwm_new_comparator()`
- `cbs` - [in] Group of callback functions
- `user_data` - [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_FAIL: Set event callbacks failed because of other error

#### esp_err_t mcpwm_comparator_set_compare_value
```c
uint32_t cmp_ticks)
```

Set MCPWM comparator’s compare value.

**Parameters**
- `cmpr` - [in] MCPWM comparator handle, allocated by `mcpwm_new_comparator()`
- `cmp_ticks` - [in] The new compare value

**Returns**
- ESP_OK: Set MCPWM compare value successfully
- ESP_ERR_INVALID_ARG: Set MCPWM compare value failed because of invalid argument (e.g. the cmp_ticks is out of range)
- ESP_ERR_INVALID_STATE: Set MCPWM compare value failed because the operator doesn’t have a timer connected
• ESP_FAIL: Set MCPWM compare value failed because of other error

**Structures**

```c
struct mcpwm_comparator_config_t
MCPWM comparator configuration.
```

**Public Members**

```c
int intr_priority
MCPWM comparator interrupt priority, if set to 0, the driver will try to allocate an interrupt with a
relative low priority (1,2,3)
```

```c
uint32_t update_cmp_on_te
Whether to update compare value when timer count equals to zero (tez)
```

```c
uint32_t update_cmp_on_tep
Whether to update compare value when timer count equals to peak (tep)
```

```c
uint32_t update_cmp_on_sync
Whether to update compare value on sync event
```

```c
struct mcpwm_comparator_config_t::[anonymous] flags
Extra configuration flags for comparator
```

```c
struct mcpwm_comparator_event_callbacks_t
Group of supported MCPWM compare event callbacks.
```

**Note:** The callbacks are all running under ISR environment

**Public Members**

```c
mcpwm_compare_event_cb_t on_reach
ISR callback function which would be invoked when counter reaches compare value
```

**Header File**

```c
• components/driver/mcpwm/include/driver/mcpwm_gen.h
```

**Functions**

```c
esp_err_t mcpwm_new_generator (mcpwm_oper_handle_t oper, const mcpwm_generator_config_t *config,
                              mcpwm_gen_handle_t *ret_gen)
```

Allocate MCPWM generator from given operator.

**Parameters**

```c
• oper - [in] MCPWM operator, allocated by mcpwm_new_operator()
• config - [in] MCPWM generator configuration
• ret_gen - [out] Returned MCPWM generator
```

**Returns**
Chapter 2. API Reference

• ESP_OK: Create MCPWM generator successfully
• ESP_ERR_INVALID_ARG: Create MCPWM generator failed because of invalid argument
• ESP_ERR_NO_MEM: Create MCPWM generator failed because out of memory
• ESP_ERR_NOT_FOUND: Create MCPWM generator failed because can’t find free resource
• ESP_FAIL: Create MCPWM generator failed because of other error

`esp_err_t mcpwm_del_generator (mcpwm_gen_handle_t gen)`
Delete MCPWM generator.

Parameters  gen - [in] MCPWM generator handle, allocated by mcpwm_new_generator()

Returns
• ESP_OK: Delete MCPWM generator successfully
• ESP_ERR_INVALID_ARG: Delete MCPWM generator failed because of invalid argument
• ESP_FAIL: Delete MCPWM generator failed because of other error

`esp_err_t mcpwm_generator_set_force_level (mcpwm_gen_handle_t gen, int level, bool hold_on)`
Set force level for MCPWM generator.

**Note:** The force level will be applied to the generator immediately, regardless any other events that would change the generator’s behaviour.

**Note:** If the `hold_on` is true, the force level will retain forever, until user removes the force level by setting the force level to -1.

**Note:** If the `hold_on` is false, the force level can be overridden by the next event action.

**Note:** The force level set by this function can be inverted by GPIO matrix or dead-time module. So the level set here doesn’t equal to the final output level.

Parameters
• gen - [in] MCPWM generator handle, allocated by mcpwm_new_generator()
• level - [in] GPIO level to be applied to MCPWM generator, specially, -1 means to remove the force level
• hold_on - [in] Whether the forced PWM level should retain (i.e. will remain unchanged until manually remove the force level)

Returns
• ESP_OK: Set force level for MCPWM generator successfully
• ESP_ERR_INVALID_ARG: Set force level for MCPWM generator failed because of invalid argument
• ESP_FAIL: Set force level for MCPWM generator failed because of other error

`esp_err_t mcpwm_generator_set_action_on_timer_event (mcpwm_gen_handle_t gen, mcpwm_gen_timer_event_action_t ev_act)`
Set generator action on MCPWM timer event.

Parameters
• gen - [in] MCPWM generator handle, allocated by mcpwm_new_generator()
• ev_act - [in] MCPWM timer event action, can be constructed by MCPWM_GEN_TIMER_EVENT_ACTION helper macro

Returns
Chapter 2. API Reference

- ESP_OK: Set generator action successfully
- ESP_ERR_INVALID_ARG: Set generator action failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set generator action failed because of timer is not connected to operator
- ESP_FAIL: Set generator action failed because of other error

```
esp_err_t mcpwm_generator_set_actions_on_timer_event (mcpwm_gen_handle_t gen,
    mcpwm_gen_timer_event_action_t ev_act, ...)
```

Set generator actions on multiple MCPWM timer events.

**Note:** This is an aggregation version of `mcpwm_generator_set_action_on_timer_event`, which allows user to set multiple actions in one call.

**Parameters**
- `gen` — [in] MCPWM generator handle, allocated by `mcpwm_new_generator()`
- `ev_act` — [in] MCPWM timer event action list, must be terminated by `MCPWM_GEN_TIMER_EVENT_ACTION_END()`

**Returns**
- ESP_OK: Set generator actions successfully
- ESP_ERR_INVALID_ARG: Set generator actions failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set generator actions failed because of timer is not connected to operator
- ESP_FAIL: Set generator actions failed because of other error

```
esp_err_t mcpwm_generator_set_action_on_compare_event (mcpwm_gen_handle_t generator,
    mcpwm_gen_compare_event_action_t ev_act)
```

Set generator action on MCPWM compare event.

**Parameters**
- `generator` — [in] MCPWM generator handle, allocated by `mcpwm_new_generator()`
- `ev_act` — [in] MCPWM compare event action, can be constructed by `MCPWM_GEN_COMPARE_EVENT_ACTION` helper macro

**Returns**
- ESP_OK: Set generator action successfully
- ESP_ERR_INVALID_ARG: Set generator action failed because of invalid argument
- ESP_FAIL: Set generator action failed because of other error

```
esp_err_t mcpwm_generator_set_actions_on_compare_event (mcpwm_gen_handle_t generator,
    mcpwm_gen_compare_event_action_t ev_act, ...)
```

Set generator actions on multiple MCPWM compare events.

**Note:** This is an aggregation version of `mcpwm_generator_set_action_on_compare_event`, which allows user to set multiple actions in one call.

**Parameters**
- `generator` — [in] MCPWM generator handle, allocated by `mcpwm_new_generator()`
- `ev_act` — [in] MCPWM compare event action list, must be terminated by `MCPWM_GEN_COMPARE_EVENT_ACTION_END()`

**Returns**
- ESP_OK: Set generator actions successfully
- ESP_ERR_INVALID_ARG: Set generator actions failed because of invalid argument
• ESP_FAIL: Set generator actions failed because of other error

```c
esp_err_t mcpwm_generator_set_action_on_brake_event (mcpwm_gen_handle_t generator, mcpwm_gen_brake_event_action_t ev_act)
```

Set generator action on MCPWM brake event.

**Parameters**
- `generator` [-][in] MCPWM generator handle, allocated by \texttt{mcpwm_new_generator()}
- `ev_act` [-][in] MCPWM brake event action, can be constructed by \texttt{MCPWM_GEN_BRAKE_EVENT_ACTION} helper macro

**Returns**
- ESP_OK: Set generator action successfully
- ESP_ERR_INVALID_ARG: Set generator action failed because of invalid argument
- ESP_FAIL: Set generator action failed because of other error

```c
esp_err_t mcpwm_generator_set_actions_on_brake_event (mcpwm_gen_handle_t generator, mcpwm_gen_brake_event_action_t ev_act, ...)
```

Set generator actions on multiple MCPWM brake events.

**Note:** This is an aggregation version of \texttt{mcpwm_generator_set_action_on_brake_event}, which allows user to set multiple actions in one call.

**Parameters**
- `generator` [-][in] MCPWM generator handle, allocated by \texttt{mcpwm_new_generator()}
- `ev_act` [-][in] MCPWM brake event action list, must be terminated by \texttt{MCPWM_GEN_BRAKE_EVENT_ACTION_END()} 

**Returns**
- ESP_OK: Set generator actions successfully
- ESP_ERR_INVALID_ARG: Set generator actions failed because of invalid argument
- ESP_FAIL: Set generator actions failed because of other error

```c
esp_err_t mcpwm_generator_set_dead_time (mcpwm_gen_handle_t in_generator, mcpwm_gen_handle_t out_generator, const mcpwm_dead_time_config_t *config)
```

Set dead time for MCPWM generator.

**Note:** Due to a hardware limitation, you can’t set rising edge delay for both MCPWM generator 0 and 1 at the same time, otherwise, there will be a conflict inside the dead time module. The same goes for the falling edge setting. But you can set both the rising edge and falling edge delay for the same MCPWM generator.

**Parameters**
- `in_generator` [-][in] MCPWM generator, before adding the dead time
- `out_generator` [-][in] MCPWM generator, after adding the dead time
- `config` [-][in] MCPWM dead time configuration

**Returns**
- ESP_OK: Set dead time for MCPWM generator successfully
- ESP_ERR_INVALID_ARG: Set dead time for MCPWM generator failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set dead time for MCPWM generator failed because of invalid state (e.g. delay module is already in use by other generator)
- ESP_FAIL: Set dead time for MCPWM generator failed because of other error
Chapter 2. API Reference

Structures

```c
struct mcpwm_generator_config_t
MCPWM generator configuration.
```

**Public Members**

```c
int gen_gpio_num
    The GPIO number used to output the PWM signal
```

```c
uint32_t invert_pwm
    Whether to invert the PWM signal (done by GPIO matrix)
```

```c
uint32_t io_loop_back
    For debug/test, the signal output from the GPIO will be fed to the input path as well
```

```c
uint32_t io_od_mode
    Configure the GPIO as open-drain mode
```

```c
uint32_t pull_up
    Whether to pull up internally
```

```c
uint32_t pull_down
    Whether to pull down internally
```

```c
struct mcpwm_generator_config_t::[anonymous] flags
    Extra configuration flags for generator
```

```c
struct mcpwm_gen_timer_event_action_t
    Generator action on specific timer event.
```

**Public Members**

```c
mcpwm_timer_direction_t direction
    Timer direction
```

```c
mcpwm_timer_event_t event
    Timer event
```

```c
mcpwm_generator_action_t action
    Generator action should perform
```

```c
struct mcpwm_gen_compare_event_action_t
    Generator action on specific comparator event.
```

**Public Members**
mcpwm_timer_direction_t \textbf{direction}  
Timer direction

mcpwm_cmpr_handle_t \textbf{comparator}  
Comparator handle

mcpwm_generator_action_t \textbf{action}  
Generator action should perform

\textbf{struct} mcpwm_gen_brake_event_action_t  
Generator action on specific brake event.

\textbf{Public Members}

mcpwm_timer_direction_t \textbf{direction}  
Timer direction

mcpwm_operator_brake_mode_t \textbf{brake_mode}  
Brake mode

mcpwm_generator_action_t \textbf{action}  
Generator action should perform

\textbf{struct} mcpwm_dead_time_config_t  
MCPWM dead time configuration structure.

\textbf{Public Members}

\textbf{uint32_t} \textbf{posedge_delay_ticks}  
delay time applied to rising edge, 0 means no rising delay time

\textbf{uint32_t} \textbf{negedge_delay_ticks}  
delay time applied to falling edge, 0 means no falling delay time

\textbf{uint32_t} \textbf{invert_output}  
Invert the signal after applied the dead time

\textbf{struct} mcpwm_dead_time_config_t::[anonymous] \textbf{flags}  
Extra flags for dead time configuration

\textbf{Macros}

\textbf{MCPWM_GEN_TIMER_EVENT_ACTION (dir, ev, act)}  
Help macros to construct a \textit{mcpwm_gen_timer_event_action_t} entry.

\textbf{MCPWM_GEN_TIMER_EVENT_ACTION_END ()}

\textbf{MCPWM_GENCOMPARE_EVENT_ACTION (dir, cmp, act)}  
Help macros to construct a \textit{mcpwm_gen_compare_event_action_t} entry.
MCPWM_GEN_COMPARE_EVENT_ACTION_END();

MCPWM_GEN_BRAKE_EVENT_ACTION(dir, mode, act)

Help macros to construct a `mcpwm_gen_brake_event_action_t` entry.

MCPWM_GEN_BRAKE_EVENT_ACTION_END();

Header File

- components/driver/mcpwm/include/driver/mcpwm_fault.h

Functions

`esp_err_t mcpwm_new_gpio_fault(const mcpwm_gpio_fault_config_t *config, mcpwm_fault_handle_t *ret_fault)`

Create MCPWM GPIO fault.

**Parameters**

- config - [in] MCPWM GPIO fault configuration
- ret_fault - [out] Returned GPIO fault handle

**Returns**

- ESP_OK: Create MCPWM GPIO fault successfully
- ESP_ERR_INVALID_ARG: Create MCPWM GPIO fault failed because of invalid argument
- ESP_ERR_NO_MEM: Create MCPWM GPIO fault failed because out of memory
- ESP_ERR_NOT_FOUND: Create MCPWM GPIO fault failed because can’t find free resource
- ESP_FAIL: Create MCPWM GPIO fault failed because of other error

`esp_err_t mcpwm_new_soft_fault(const mcpwm_soft_fault_config_t *config, mcpwm_fault_handle_t *ret_fault)`

Create MCPWM software fault.

**Parameters**

- config - [in] MCPWM software fault configuration
- ret_fault - [out] Returned software fault handle

**Returns**

- ESP_OK: Create MCPWM software fault successfully
- ESP_ERR_INVALID_ARG: Create MCPWM software fault failed because of invalid argument
- ESP_ERR_NO_MEM: Create MCPWM software fault failed because out of memory
- ESP_FAIL: Create MCPWM software fault failed because of other error

`esp_err_t mcpwm_del_fault(mcpwm_fault_handle_t fault)`

Delete MCPWM fault.

**Parameters**

- fault - [in] MCPWM fault handle allocated by `mcpwm_new_gpio_fault()` or `mcpwm_new_soft_fault()`

**Returns**

- ESP_OK: Delete MCPWM fault successfully
- ESP_ERR_INVALID_ARG: Delete MCPWM fault failed because of invalid argument
- ESP_FAIL: Delete MCPWM fault failed because of other error

`esp_err_t mcpwm_soft_fault_activate(mcpwm_fault_handle_t fault)`

Activate the software fault, trigger the fault event for once.

**Parameters**

- fault - [in] MCPWM soft fault, allocated by `mcpwm_new_soft_fault()`

**Returns**

- ESP_OK: Trigger MCPWM software fault event successfully
- ESP_ERR_INVALID_ARG: Trigger MCPWM software fault event failed because of invalid argument
• ESP_FAIL: Trigger MCPWM software fault event failed because of other error

```
esp_err_t mcpwm_fault_register_event_callbacks(mcpwm_fault_handle_t fault, const mcpwm_fault_event_callbacks_t *cbs, void *user_data)
```

Set event callbacks for MCPWM fault.

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the `cbs` structure to NULL.

**Parameters**
- **fault** [in] MCPWM GPIO fault handle, allocated by `mcpwm_new_gpio_fault()`
- **cbs** [in] Group of callback functions
- **user_data** [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_FAIL: Set event callbacks failed because of other error

**Structures**

```
struct mcpwm_gpio_fault_config_t
```

MCPWM GPIO fault configuration structure.

**Public Members**

- **int group_id**
  In which MCPWM group that the GPIO fault belongs to

- **int intr_priority**
  MCPWM GPIO fault interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1,2,3)

- **int gpio_num**
  GPIO used by the fault signal

- **uint32_t active_level**
  On which level the fault signal is treated as active

- **uint32_t io_loop_back**
  For debug/test, the signal output from the GPIO will be fed to the input path as well

- **uint32_t pull_up**
  Whether to pull up internally

- **uint32_t pull_down**
  Whether to pull down internally

```
struct mcpwm_gpio_fault_config_t::[anonymous] flags
```

Extra configuration flags for GPIO fault
Chapter 2. API Reference

struct mcpwm_soft_fault_config_t
MCPWM software fault configuration structure.

struct mcpwm_fault_event_callbacks_t
Group of supported MCPWM fault event callbacks.

Note: The callbacks are all running under ISR environment

Public Members

mcpwm_fault_event_cb_t on_fault_enter
ISR callback function that would be invoked when fault signal becomes active

mcpwm_fault_event_cb_t on_fault_exit
ISR callback function that would be invoked when fault signal becomes inactive

Header File

• components/driver/mcpwm/include/driver/mcpwm_sync.h

Functions

esp_err_t mcpwm_new_timer_sync_src
(mcpwm_timer_handle_t timer, const
mcpwm_timer_sync_src_config_t *config, mcpwm_sync_handle_t *ret_sync)
Create MCPWM timer sync source.

Parameters

• timer – [in] MCPWM timer handle, allocated by mcpwm_new_timer()
• config – [in] MCPWM timer sync source configuration
• ret_sync – [out] Returned MCPWM sync handle

Returns

• ESP_OK: Create MCPWM timer sync source successfully
• ESP_ERR_INVALID_ARG: Create MCPWM timer sync source failed because of invalid argument
• ESP_ERR_NO_MEM: Create MCPWM timer sync source failed because out of memory
• ESP_ERR_INVALID_STATE: Create MCPWM timer sync source failed because the timer has created a sync source before
• ESP_FAIL: Create MCPWM timer sync source failed because of other error

esp_err_t mcpwm_new_gpio_sync_src
(const mcpwm_gpio_sync_src_config_t *config,
mcpwm_sync_handle_t *ret_sync)
Create MCPWM GPIO sync source.

Parameters

• config – [in] MCPWM GPIO sync source configuration
• ret_sync – [out] Returned MCPWM GPIO sync handle

Returns

• ESP_OK: Create MCPWM GPIO sync source successfully
• ESP_ERR_INVALID_ARG: Create MCPWM GPIO sync source failed because of invalid argument
• ESP_ERR_NO_MEM: Create MCPWM GPIO sync source failed because out of memory
• ESP_ERR_NOT_FOUND: Create MCPWM GPIO sync source failed because can’t find free resource
Chapter 2. API Reference

• ESP_FAIL: Create MCPWM GPIO sync source failed because of other error

```c
esp_err_t mcpwm_new_soft_sync_src(const mcpwm_soft_sync_config_t *config, mcpwm_sync_handle_t *ret_sync)
```

Create MCPWM software sync source.

Parameters

- `config` - [in] MCPWM software sync source configuration
- `ret_sync` - [out] Returned software sync handle

Returns

- ESP_OK: Create MCPWM software sync successfully
- ESP_ERR_INVALID_ARG: Create MCPWM software sync failed because of invalid argument
- ESP_ERR_NO_MEM: Create MCPWM software sync failed because out of memory
- ESP_FAIL: Create MCPWM software sync failed because of other error

```c
esp_err_t mcpwm_del_sync_src(mcpwm_sync_handle_t sync)
```

Delete MCPWM sync source.

Parameters

- `sync` - [in] MCPWM sync handle, allocated by mcpwm_new_timer_sync_src() or mcpwm_new_gpio_sync_src() or mcpwm_new_soft_sync_src()

Returns

- ESP_OK: Delete MCPWM sync source successfully
- ESP_ERR_INVALID_ARG: Delete MCPWM sync source failed because of invalid argument
- ESP_FAIL: Delete MCPWM sync source failed because of other error

```c
esp_err_t mcpwm_soft_sync_activate(mcpwm_sync_handle_t sync)
```

Activate the software sync, trigger the sync event once.

Parameters

- `sync` - [in] MCPWM soft sync handle, allocated by mcpwm_new_soft_sync_src()

Returns

- ESP_OK: Trigger MCPWM software sync event successfully
- ESP_ERR_INVALID_ARG: Trigger MCPWM software sync event failed because of invalid argument
- ESP_FAIL: Trigger MCPWM software sync event failed because of other error

Structures

```c
struct mcpwm_timer_sync_src_config_t
```

MCPWM timer sync source configuration.

```c
struct mcpwm_gpio_sync_src_config_t
```

MCPWM GPIO sync source configuration.

**Public Members**

```c
mcpwm_timer_event_t timer_event
```

Timer event, upon which MCPWM timer will generate the sync signal

```c
uint32_t propagate_input_sync
```

The input sync signal would be routed to its sync output

```c
struct mcpwm_timer_sync_src_config_t::[anonymous] flags
```

Extra configuration flags for timer sync source

```c
struct mcpwm_gpio_sync_src_config_t
```

MCPWM GPIO sync source configuration.
Chapter 2. API Reference

Public Members

int group_id
MCPWM group ID

int gpio_num
GPIO used by sync source

uint32_t active_neg
Whether the sync signal is active on negedge, by default, the sync signal’s posedge is treated as active

uint32_t io_loop_back
For debug/test, the signal output from the GPIO will be fed to the input path as well

uint32_t pull_up
Whether to pull up internally

uint32_t pull_down
Whether to pull down internally

struct mcpwm_gpio_sync_src_config_t::[anonymous] flags
Extra configuration flags for GPIO sync source

struct mcpwm_soft_sync_config_t
MCPWM software sync configuration structure.

Header File

- components/driver/mcpwm/include/driver/mcpwm_cap.h

Functions

esp_err_t mcpwm_new_capture_timer (const mcpwm_capture_timer_config_t *config,
mcpwm_cap_timer_handle_t *ret_cap_timer)
Create MCPWM capture timer.

Parameters

- config [in] MCPWM capture timer configuration
- ret_cap_timer [out] Returned MCPWM capture timer handle

Returns

- ESP_OK: Create MCPWM capture timer successfully
- ESP.ERR.INVALID_ARG: Create MCPWM capture timer failed because of invalid argument
- ESP.ERR.NO_MEM: Create MCPWM capture timer failed because out of memory
- ESP.ERR.NOT_FOUND: Create MCPWM capture timer failed because can’t find free resource
- ESP.FAIL: Create MCPWM capture timer failed because of other error

esp_err_t mcpwm_del_capture_timer (mcpwm_cap_timer_handle_t cap_timer)
Delete MCPWM capture timer.

Parameters
cap_timer [in] MCPWM capture timer, allocated by mcpwm_new_capture_timer()

Returns

- ESP_OK: Delete MCPWM capture timer successfully
• ESP_ERR_INVALID_ARG: Delete MCPWM capture timer failed because of invalid argument
• ESP_FAIL: Delete MCPWM capture timer failed because of other error

**esp_err_t mcpwm_capture_timer_enable** *(mcpwm_cap_timer_handle_t cap_timer)*  
Enable MCPWM capture timer.

**Parameters**  
cap_timer ⚶ [in] MCPWM capture timer handle, allocated by mcpwm_new_capture_timer()

**Returns**  
• ESP_OK: Enable MCPWM capture timer successfully
• ESP_ERR_INVALID_ARG: Enable MCPWM capture timer failed because of invalid argument
• ESP_ERR_INVALID_STATE: Enable MCPWM capture timer failed because timer is enabled already
• ESP_FAIL: Enable MCPWM capture timer failed because of other error

**esp_err_t mcpwm_capture_timer_disable** *(mcpwm_cap_timer_handle_t cap_timer)*  
Disable MCPWM capture timer.

**Parameters**  
cap_timer ⚶ [in] MCPWM capture timer handle, allocated by mcpwm_new_capture_timer()

**Returns**  
• ESP_OK: Disable MCPWM capture timer successfully
• ESP_ERR_INVALID_ARG: Disable MCPWM capture timer failed because of invalid argument
• ESP_ERR_INVALID_STATE: Disable MCPWM capture timer failed because timer is disabled already
• ESP_FAIL: Disable MCPWM capture timer failed because of other error

**esp_err_t mcpwm_capture_timer_start** *(mcpwm_cap_timer_handle_t cap_timer)*  
Start MCPWM capture timer.

**Parameters**  
cap_timer ⚶ [in] MCPWM capture timer, allocated by mcpwm_new_capture_timer()

**Returns**  
• ESP_OK: Start MCPWM capture timer successfully
• ESP_ERR_INVALID_ARG: Start MCPWM capture timer failed because of invalid argument
• ESP_FAIL: Start MCPWM capture timer failed because of other error

**esp_err_t mcpwm_capture_timer_stop** *(mcpwm_cap_timer_handle_t cap_timer)*  
Start MCPWM capture timer.

**Parameters**  
cap_timer ⚶ [in] MCPWM capture timer, allocated by mcpwm_new_capture_timer()

**Returns**  
• ESP_OK: Stop MCPWM capture timer successfully
• ESP_ERR_INVALID_ARG: Stop MCPWM capture timer failed because of invalid argument
• ESP_FAIL: Stop MCPWM capture timer failed because of other error

**esp_err_t mcpwm_capture_timer_get_resolution** *(mcpwm_cap_timer_handle_t cap_timer, uint32_t *out_resolution)*  
Get MCPWM capture timer resolution, in Hz.

**Parameters**  
cap_timer ⚶ [in] MCPWM capture timer, allocated by mcpwm_new_capture_timer()

**Returns**  
• ESP_OK: Get capture timer resolution successfully
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG: Get capture timer resolution failed because of invalid argument
- ESP_FAIL: Get capture timer resolution failed because of other error

```c
esp_err_t mcpwm_capture_timer_set_phase_on_sync(mcpwm_cap_timer_handle_t cap_timer, const mcpwm_capture_timer_sync_phase_config_t *config)
```

Set sync phase for MCPWM capture timer.

**Parameters**
- `cap_timer` - [in] MCPWM capture timer, allocated by `mcpwm_new_capture_timer()`
- `config` - [in] MCPWM capture timer sync phase configuration

**Returns**
- ESP_OK: Set sync phase for MCPWM capture timer successfully
- ESP_ERR_INVALID_ARG: Set sync phase for MCPWM capture timer failed because of invalid argument
- ESP_FAIL: Set sync phase for MCPWM capture timer failed because of other error

```c
esp_err_t mcpwm_new_capture_channel(mcpwm_cap_timer_handle_t cap_timer, const mcpwm_capture_channel_config_t *config, mcpwm_cap_channel_handle_t *ret_cap_channel)
```

Create MCPWM capture channel.

**Note:** The created capture channel won’t be enabled until calling `mcpwm_capture_channel_enable`

**Parameters**
- `cap_timer` - [in] MCPWM capture timer, allocated by `mcpwm_new_capture_timer()`
  will be connected to the new capture channel
- `config` - [in] MCPWM capture channel configuration
- `ret_cap_channel` - [out] Returned MCPWM capture channel

**Returns**
- ESP_OK: Create MCPWM capture channel successfully
- ESP_ERR_INVALID_ARG: Create MCPWM capture channel failed because of invalid argument
- ESP_ERR_NO_MEM: Create MCPWM capture channel failed because out of memory
- ESP_ERR_NOT_FOUND: Create MCPWM capture channel failed because can’t find free resource
- ESP_FAIL: Create MCPWM capture channel failed because of other error

```c
esp_err_t mcpwm_del_capture_channel(mcpwm_cap_channel_handle_t cap_channel)
```

Delete MCPWM capture channel.

**Parameters**
- `cap_channel` - [in] MCPWM capture channel handle, allocated by `mcpwm_new_capture_channel()`

**Returns**
- ESP_OK: Delete MCPWM capture channel successfully
- ESP_ERR_INVALID_ARG: Delete MCPWM capture channel failed because of invalid argument
- ESP_FAIL: Delete MCPWM capture channel failed because of other error

```c
esp_err_t mcpwm_capture_channel_enable(mcpwm_cap_channel_handle_t cap_channel)
```

Enable MCPWM capture channel.

**Note:** This function will transit the channel state from init to enable.
### Note:
This function will enable the interrupt service, if it’s lazy installed in `mcpwm_capture_channel_register_event_callbacks()`.

**Parameters**
- `cap_channel` - [in] MCPWM capture channel handle, allocated by `mcpwm_new_capture_channel()`

**Returns**
- ESP_OK: Enable MCPWM capture channel successfully
- ESP_ERR_INVALID_ARG: Enable MCPWM capture channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Enable MCPWM capture channel failed because the channel is already enabled
- ESP_FAIL: Enable MCPWM capture channel failed because of other error

`esp_err_t mcpwm_capture_channel_disable(mcpwm_cap_channel_handle_t cap_channel)`

Disable MCPWM capture channel.

**Parameters**
- `cap_channel` - [in] MCPWM capture channel handle, allocated by `mcpwm_new_capture_channel()`

**Returns**
- ESP_OK: Disable MCPWM capture channel successfully
- ESP_ERR_INVALID_ARG: Disable MCPWM capture channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Disable MCPWM capture channel failed because the channel is not enabled yet
- ESP_FAIL: Disable MCPWM capture channel failed because of other error

`esp_err_t mcpwm_capture_channel_register_event_callbacks(mcpwm_cap_channel_handle_t cap_channel, const mcpwm_capture_event_callbacks_t *cbs, void *user_data)`

Set event callbacks for MCPWM capture channel.

**Note:** The first call to this function needs to be before the call to `mcpwm_capture_channel_enable`

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the `cbs` structure to NULL.

**Parameters**
- `cap_channel` - [in] MCPWM capture channel handle, allocated by `mcpwm_new_capture_channel()`
- `cbs` - [in] Group of callback functions
- `user_data` - [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set event callbacks failed because the channel is not in init state
- ESP_FAIL: Set event callbacks failed because of other error

`esp_err_t mcpwm_capture_channel_trigger_soft_catch(mcpwm_cap_channel_handle_t cap_channel)`

Trigger a catch by software.
Chapter 2. API Reference

Parameters cap_channel - [in] MCPWM capture channel handle, allocated by mcpwm_new_capture_channel()

Returns

- ESP_OK: Trigger software catch successfully
- ESP_ERR_INVALID_ARG: Trigger software catch failed because of invalid argument
- ESP_ERR_INVALID_STATE: Trigger software catch failed because the channel is not enabled yet
- ESP_FAIL: Trigger software catch failed because of other error

Structures

struct mcpwm_capture_timer_config_t
MCPWM capture timer configuration structure.

Public Members

int group_id
Specify from which group to allocate the capture timer

mcpwm_capture_clock_source_t clk_src
MCPWM capture timer clock source

uint32_t resolution_hz
Resolution of capture timer

struct mcpwm_capture_timer_sync_phase_config_t
MCPWM Capture timer sync phase configuration.

Public Members

mcpwm_sync_handle_t sync_src
The sync event source

uint32_t count_value
The count value that should lock to upon sync event

mcpwm_timer_direction_t direction
The count direction that should lock to upon sync event

struct mcpwm_capture_channel_config_t
MCPWM capture channel configuration structure.

Public Members

int gpio_num
GPIO used capturing input signal
**Chapter 2. API Reference**

```c
int intr_priority
MCPWM capture interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1,2,3)
```

```c
uint32_t prescale
Prescale of input signal, effective frequency = cap_input_clk/prescale
```

```c
uint32_t pos_edge
Whether to capture on positive edge
```

```c
uint32_t neg_edge
Whether to capture on negative edge
```

```c
uint32_t pull_up
Whether to pull up internally
```

```c
uint32_t pull_down
Whether to pull down internally
```

```c
uint32_t invert_cap_signal
Invert the input capture signal
```

```c
uint32_t io_loop_back
For debug/test, the signal output from the GPIO will be fed to the input path as well
```

```c
uint32_t keep_io_conf_at_exit
For debug/test, whether to keep the GPIO configuration when capture channel is deleted. By default, driver will reset the GPIO pin at exit.
```

```c
struct mcpwm_capture_channel_config_t::[anonymous] flags
Extra configuration flags for capture channel
```

```c
struct mcpwm_capture_event_callbacks_t
Group of supported MCPWM capture event callbacks.
```

---

**Note:** The callbacks are all running under ISR environment

**Public Members**

```c
mcpwm_capture_event_cb_t on_cap
Callback function that would be invoked when capture event occurred
```

**Header File**

- components/driver/mcpwm/include/driver/mcpwm_types.h
Structures

struct mcpwm_timer_event_data_t
MCPWM timer event data.

Public Members

uint32_t count_value
MCPWM timer count value

mcpwm_timer_direction_t direction
MCPWM timer count direction

struct mcpwm_brake_event_data_t
MCPWM brake event data.

struct mcpwm_fault_event_data_t
MCPWM fault event data.

struct mcpwm_compare_event_data_t
MCPWM compare event data.

Public Members

uint32_t compare_ticks
Compare value

mcpwm_timer_direction_t direction
Count direction

struct mcpwm_capture_event_data_t
MCPWM capture event data.

Public Members

uint32_t cap_value
Captured value

mcpwm_capture_edge_t cap_edge
Capture edge

Type Definitions

typedef struct mcpwm_timer_t *mcpwm_timer_handle_t
Type of MCPWM timer handle.

typedef struct mcpwm_oper_t *mcpwm_oper_handle_t
Type of MCPWM operator handle.
typedef struct mcpwm_cmpr_t *mcpwm_cmpr_handle_t
    Type of MCPWM comparator handle.

typedef struct mcpwm_gen_t *mcpwm_gen_handle_t
    Type of MCPWM generator handle.

typedef struct mcpwm_fault_t *mcpwm_fault_handle_t
    Type of MCPWM fault handle.

typedef struct mcpwm_sync_t *mcpwm_sync_handle_t
    Type of MCPWM sync handle.

typedef struct mcpwm_cap_timer_t *mcpwm_cap_timer_handle_t
    Type of MCPWM capture timer handle.

typedef struct mcpwm_cap_channel_t *mcpwm_cap_channel_handle_t
    Type of MCPWM capture channel handle.

typedef bool (*mcpwm_timer_event_cb_t)(mcpwm_timer_handle_t timer, const mcpwm_timer_event_data_t *edata, void *user_ctx)
    MCPWM timer event callback function.

    Param timer [in] MCPWM timer handle
    Param edata [in] MCPWM timer event data, fed by driver
    Param user_ctx [in] User data, set in mcpwm_timer_register_event_callbacks()
    Return Whether a high priority task has been waken up by this function

typedef bool (*mcpwm_brake_event_cb_t)(mcpwm_oper_handle_t oper, const mcpwm_brake_event_data_t *edata, void *user_ctx)
    MCPWM operator brake event callback function.

    Param oper [in] MCPWM operator handle
    Param edata [in] MCPWM brake event data, fed by driver
    Param user_ctx [in] User data, set in mcpwm_operator_register_event_callbacks()
    Return Whether a high priority task has been waken up by this function

typedef bool (*mcpwm_fault_event_cb_t)(mcpwm_fault_handle_t fault, const mcpwm_fault_event_data_t *edata, void *user_ctx)
    MCPWM fault event callback function.

    Param fault MCPWM fault handle
    Param edata MCPWM fault event data, fed by driver
    Param user_ctx User data, set in mcpwm_fault_register_event_callbacks()
    Return whether a task switch is needed after the callback returns

typedef bool (*mcpwm_compare_event_cb_t)(mcpwm_cmpr_handle_t comparator, const mcpwm_compare_event_data_t *edata, void *user_ctx)
    MCPWM comparator event callback function.

    Param comparator MCPWM comparator handle
    Param edata MCPWM comparator event data, fed by driver
    Param user_ctx User data, set in mcpwm_comparator_register_event_callbacks()
    Return Whether a high priority task has been waken up by this function
typedef bool (*mcpwm_capture_event_cb_t)(mcpwm_cap_channel_handle_t cap_channel, const mcpwm_capture_event_data_t *edata, void *user_ctx)

MCPWM capture event callback function.

- **Param cap_channel**: MCPWM capture channel handle
- **Param edata**: MCPWM capture event data, fed by driver
- **Param user_ctx**: User data, set in `mcpwm_capture_channel_register_event_callbacks()`
- **Return**: Whether a high priority task has been woken up by this function

**Header File**
- `components/hal/include/hal/mcpwm_types.h`

**Type Definitions**

typedef `soc_periph_mcpwm_timer_clk_src_t` mcpwm_timer_clock_source_t
MCPWM timer clock source.

typedef `soc_periph_mcpwm_capture_clk_src_t` mcpwm_capture_clock_source_t
MCPWM capture clock source.

typedef `soc_periph_mcpwm_carrier_clk_src_t` mcpwm_carrier_clock_source_t
MCPWM carrier clock source.

**Enumerations**

enum mcpwm_timer_direction_t
MCPWM timer count direction.

- **Values**:
  
  - Enumerator `MCPWM_TIMER_DIRECTION_UP`
    Counting direction: Increase
  
  - Enumerator `MCPWM_TIMER_DIRECTION_DOWN`
    Counting direction: Decrease

enum mcpwm_timer_event_t
MCPWM timer events.

- **Values**:
  
  - Enumerator `MCPWM_TIMER_EVENT_EMPTY`
    MCPWM timer counts to zero (i.e. counter is empty)
  
  - Enumerator `MCPWM_TIMER_EVENT_FULL`
    MCPWM timer counts to peak (i.e. counter is full)
  
  - Enumerator `MCPWM_TIMER_EVENT_INVALID`
    MCPWM timer invalid event
enum `mcpwm_timer_count_mode_t`
MCPWM timer count modes.

Values:

enumerator `MCPWM_TIMER_COUNT_MODE_PAUSE`
MCPWM timer paused

enumerator `MCPWM_TIMER_COUNT_MODE_UP`
MCPWM timer counting up

enumerator `MCPWM_TIMER_COUNT_MODE_DOWN`
MCPWM timer counting down

enumerator `MCPWM_TIMER_COUNT_MODE_UP_DOWN`
MCPWM timer counting up and down

enum `mcpwm_timer_start_stop_cmd_t`
MCPWM timer commands, specify the way to start or stop the timer.

Values:

enumerator `MCPWM_TIMER_STOP_EMPTY`
MCPWM timer stops when next count reaches zero

enumerator `MCPWM_TIMER_STOP_FULL`
MCPWM timer stops when next count reaches peak

enumerator `MCPWM_TIMER_START_NO_STOP`
MCPWM timer starts counting, and don’t stop until received stop command

enumerator `MCPWM_TIMER_START_STOP_EMPTY`
MCPWM timer starts counting and stops when next count reaches zero

enumerator `MCPWM_TIMER_START_STOP_FULL`
MCPWM timer starts counting and stops when next count reaches peak

enum `mcpwm_generator_action_t`
MCPWM generator actions.

Values:

enumerator `MCPWM_GEN_ACTION_KEEP`
Generator action: Keep the same level

enumerator `MCPWM_GEN_ACTION_LOW`
Generator action: Force to low level

enumerator `MCPWM_GEN_ACTION_HIGH`
Generator action: Force to high level
2.6.13 Pulse Counter (PCNT)

Introduction

The PCNT (Pulse Counter) module is designed to count the number of rising and/or falling edges of input signals. The ESP32 contains multiple pulse counter units in the module. Each unit is in effect an independent counter with multiple channels, where each channel can increment/decrement the counter on a rising/falling edge. Furthermore, each channel can be configured separately.

PCNT channels can react to signals of edge type and level type, however for simple applications, detecting the edge signal is usually sufficient. PCNT channels can be configured react to both pulse edges (i.e., rising and falling edge), and can be configured to increase, decrease or do nothing to the unit’s counter on each edge. The level signal is the so-called control signal, which is used to control the counting mode of the edge signals that are attached to the same channel. By combining the usage of both edge and level signals, a PCNT unit can act as a quadrature decoder.

Besides that, PCNT unit is equipped with a separate glitch filter, which is helpful to remove noise from the signal.

Typically, a PCNT module can be used in scenarios like:

- Calculate periodic signal’s frequency by counting the pulse numbers within a time slice
- Decode quadrature signals into speed and direction

---

1 Different ESP chip series might have different number of PCNT units and channels. Please refer to the [TRM] for details. The driver won’t forbid you from applying for more PCNT units and channels, but it will return error when all available hardware resources are used up. Please always check the return value when doing resource allocation (e.g., `pcnt_new_unit()`).
Functional Overview

Description of the PCNT functionality is divided into the following sections:

- **Resource Allocation** - covers how to allocate PCNT units and channels with properly set of configurations. It also covers how to recycle the resources when they finished working.
- **Set Up Channel Actions** - covers how to configure the PCNT channel to behave on different signal edges and levels.
- **Watch Points** - describes how to configure PCNT watch points (i.e., tell PCNT unit to trigger an event when the count reaches a certain value).
- **Register Event Callbacks** - describes how to hook your specific code to the watch point event callback function.
- **Enable and Disable Unit** - describes how to enable and disable the PCNT unit.
- **Unit IO Control** - describes IO control functions of PCNT unit, like enable glitch filter, start and stop unit, get and clear count value.
- **Power Management** - describes what functionality will prevent the chip from going into low power mode.
- **IRAM Safe** - describes tips on how to make the PCNT interrupt and IO control functions work better along with a disabled cache.
- **Thread Safety** - lists which APIs are guaranteed to be thread safe by the driver.
- **Kconfig Options** - lists the supported Kconfig options that can be used to make a different effect on driver behavior.

**Resource Allocation**

The PCNT unit and channel are represented by `pcnt_unit_handle_t` and `pcnt_channel_handle_t` respectively. All available units and channels are maintained by the driver in a resource pool, so you do not need to know the exact underlying instance ID.

**Install PCNT Unit**

To install a PCNT unit, there’s a configuration structure that needs to be given in advance:

```c
pcnt_unit_config_t:
```

- `pcnt_unit_config_t::low_limit` and `pcnt_unit_config_t::high_limit` specify the range for the internal hardware counter. The counter will reset to zero automatically when it crosses either the high or low limit.
- `pcnt_unit_config_t::accum_count` sets whether to create an internal accumulator for the counter. This is helpful when you want to extend the counter’s width, which by default is 16bit at most, defined in the hardware. See also `Compensate Overflow Loss` for how to use this feature to compensate the overflow loss.
- `pcnt_unit_config_t::intr_priority` sets the priority of the timer interrupt. If it is set to 0, the driver will allocate an interrupt with a default priority. Otherwise, the driver will use the given priority.

**Note:** Since all PCNT units share the same interrupt source, when installing multiple PCNT units make sure that the interrupt priority `pcnt_unit_config_t::intr_priority` is the same for each unit.

Unit allocation and initialization is done by calling a function `pcnt_new_unit()` with `pcnt_unit_config_t` as an input parameter. The function will return a PCNT unit handle only when it runs correctly. Specifically, when there are no more free PCNT units in the pool (i.e. unit resources have been used up), then this function will return `ESP_ERR_NOT_FOUND` error. The total number of available PCNT units is recorded by `SOC_PCNT_UNITS_PER_GROUP` for reference.

If a previously created PCNT unit is no longer needed, it’s recommended to recycle the resource by calling `pcnt_del_unit()`. Which in return allows the underlying unit hardware to be used for other purposes. Before deleting a PCNT unit, one should ensure the following prerequisites:

- The unit is in the init state, in other words, the unit is either disabled by `pcnt_unit_disable()` or not enabled yet.
- The attached PCNT channels are all removed by `pcnt_del_channel()`.

```
#define EXAMPLE_PCNT_HIGH_LIMIT 100
#define EXAMPLE_PCNT_LOW_LIMIT -100
```

(continues on next page)
pcnt_unit_config_t unit_config = {
    .high_limit = EXAMPLE_PCNT_HIGH_LIMIT,
    .low_limit = EXAMPLE_PCNT_LOW_LIMIT,
};
pcnt_unit_handle_t pcnt_unit = NULL;
ESP_ERROR_CHECK(pcnt_new_unit(&unit_config, &pcnt_unit));

Install PCNT Channel  To install a PCNT channel, you must initialize a pcnt_chan_config_t structure in advance, and then call pcnt_new_channel(). The configuration fields of the pcnt_chan_config_t structure are described below:

- `pcnt_chan_config_t::edge_gpio_num` and `pcnt_chan_config_t::level_gpio_num` specify the GPIO numbers used by edge type signal and level type signal. Please note, either of them can be assigned to -1 if it’s not actually used, and thus it will become a virtual IO. For some simple pulse counting applications where one of the level/edge signals is fixed (i.e., never changes), you can reclaim a GPIO by setting the signal as a virtual IO on channel allocation. Setting the level/edge signal as a virtual IO will cause that signal to be internally routed to a fixed High/Low logic level, thus allowing you to save a GPIO for other purposes.
- `pcnt_chan_config_t::virt_edge_io_level` and `pcnt_chan_config_t::virt_level_io_level` specify the virtual IO level for edge and level input signal, to ensure a deterministic state for such control signal. Please note, they are only valid when either `pcnt_chan_config_t::edge_gpio_num` or `pcnt_chan_config_t::level_gpio_num` is assigned to -1.
- `pcnt_chan_config_t::invert_edge_input` and `pcnt_chan_config_t::invert_level_input` are used to decide whether to invert the input signals before they going into PCNT hardware. The invert is done by GPIO matrix instead of PCNT hardware.
- `pcnt_chan_config_t::io_loop_back` is for debug only, which enables both the GPIO’s input and output paths. This can help to simulate the pulse signals by function `gpio_set_level()` on the same GPIO.

Channel allocating and initialization is done by calling a function `pcnt_new_channel()` with the above `pcnt_chan_config_t` as an input parameter plus a PCNT unit handle returned from `pcnt_new_unit()`. This function will return a PCNT channel handle if it runs correctly. Specifically, when there are no more free PCNT channel within the unit (i.e. channel resources have been used up), then this function will return ESP_ERR_NOT_FOUND error. The total number of available PCNT channels within the unit is recorded by SOC_PCNT_CHANNELS_PER_UNIT for reference. Note that, when install a PCNT channel for a specific unit, one should ensure the unit is in the init state, otherwise this function will return ESP_ERR_INVALID_STATE error.

If a previously created PCNT channel is no longer needed, it’s recommended to recycle the resources by calling `pcnt_del_channel()`. Which in return allows the underlying channel hardware to be used for other purposes.

```c
#define EXAMPLE_CHAN_GPIO_A 0
#define EXAMPLE_CHAN_GPIO_B 2

pcnt_chan_config_t chan_config = {
    .edge_gpio_num = EXAMPLE_CHAN_GPIO_A,
    .level_gpio_num = EXAMPLE_CHAN_GPIO_B,
};
pcnt_channel_handle_t pcnt_chan = NULL;
ESP_ERROR_CHECK(pcnt_new_channel(pcnt_unit, &chan_config, &pcnt_chan));
```

Set Up Channel Actions  The PCNT will increase/decrease/hold its internal count value when the input pulse signal toggles. You can set different actions for edge signal and/or level signal.

- `pcnt_channel_set_edge_action()` function is to set specific actions for rising and falling edge of the signal attached to the `pcnt_chan_config_t::edge_gpio_num`. Supported actions are listed in `pcnt_channel_edge_action_t`.

```c
```
**pcnt_channel_set_level_action()** function is to set specific actions for high and low level of the signal attached to the `pcnt_chan_config_t::level_gpio_num`. Supported actions are listed in `pcnt_channel_level_action_t`. This function is not mandatory if the `pcnt_chan_config_t::level_gpio_num` is set to -1 when allocating PCNT channel by `pcnt_new_channel()`.

```c
// decrease the counter on rising edge, increase the counter on falling edge
ESP_ERROR_CHECK(pcnt_channel_set_edge_action(pcnt_chan, PCNT_CHANNEL_EDGE_ACTION_,
                        DECREASE, PCNT_CHANNEL_EDGE_ACTION_INCREASE));

// keep the counting mode when the control signal is high level, and reverse the counting mode when the control signal is low level
ESP_ERROR_CHECK(pcnt_channel_set_level_action(pcnt_chan, PCNT_CHANNEL_LEVEL_ACTION_,
                        KEEP, PCNT_CHANNEL_LEVEL_ACTION_INVERSE));
```

**Watch Points** Each PCNT unit can be configured to watch several different values that you’re interested in. The value to be watched is also called Watch Point. The watch point itself can’t exceed the range set in `pcnt_unit_config_t` by `pcnt_unit_config_t::low_limit` and `pcnt_unit_config_t::high_limit`. When the counter reaches either watch point, a watch event will be triggered and notify you by interrupt if any watch event callback has ever registered in `pcnt_unit_register_event_callbacks()`. See **Register Event Callbacks** for how to register event callbacks.

The watch point can be added and removed by `pcnt_unit_add_watch_point()` and `pcnt_unit_remove_watch_point()`. The commonly used watch points are: zero cross, maximum / minimum count and other threshold values. The number of available watch point is limited, `pcnt_unit_add_watch_point()` will return error `ESP_ERR_NOT_FOUND` if it can’t find any free hardware resource to save the watch point. You can’t add the same watch point for multiple times, otherwise it will return error `ESP_ERR_INVALID_STATE`.

It is recommended to remove the unused watch point by `pcnt_unit_remove_watch_point()` to recycle the watch point resources.

```c
// add zero across watch point
ESP_ERROR_CHECK(pcnt_unit_add_watch_point(pcnt_unit, 0));

// add high limit watch point
ESP_ERROR_CHECK(pcnt_unit_add_watch_point(pcnt_unit, EXAMPLE_PCNT_HIGH_LIMIT));
```

**Note:** Due to the hardware limitation, after adding a watch point, you should call `pcnt_unit_clear_count()` to make it take effect.

**Register Event Callbacks** When PCNT unit reaches any enabled watch point, specific event will be generated and notify the CPU by interrupt. If you have some function that want to get executed when event happens, you should hook your function to the interrupt service routine by calling `pcnt_unit_register_event_callbacks()`. All supported event callbacks are listed in the `pcnt_event_callbacks_t`:

- `pcnt_event_callbacks_t::on_reach` sets a callback function for watch point event. As this function is called within the ISR context, you must ensure that the function doesn’t attempt to block (e.g., by making sure that only FreeRTOS APIs with ISR suffix are called from within the function). The function prototype is declared in `pcnt_watch_cb_t`.

You can save their own context to `pcnt_unit_register_event_callbacks()` as well, via the parameter `user_ctx`. This user data will be directly passed to the callback functions.

In the callback function, the driver will fill in the event data of specific event. For example, the watch point event data is declared as `pcnt_watch_event_data_t`:

- `pcnt_watch_event_data_t::watch_point_value` saves the watch point value that triggers the event.
• `pcnt_watch_event_data_t::zero_cross_mode` saves how the PCNT unit crosses the zero point in the latest time. The possible zero cross modes are listed in the `pcnt_unit_zero_cross_mode_t`. Usually different zero cross mode means different counting direction and counting step size.

Registering callback function will result in lazy installation of interrupt service, thus this function should only be called before the unit is enabled by `pcnt_unit_enable()`. Otherwise, it can return `ESP_ERR_INVALID_STATE` error.

```c
static bool example_pcnt_on_reach(pcnt_unit_handle_t unit, const pcnt_watch_event_data_t *edata, void *user_ctx)
{
    BaseType_t high_task_wakeup;
    QueueHandle_t queue = (QueueHandle_t)user_ctx;
    // send watch point to queue, from this interrupt callback
    xQueueSendFromISR(queue, &(edata->watch_point_value), &high_task_wakeup);
    // return whether a high priority task has been waken up by this function
    return (high_task_wakeup == pdTRUE);
}

pcnt_event_callbacks_t cbs = {
    .on_reach = example_pcnt_on_reach,
};
QueueHandle_t queue = xQueueCreate(10, sizeof(int));
ESP_ERROR_CHECK(pcnt_unit_register_eventCallbacks(pcnt_unit, &cbs, queue));
```

**Set Glitch Filter**  The PCNT unit features filters to ignore possible short glitches in the signals. The parameters that can be configured for the glitch filter are listed in `pcnt_glitch_filter_config_t`:

- `pcnt_glitch_filter_config_t::max_glitch_ns` sets the maximum glitch width, in nanoseconds. If a signal pulse’s width is smaller than this value, then it will be treated as noise and won’t increase/decrease the internal counter.

You can enable the glitch filter for PCNT unit by calling `pcnt_unit_set_glitch_filter()` with the filter configuration provided above. Particularly, you can disable the glitch filter later by calling `pcnt_unit_set_glitch_filter()` with a `NULL` filter configuration.

This function should be called when the unit is in the init state. Otherwise, it will return `ESP_ERR_INVALID_STATE` error.

**Note:** The glitch filter is clocked from APB. For the counter not to miss any pulses, the maximum glitch width should be longer than one APB_CLK cycle (usually 12.5 ns if APB equals 80MHz). As the APB frequency would be changed after DFS (Dynamic Frequency Scaling) enabled, which means the filter won’t work as expect in that case. So the driver will install a PM lock for PCNT unit during the first time you enable the glitch filter. For more information related to power management strategy used in PCNT driver, please see Power Management.

```c
pcnt_glitch_filter_config_t filter_config = {
    .max_glitch_ns = 1000,
};
ESP_ERROR_CHECK(pcnt_unit_set_glitch_filter(pcnt_unit, &filter_config));
```

**Enable and Disable Unit** Before doing IO control to the PCNT unit, you need to enable it first, by calling `pcnt_unit_enable()`. Internally, this function will:

- switch the PCNT driver state from `init` to `enable`.
- enable the interrupt service if it has been lazy installed in `pcnt_unit_register_eventcallbacks()`.
- acquire a proper power management lock if it has been lazy installed in `pcnt_unit_set_glitch_filter()`. See also Power Management for more information.
Chapter 2. API Reference

On the contrary, calling `pcnt_unit_disable()` will do the opposite, that is, put the PCNT driver back to the `init` state, disable the interrupts service and release the power management lock.

**Unit IO Control**

**Start/Stop and Clear** Calling `pcnt_unit_start()` will make the PCNT unit start to work, increase or decrease counter according to pulse signals. On the contrary, calling `pcnt_unit_stop()` will stop the PCNT unit but retain current count value. Instead, clearing counter can only be done by calling `pcnt_unit_clear_count()`.

Note, `pcnt_unit_start()` and `pcnt_unit_stop()` should be called when the unit has been enabled by `pcnt_unit_enable()`. Otherwise, it will return `ESP_ERR_INVALID_STATE` error.

**Get Count Value** You can read current count value at any time by calling `pcnt_unit_get_count()`. The returned count value is a `signed` integer, where the sign can be used to reflect the direction.

```c
int pulse_count = 0;
ESP_ERROR_CHECK(pcnt_unit_get_count(pcnt_unit, &pulse_count));
```

**Compensate Overflow Loss** The internal hardware counter will be cleared to zero automatically when it reaches high or low limit. If you want to compensate for that count loss and extend the counter’s bit-width, you can:

1. Enable `pcnt_unit_config_t::accum_count` when installing the PCNT unit.
2. Add the high/low limit as the `Watch Points`.
3. Now, the returned count value from the `pcnt_unit_get_count()` function not only reflects the hardware’s count value, but also accumulates the high/low overflow loss to it.

**Power Management** When power management is enabled (i.e. `CONFIG_PM_ENABLE` is on), the system will adjust the APB frequency before going into light sleep, thus potentially changing the behavior of PCNT glitch filter and leading to valid signal being treated as noise.

However, the driver can prevent the system from changing APB frequency by acquiring a power management lock of type `ESP_PM_APB_FREQ_MAX`. Whenever you enable the glitch filter by `pcnt_unit_set_glitch_filter()`, the driver will guarantee that the power management lock is acquired after the PCNT unit is enabled by `pcnt_unit_enable()`. Likewise, the driver releases the lock after `pcnt_unit_disable()` is called.

**IRAM Safe** By default, the PCNT interrupt will be deferred when the Cache is disabled for reasons like writing/erasing Flash. Thus the alarm interrupt will not get executed in time, which is not expected in a real-time application.

There’s a Kconfig option `CONFIG_PCNT_ISR_IRAM_SAFE` that will:

1. Enable the interrupt being serviced even when cache is disabled
2. Place all functions that used by the ISR into IRAM
3. Place driver object into DRAM (in case it’s mapped to PSRAM by accident)

This will allow the interrupt to run while the cache is disabled but will come at the cost of increased IRAM consumption.

2 `pcnt_event_callbacks_t::on_reach` callback and the functions invoked by itself should also be placed in IRAM, you need to take care of them by themselves.
There’s another Kconfig option `CONFIG_PCNT_CTRL_FUNC_IN_IRAM` that can put commonly used IO control functions into IRAM as well. So that these functions can also be executable when the cache is disabled. These IO control functions are as follows:

- `pcnt_unit_start()`
- `pcnt_unit_stop()`
- `pcnt_unit_clear_count()`
- `pcnt_unit_get_count()`

**Thread Safety**  The factory functions `pcnt_new_unit()` and `pcnt_new_channel()` are guaranteed to be thread safe by the driver, which means, you can call them from different RTOS tasks without protection by extra locks. The following functions are allowed to run under ISR context, the driver uses a critical section to prevent them being called concurrently in both task and ISR.

- `pcnt_unit_start()`
- `pcnt_unit_stop()`
- `pcnt_unit_clear_count()`
- `pcnt_unit_get_count()`

Other functions that take the `pcnt_unit_handle_t` and `pcnt_channel_handle_t` as the first positional parameter, are not treated as thread safe. This means you should avoid calling them from multiple tasks.

**Kconfig Options**

- `CONFIG_PCNT_CTRL_FUNC_IN_IRAM` controls where to place the PCNT control functions (IRAM or Flash), see IRAM Safe for more information.
- `CONFIG_PCNT_ISR_IRAM_SAFE` controls whether the default ISR handler can work when cache is disabled, see IRAM Safe for more information.
- `CONFIG_PCNT_ENABLE_DEBUG_LOG` is used to enabled the debug log output. Enable this option will increase the firmware binary size.

**Application Examples**

- Decode the quadrature signals from rotary encoder: `peripherals/pcnt/rotary_encoder`.

**API Reference**

**Header File**

- `components/driver/pcnt/include/driver/pulse_cnt.h`

**Functions**

```c
esp_err_t pcnt_new_unit (const pcnt_unit_config_t *config, pcnt_unit_handle_t *ret_unit)
```

Create a new PCNT unit, and return the handle.

**Note:** The newly created PCNT unit is put in the init state.

**Parameters**

- `config` - [in] PCNT unit configuration
- `ret_unit` - [out] Returned PCNT unit handle

**Returns**

- `ESP_OK`: Create PCNT unit successfully
- `ESP_ERR_INVALID_ARG`: Create PCNT unit failed because of invalid argument (e.g. high/low limit value out of the range)
- `ESP_ERR_NO_MEM`: Create PCNT unit failed because out of memory
• ESP_ERR_NOT_FOUND: Create PCNT unit failed because all PCNT units are used up and no more free one
• ESP_FAIL: Create PCNT unit failed because of other error

`esp_err_t pcnt_del_unit (pcnt_unit_handle_t unit)`
Delete the PCNT unit handle.

**Note:** A PCNT unit can’t be in the enable state when this function is invoked. See also `pcnt_unit_disable()` for how to disable a unit.

**Parameters**
- `unit` – [in] PCNT unit handle created by `pcnt_new_unit()`

**Returns**
- ESP_OK: Delete the PCNT unit successfully
- ESP_ERR_INVALID_ARG: Delete the PCNT unit failed because of invalid argument
- ESP_ERR_INVALID_STATE: Delete the PCNT unit failed because the unit is not in init state or some PCNT channel is still in working
- ESP_FAIL: Delete the PCNT unit failed because of other error

`esp_err_t pcnt_unit_set_glitch_filter (pcnt_unit_handle_t unit, const pcnt_glitch_filter_config_t *config)`
Set glitch filter for PCNT unit.

**Note:** The glitch filter module is clocked from APB, and APB frequency can be changed during DFS, which in return make the filter out of action. So this function will lazy-install a PM lock internally when the power management is enabled. With this lock, the APB frequency won’t be changed. The PM lock can be uninstalled in `pcnt_del_unit()`.

**Note:** This function should be called when the PCNT unit is in the init state (i.e. before calling `pcnt_unit_enable()`)

**Parameters**
- `unit` – [in] PCNT unit handle created by `pcnt_new_unit()`
- `config` – [in] PCNT filter configuration, set config to NULL means disabling the filter function

**Returns**
- ESP_OK: Set glitch filter successfully
- ESP_ERR_INVALID_ARG: Set glitch filter failed because of invalid argument (e.g. glitch width is too big)
- ESP_ERR_INVALID_STATE: Set glitch filter failed because the unit is not in the init state
- ESP_FAIL: Set glitch filter failed because of other error

`esp_err_t pcnt_unit_enable (pcnt_unit_handle_t unit)`
Enable the PCNT unit.

**Note:** This function will transit the unit state from init to enable.

**Note:** This function will enable the interrupt service, if it’s lazy installed in `pcnt_unit_register_event_callbacks()`.
Note: This function will acquire the PM lock if it’s lazy installed in pcnt_unit_set_glitch_filter().

Note: Enable a PCNT unit doesn’t mean to start it. See also pcnt_unit_start() for how to start the PCNT counter.

**Parameters**

- unit – [in] PCNT unit handle created by pcnt_new_unit()

**Returns**

- ESP_OK: Enable PCNT unit successfully
- ESP_ERR_INVALID_ARG: Enable PCNT unit failed because of invalid argument
- ESP_ERR_INVALID_STATE: Enable PCNT unit failed because the unit is already enabled
- ESP_FAIL: Enable PCNT unit failed because of other error

**esp_err_t** pcnt_unit_disable (pcnt_unit_handle_t unit)

Disable the PCNT unit.

Note: This function will do the opposite work to the pcnt_unit_enable()

Note: Disable a PCNT unit doesn’t mean to stop it. See also pcnt_unit_stop() for how to stop the PCNT counter.

**Parameters**

- unit – [in] PCNT unit handle created by pcnt_new_unit()

**Returns**

- ESP_OK: Disable PCNT unit successfully
- ESP_ERR_INVALID_ARG: Disable PCNT unit failed because of invalid argument
- ESP_ERR_INVALID_STATE: Disable PCNT unit failed because the unit is not enabled yet
- ESP_FAIL: Disable PCNT unit failed because of other error

**esp_err_t** pcnt_unit_start (pcnt_unit_handle_t unit)

Start the PCNT unit, the counter will start to count according to the edge and/or level input signals.

Note: This function should be called when the unit is in the enable state (i.e. after calling pcnt_unit_enable())

Note: This function is allowed to run within ISR context

Note: This function will be placed into IRAM if CONFIG_PCNT_CTRL_FUNC_IN_IRAM is on, so that it’s allowed to be executed when Cache is disabled

**Parameters**

- unit – [in] PCNT unit handle created by pcnt_new_unit()

**Returns**

- ESP_OK: Start PCNT unit successfully
- ESP_ERR_INVALID_ARG: Start PCNT unit failed because of invalid argument
- ESP_ERR_INVALID_STATE: Start PCNT unit failed because the unit is not enabled yet
- ESP_FAIL: Start PCNT unit failed because of other error
**esp_err_t pcnt_unit_stop (pcnt_unit_handle_t unit)**

Stop PCNT from counting.

**Note:** This function should be called when the unit is in the enable state (i.e. after calling pcnt_unit_enable()).

**Note:** The stop operation won’t clear the counter. Also see pcnt_unit_clear_count() for how to clear pulse count value.

**Note:** This function is allowed to run within ISR context.

**Note:** This function will be placed into IRAM if CONFIG_PCNT_CTRL_FUNC_IN_IRAM, so that it is allowed to be executed when Cache is disabled.

**Parameters**

unit - [in] PCNT unit handle created by pcnt_new_unit()

**Returns**

- ESP_OK: Stop PCNT unit successfully
- ESP_ERR_INVALID_ARG: Stop PCNT unit failed because of invalid argument
- ESP_ERR_INVALID_STATE: Stop PCNT unit failed because the unit is not enabled yet
- ESP_FAIL: Stop PCNT unit failed because of other error

**esp_err_t pcnt_unit_clear_count (pcnt_unit_handle_t unit)**

Clear PCNT pulse count value to zero.

**Note:** It’s recommended to call this function after adding a watch point by pcnt_unit_add_watch_point(), so that the newly added watch point is effective immediately.

**Note:** This function is allowed to run within ISR context.

**Note:** This function will be placed into IRAM if CONFIG_PCNT_CTRLFUNC_IN_IRAM, so that it’s allowed to be executed when Cache is disabled.

**Parameters**

unit - [in] PCNT unit handle created by pcnt_new_unit()

**Returns**

- ESP_OK: Clear PCNT pulse count successfully
- ESP_ERR_INVALID_ARG: Clear PCNT pulse count failed because of invalid argument
- ESP_FAIL: Clear PCNT pulse count failed because of other error

**esp_err_t pcnt_unit_get_count (pcnt_unit_handle_t unit, int *value)**

Get PCNT count value.

**Note:** This function is allowed to run within ISR context.
Note: This function will be placed into IRAM if `CONFIG_PCNT_CTRL_FUNC_IN_IRAM`, so that it’s allowed to be executed when Cache is disabled.

**Parameters**
- **unit** - [in] PCNT unit handle created by `pcnt_new_unit()`
- **value** - [out] Returned count value

**Returns**
- ESP_OK: Get PCNT pulse count successfully
- ESP_ERR_INVALID_ARG: Get PCNT pulse count failed because of invalid argument
- ESP_FAIL: Get PCNT pulse count failed because of other error

```c
esp_err_t pcnt_unit_register_event_callbacks(pcnt_unit_handle_t unit, const pcnt_event_callbacks_t *cbs, void *user_data)
```

Set event callbacks for PCNT unit.

Note: User registered callbacks are expected to be runnable within ISR context

Note: The first call to this function needs to be before the call to `pcnt_unit_enable`

Note: User can deregister a previously registered callback by calling this function and setting the callback member in the `cbs` structure to NULL.

**Parameters**
- **unit** - [in] PCNT unit handle created by `pcnt_new_unit()`
- **cbs** - [in] Group of callback functions
- **user_data** - [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
- ESP_ERR_INVALID_STATE: Set event callbacks failed because the unit is not in init state
- ESP_FAIL: Set event callbacks failed because of other error

```c
esp_err_t pcnt_unit_add_watch_point(pcnt_unit_handle_t unit, int watch_point)
```

Add a watch point for PCNT unit, PCNT will generate an event when the counter value reaches the watch point value.

**Parameters**
- **unit** - [in] PCNT unit handle created by `pcnt_new_unit()`
- **watch_point** - [in] Value to be watched

**Returns**
- ESP_OK: Add watch point successfully
- ESP_ERR_INVALID_ARG: Add watch point failed because of invalid argument (e.g. the value to be watched is out of the limitation set in `pcnt_unit_config_t`)
- ESP_ERR_INVALID_STATE: Add watch point failed because the same watch point has already been added
- ESP_ERR_NOT_FOUND: Add watch point failed because no more hardware watch point can be configured
- ESP_FAIL: Add watch point failed because of other error

```c
esp_err_t pcnt_unit_remove_watch_point(pcnt_unit_handle_t unit, int watch_point)
```

Remove a watch point for PCNT unit.
Chapter 2. API Reference

Parameters
- **unit** - [in] PCNT unit handle created by `pcnt_new_unit()`
- **watch_point** - [in] Watch point value

Returns
- **ESP_OK**: Remove watch point successfully
- **ESP_ERR_INVALID_ARG**: Remove watch point failed because of invalid argument
- **ESP_ERR_INVALID_STATE**: Remove watch point failed because the watch point was not added by `pcnt_unit_add_watch_point()` yet
- **ESP_FAIL**: Remove watch point failed because of other error

```c
esp_err_t pcnt_new_channel(pcnt_unit_handle_t unit, const pcnt_chan_config_t *config,
                           pcnt_channel_handle_t *ret_chan)
```
Create PCNT channel for specific unit, each PCNT has several channels associated with it.

**Note:** This function should be called when the unit is in init state (i.e. before calling `pcnt_unit_enable()`)

Parameters
- **unit** - [in] PCNT unit handle created by `pcnt_new_unit()`
- **config** - [in] PCNT channel configuration
- **ret_chan** - [out] Returned channel handle

Returns
- **ESP_OK**: Create PCNT channel successfully
- **ESP_ERR_INVALID_ARG**: Create PCNT channel failed because of invalid argument
- **ESP_ERR_NO_MEM**: Create PCNT channel failed because of insufficient memory
- **ESP_ERR_NOT_FOUND**: Create PCNT channel failed because all PCNT channels are used up and no more free one
- **ESP_ERR_INVALID_STATE**: Create PCNT channel failed because the unit is not in the init state
- **ESP_FAIL**: Create PCNT channel failed because of other error

```c
esp_err_t pcnt_del_channel(pcnt_channel_handle_t chan)
```
Delete the PCNT channel.

**Parameters** **chan** - [in] PCNT channel handle created by `pcnt_new_channel()`

Returns
- **ESP_OK**: Delete the PCNT channel successfully
- **ESP_ERR_INVALID_ARG**: Delete the PCNT channel failed because of invalid argument
- **ESP_FAIL**: Delete the PCNT channel failed because of other error

```c
esp_err_t pcnt_channel_set_edge_action(pcnt_channel_handle_t chan,
                                       pcnt_channel_edge_action_t pos_act,
                                       pcnt_channel_edge_action_t neg_act)
```
Set channel actions when edge signal changes (e.g. falling or rising edge occurred). The edge signal is input from the `edge_gpio_num` configured in `pcnt_chan_config_t`. We use these actions to control when and how to change the counter value.

**Parameters**
- **chan** - [in] PCNT channel handle created by `pcnt_new_channel()`
- **pos_act** - [in] Action on posedge signal
- **neg_act** - [in] Action on negedge signal

Returns
- **ESP_OK**: Set edge action for PCNT channel successfully
- **ESP_ERR_INVALID_ARG**: Set edge action for PCNT channel failed because of invalid argument
- **ESP_FAIL**: Set edge action for PCNT channel failed because of other error
esp_err_t pcnt_channel_set_level_action(pcnt_channel_handle_t chan, pcnt_channel_level_action_t high_act, pcnt_channel_level_action_t low_act)

Set channel actions when level signal changes (e.g. signal level goes from high to low). The level signal is input from the level_gpio_num configured in pcnt_chan_config_t. We use these actions to control when and how to change the counting mode.

Parameters

• chan - [in] PCNT channel handle created by pcnt_new_channel()
• high_act - [in] Action on high level signal
• low_act - [in] Action on low level signal

Returns

• ESP_OK: Set level action for PCNT channel successfully
• ESP_ERR_INVALID_ARG: Set level action for PCNT channel failed because of invalid argument
• ESP_FAIL: Set level action for PCNT channel failed because of other error

Structures

struct pcnt_watch_event_data_t

PCNT watch event data.

Public Members

int watch_point_value

Watch point value that triggered the event

pcnt_unit_zero_cross_mode_t zero_cross_mode

Zero cross mode

struct pcnt_event_callbacks_t

Group of supported PCNT callbacks.

Note: The callbacks are all running under ISR environment

Note: When CONFIG_PCNT_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM.

Public Members

pcnt_watch_cb_t on_reach

Called when PCNT unit counter reaches any watch point

struct pcnt_unit_config_t

PCNT unit configuration.

Public Members
int **low_limit**
Low limitation of the count unit, should be lower than 0

int **high_limit**
High limitation of the count unit, should be higher than 0

int **intr_priority**
PCNT interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1,2,3)

uint32_t **accum_count**
Whether to accumulate the count value when overflows at the high/low limit

struct **pcnt_unit_config_t::[anonymous] flags**
Extra flags

struct **pcnt_chan_config_t**
PCNT channel configuration.

**Public Members**

int **edge_gpio_num**
GPIO number used by the edge signal, input mode with pull up enabled. Set to -1 if unused

int **level_gpio_num**
GPIO number used by the level signal, input mode with pull up enabled. Set to -1 if unused

uint32_t **invert_edge_input**
Invert the input edge signal

uint32_t **invert_level_input**
Invert the input level signal

uint32_t **virt_edge_io_level**
Virtual edge IO level, 0: low, 1: high. Only valid when edge_gpio_num is set to -1

uint32_t **virt_level_io_level**
Virtual level IO level, 0: low, 1: high. Only valid when level_gpio_num is set to -1

uint32_t **io_loop_back**
For debug/test, the signal output from the GPIO will be fed to the input path as well

struct **pcnt_chan_config_t::[anonymous] flags**
Channel config flags

struct **pcnt_glitch_filter_config_t**
PCNT glitch filter configuration.
Public Members

`uint32_t max_glitch_ns`

Pulse width smaller than this threshold will be treated as glitch and ignored, in the unit of ns

Type Definitions

```c
typedef struct pcnt_unit_t *pcnt_unit_handle_t
    Type of PCNT unit handle.

typedef struct pcnt_chan_t *pcnt_channel_handle_t
    Type of PCNT channel handle.

typedef bool (*pcnt_watch_cb_t)(pcnt_unit_handle_t unit, const pcnt_watch_event_data_t *edata, void *user_ctx)
    PCNT watch event callback prototype.
```

**Note:** The callback function is invoked from an ISR context, so it should meet the restrictions of not calling any blocking APIs when implementing the callback. e.g. must use ISR version of FreeRTOS APIs.

**Param unit** [in] PCNT unit handle
**Param edata** [in] PCNT event data, fed by the driver
**Param user_ctx** [in] User data, passed from `pcnt_unit_register_event_callbacks()`
**Return** Whether a high priority task has been woken up by this function

Header File

- `components/hal/include/hal/pcnt_types.h`

Enumerations

```c
enum pcnt_channel_level_action_t
    PCNT channel action on control level.

    Values:

    enumerator PCNT_CHANNEL_LEVEL_ACTION_KEEP
        Keep current count mode

    enumerator PCNT_CHANNEL_LEVEL_ACTION_INVERSE
        Invert current count mode (increase -> decrease, decrease -> increase)

    enumerator PCNT_CHANNEL_LEVEL_ACTION_HOLD
        Hold current count value
```

```c
enum pcnt_channel_edge_action_t
    PCNT channel action on signal edge.

    Values:

    enumerator PCNT_CHANNEL_EDGE_ACTION_HOLD
        Hold current count value
```
**Chapter 2. API Reference**

```c
enum pcnt_unit_zero_cross_mode_t
    PCNTunitzerocrossmode.

    Values:
    enumerator PCNT_UNIT_ZERO_CROSS_POS_ZERO
        start from positive value, end to zero, i.e. +N->0
    enumerator PCNT_UNIT_ZERO_CROSS_NEG_ZERO
        start from negative value, end to zero, i.e. -N->0
    enumerator PCNT_UNIT_ZERO_CROSS_NEG_POS
        start from negative value, end to positive value, i.e. -N->+M
    enumerator PCNT_UNIT_ZERO_CROSS_POS_NEG
        start from positive value, end to negative value, i.e. +N->-M
```

### 2.6.14 Remote Control Transceiver (RMT)

**Introduction**

The RMT (Remote Control Transceiver) peripheral was designed to act as an infrared transceiver. However, due to the flexibility of its data format, RMT can be extended to a versatile and general-purpose transceiver, transmitting or receiving many other types of signals. From the perspective of network layering, the RMT hardware contains both physical and data link layers. The physical layer defines the communication media and bit signal representation. The data link layer defines the format of an RMT frame. The minimal data unit in the frame is called the RMT symbol, which is represented by `rmt_symbol_word_t` in the driver.

ESP32 contains multiple channels in the RMT peripheral\(^1\). Each channel can be independently configured as either transmitter or receiver.

Typically, the RMT peripheral can be used in the following scenarios:

- Transmit or receive infrared signals, with any IR protocols, e.g., NEC
- General-purpose sequence generator
- Transmit signals in a hardware-controlled loop, with a finite or infinite number of times
- Multi-channel simultaneous transmission
- Modulate the carrier to the output signal or demodulate the carrier from the input signal

**Layout of RMT Symbols**  The RMT hardware defines data in its own pattern – the RMT symbol. The diagram below illustrates the bit fields of an RMT symbol. Each symbol consists of two pairs of two values. The first value in the pair is a 15-bit value representing the signal’s duration in units of RMT ticks. The second in the pair is a 1-bit value representing the signal’s logic level, i.e., high or low.

\(^1\) Different ESP chip series might have different numbers of RMT channels. Please refer to [TRM] for details. The driver does not forbid you from applying for more RMT channels, but it returns an error when there are no hardware resources available. Please always check the return value when doing Resource Allocation.
RMT Transmitter Overview

The data path and control path of an RMT TX channel is illustrated in the figure below:

The driver encodes the user’s data into RMT data format, then the RMT transmitter can generate the waveforms according to the encoding artifacts. It is also possible to modulate a high-frequency carrier signal before being routed to a GPIO pad.

RMT Receiver Overview

The data path and control path of an RMT RX channel is illustrated in the figure below:

The RMT receiver can sample incoming signals into RMT data format, and store the data in memory. It is also possible to tell the receiver the basic characteristics of the incoming signal, so that the signal’s stop condition can be recognized, and signal glitches and noise can be filtered out. The RMT peripheral also supports demodulating the high-frequency carrier from the base signal.

Functional Overview

The description of the RMT functionality is divided into the following sections:

- **Resource Allocation** - covers how to allocate and properly configure RMT channels. It also covers how to recycle channels and other resources when they are no longer used.
- **Carrier Modulation and Demodulation** - describes how to modulate and demodulate the carrier signals for TX and RX channels respectively.
- **Register Event Callbacks** - covers how to register user-provided event callbacks in order to receive RMT channel events.
- **Enable and Disable Channel** - shows how to enable and disable the RMT channel.
- **Initiate TX Transaction** - describes the steps to initiate a transaction for a TX channel.
- **Initiate RX Transaction** - describes the steps to initiate a transaction for an RX channel.
• **Multiple Channels Simultaneous Transmission** - describes how to collect multiple channels into a sync group so that their transmissions can be started simultaneously.

• **RMT Encoder** - focuses on how to write a customized encoder by combining multiple primitive encoders that are provided by the driver.

• **Power Management** - describes how different clock sources affects power consumption.

• **IRAM Safe** - describes how disabling the cache affects the RMT driver, and tips to mitigate it.

• **Thread Safety** - lists which APIs are guaranteed to be thread-safe by the driver.

• **Kconfig Options** - describes the various Kconfig options supported by the RMT driver.

**Resource Allocation**  Both RMT TX and RX channels are represented by `rmt_channel_handle_t` in the driver. The driver internally manages which channels are available and hands out a free channel on request.

**Install RMT TX Channel**  To install an RMT TX channel, there is a configuration structure that needs to be given in advance `rmt_tx_channel_config_t`. The following list describes each member of the configuration structure.

- `rmt_tx_channel_config_t::gpio_num` sets the GPIO number used by the transmitter.
- `rmt_tx_channel_config_t::clk_src` selects the source clock for the RMT channel. The available clocks are listed in `rmt_clock_source_t`. Note that, the selected clock is also used by other channels, which means the user should ensure this configuration is the same when allocating other channels, regardless of TX or RX. For the effect on the power consumption of different clock sources, please refer to the Power Management section.
- `rmt_tx_channel_config_t::resolution_hz` sets the resolution of the internal tick counter. The timing parameter of the RMT signal is calculated based on this tick.
- `rmt_tx_channel_config_t::mem_block_symbols` has a slightly different meaning based on if the DMA backend is enabled or not.
  - If the DMA is enabled via `rmt_tx_channel_config_t::with_dma`, then this field controls the size of the internal DMA buffer. To achieve a better throughput and smaller CPU overhead, we recommend you set a large value, e.g., 1024.
  - If DMA is not used, this field controls the size of the dedicated memory block owned by the channel, which should be at least 64.
- `rmt_tx_channel_config_t::trans_queue_depth` sets the depth of the internal transaction queue, the deeper the queue, the more transactions can be prepared in the backlog.
- `rmt_tx_channel_config_t::invert_out` is used to decide whether to invert the RMT signal before sending it to the GPIO pad.
- `rmt_tx_channel_config_t::with_dma` enables the DMA backend for the channel. Using the DMA allows a significant amount of the channel’s workload to be offloaded from the CPU. However, the DMA backend is not available on all ESP chips, please refer to [TRM] before you enable this option. Or you might encounter a `ESP_ERR_NOT_SUPPORTED` error.
• `rmt_tx_channel_config_t::io_loop_back` enables both input and output capabilities on the channel’s assigned GPIO. Thus, by binding a TX and RX channel to the same GPIO, loopback can be achieved.

• `rmt_tx_channel_config_t::io_od_mode` configures the channel’s assigned GPIO as open-drain. When combined with `rmt_tx_channel_config_t::io_loop_back`, a bi-directional bus (e.g., 1-wire) can be achieved.

• `rmt_tx_channel_config_t::intr_priority` Set the priority of the interrupt. If set to 0, then the driver will use an interrupt with low or medium priority (priority level may be one of 1, 2 or 3), otherwise use the priority indicated by `rmt_tx_channel_config_t::intr_priority`. Please use the number form (1,2,3), not the bitmask form ((1<<1),(1<<2),(1<<3)). Please pay attention that once the interrupt priority is set, it cannot be changed until `rmt_del_channel()` is called.

Once the `rmt_tx_channel_config_t` structure is populated with mandatory parameters, users can call `rmt_new_tx_channel()` to allocate and initialize a TX channel. This function returns an RMT channel handle if it runs correctly. Specifically, when there are no more free channels in the RMT resource pool, this function returns `ESP_ERR_NOT_FOUND` error. If some feature (e.g., DMA backend) is not supported by the hardware, it returns `ESP_ERR_NOT_SUPPORTED` error.

```c
rmt_channel_handle_t tx_chan = NULL;
rmt_tx_channel_config_t tx_chan_config = {
    .clk_src = RMT_CLK_SRC_DEFAULT, // select source clock
    .gpio_num = 0, // GPIO number
    .mem_block_symbols = 64, // memory block size, 64 * 4 = 256 Bytes
    .resolution_hz = 1 * 1000 * 1000, // 1 MHz tick resolution, i.e., 1 tick = 1 µs
    .trans_queue_depth = 4, // set the number of transactions that can...->pend in the background
    .flags.invert_out = false, // do not invert output signal
    .flags.with_dma = false, // do not need DMA backend
};
ESP_ERROR_CHECK(rmt_new_tx_channel(&tx_chan_config, &tx_chan));
```

Install RMT RX Channel To install an RMT RX channel, there is a configuration structure that needs to be given in advance `rmt_rx_channel_config_t`. The following list describes each member of the configuration structure.

• `rmt_rx_channel_config_t::gpio_num` sets the GPIO number used by the receiver.

• `rmt_rx_channel_config_t::clk_src` selects the source clock for the RMT channel. The available clocks are listed in `rmt_clock_source_t`. Note that, the selected clock is also used by other channels, which means the user should ensure this configuration is the same when allocating other channels, regardless of TX or RX. For the effect on the power consumption of different clock sources, please refer to the Power Management section.

• `rmt_rx_channel_config_t::resolution_hz` sets the resolution of the internal tick counter. The timing parameter of the RMT signal is calculated based on this tick.

• `rmt_rx_channel_config_t::mem_block_symbols` has a slightly different meaning based on whether the DMA backend is enabled.
  - If the DMA is enabled via `rmt_rx_channel_config_t::with_dma`, this field controls the maximum size of the DMA buffer.
  - If DMA is not used, this field controls the size of the dedicated memory block owned by the channel, which should be at least 64.

• `rmt_rx_channel_config_t::invert_in` is used to invert the input signals before it is passed to the RMT receiver. The inversion is done by the GPIO matrix instead of by the RMT peripheral.

• `rmt_rx_channel_config_t::with_dma` enables the DMA backend for the channel. Using the DMA allows a significant amount of the channel’s workload to be offloaded from the CPU. However, the DMA backend is not available on all ESP chips, please refer to [TRM] before you enable this option. Or you might encounter a `ESP_ERR_NOT_SUPPORTED` error.

• `rmt_rx_channel_config_t::io_loop_back` enables both input and output capabilities on the channel’s assigned GPIO. Thus, by binding a TX and RX channel to the same GPIO, loopback can be achieved.

• `rmt_rx_channel_config_t::intr_priority` Set the priority of the interrupt. If set to 0, then the
driver will use a interrupt with low or medium priority (priority level may be one of 1, 2 or 3), otherwise use the priority indicated by `rmt_rx_channel_config_t::intr_priority`. Please use the number form (1,2,3), not the bitmask form ((1<<1),(1<<2),(1<<3)). Please pay attention that once the interrupt priority is set, it cannot be changed until `rmt_del_channel()` is called.

Once the `rmt_rx_channel_config_t` structure is populated with mandatory parameters, users can call `rmt_new_rx_channel()` to allocate and initialize an RX channel. This function returns an RMT channel handle if it runs correctly. Specifically, when there are no more free channels in the RMT resource pool, this function returns `ESP_ERR_NOT_FOUND` error. If some feature (e.g., DMA backend) is not supported by the hardware, it returns `ESP_ERR_NOT_SUPPORTED` error.

```c
rmt_channel_handle_t rx_chan = NULL;
rmt_rx_channel_config_t rx_chan_config = {
    .clk_src = RMT_CLK_SRC_DEFAULT, // select source clock
    .resolution_hz = 1 * 1000 * 1000, // 1 MHz tick resolution, i.e., 1 tick = 1 µs
    .mem_block_symbols = 64, // memory block size, 64 * 4 = 256 Bytes
    .gpio_num = 2, // GPIO number
    .flags.invert_in = false, // do not invert input signal
    .flags.with_dma = false, // do not need DMA backend
};
ESP_ERROR_CHECK(rmt_new_rx_channel(&rx_chan_config, &rx_chan));
```

**Note:** Due to a software limitation in the GPIO driver, when both TX and RX channels are bound to the same GPIO, ensure the RX Channel is initialized before the TX Channel. If the TX Channel was set up first, then during the RX Channel setup, the previous RMT TX Channel signal will be overridden by the GPIO control signal.

---

**Uninstall RMT Channel** If a previously installed RMT channel is no longer needed, it is recommended to recycle the resources by calling `rmt_del_channel()`, which in return allows the underlying software and hardware resources to be reused for other purposes.

**Carrier Modulation and Demodulation** The RMT transmitter can generate a carrier wave and modulate it onto the message signal. Compared to the message signal, the carrier signal’s frequency is significantly higher. In addition, the user can only set the frequency and duty cycle for the carrier signal. The RMT receiver can demodulate the carrier signal from the incoming signal. Note that, carrier modulation and demodulation are not supported on all ESP chips, please refer to [TRM] before configuring the carrier, or you might encounter a `ESP_ERR_NOT_SUPPORTED` error.

Carrier-related configurations lie in `rmt_carrier_config_t`:

- `rmt_carrier_config_t::frequency_hz` sets the carrier frequency, in Hz.
- `rmt_carrier_config_t::duty_cycle` sets the carrier duty cycle.
- `rmt_carrier_config_t::polarity_active_low` sets the carrier polarity, i.e., on which level the carrier is applied.
- `rmt_carrier_config_t::always_on` sets whether to output the carrier even when the data transmission has finished. This configuration is only valid for the TX channel.

**Note:** For the RX channel, we should not set the carrier frequency exactly to the theoretical value. It is recommended to leave a tolerance for the carrier frequency. For example, in the snippet below, we set the frequency to 25 KHz, instead of the 38 KHz configured on the TX side. The reason is that reflection and refraction occur when a signal travels through the air, leading to distortion on the receiver side.

```c
rmt_carrier_config_t tx_carrier_cfg = {
    .duty_cycle = 0.33, // duty cycle 33%
    .frequency_hz = 38000, // 38 KHz
    .flags.polarity_active_low = false, // carrier should be modulated to high..._level
};
```

(continues on next page)
// modulate carrier to TX channel
ESP_ERROR_CHECK(rmt_apply_carrier(tx_chan, &tx_carrier_cfg));

rmt_carrier_config_t rx_carrier_cfg = {
  .duty_cycle = 0.33, // duty cycle 33%
  .frequency_hz = 25000, // 25 KHz carrier, should be smaller than...
  .transmitter's carrier frequency
  .flags.polarity_active_low = false, // the carrier is modulated to high level
};

// demodulate carrier from RX channel
ESP_ERROR_CHECK(rmt_apply_carrier(rx_chan, &rx_carrier_cfg));

Register Event Callbacks When an event occurs on an RMT channel (e.g., transmission or receiving is completed), the CPU is notified of this event via an interrupt. If you have some function that needs to be called when a particular events occur, you can register a callback for that event to the RMT driver’s ISR (Interrupt Service Routine) by calling `rmt_tx_register_event_callbacks()` and `rmt_rx_register_event_callbacks()` for TX and RX channel respectively. Since the registered callback functions are called in the interrupt context, the user should ensure the callback function does not block, e.g., by making sure that only FreeRTOS APIs with the FromISR suffix are called from within the function. The callback function has a boolean return value used to indicate whether a higher priority task has been unblocked by the callback.

The TX channel-supported event callbacks are listed in the `rmt_tx_event_callbacks_t`:

- `rmt_tx_event_callbacks_t::on_trans_done` sets a callback function for the “trans-done” event. The function prototype is declared in `rmt_tx_done_callback_t`.

The RX channel-supported event callbacks are listed in the `rmt_rx_event_callbacks_t`:

- `rmt_rx_event_callbacks_t::on_recv_done` sets a callback function for “receive-done” event. The function prototype is declared in `rmt_rx_done_callback_t`.

Users can save their own context in `rmt_tx_register_event_callbacks()` and `rmt_rx_register_event_callbacks()` as well, via the parameter `user_data`. The user data is directly passed to each callback function.

In the callback function, users can fetch the event-specific data that is filled by the driver in the `edata`. Note that the `edata` pointer is only valid for the duration of the callback.

The TX-done event data is defined in `rmt_tx_done_event_data_t`:

- `rmt_tx_done_event_data_t::num_symbols` indicates the number of transmitted RMT symbols. This also reflects the size of the encoding artifacts. Please note, this value accounts for the EOF symbol as well, which is appended by the driver to mark the end of one transaction.

The RX-complete event data is defined in `rmt_rx_done_event_data_t`:

- `rmt_rx_done_event_data_t::received_symbols` points to the received RMT symbols. These symbols are saved in the `buffer` parameter of the `rmt_receive()` function. Users should not free this receive buffer before the callback returns.
- `rmt_rx_done_event_data_t::num_symbols` indicates the number of received RMT symbols. This value is not larger than the `buffer_size` parameter of `rmt_receive()` function. If the `buffer_size` is not sufficient to accommodate all the received RMT symbols, the driver only keeps the maximum number of symbols that the buffer can hold, and excess symbols are discarded or ignored.

Enable and Disable Channel `rmt_enable()` must be called in advance before transmitting or receiving RMT symbols. For TX channels, enabling a channel enables a specific interrupt and prepares the hardware to dispatch transactions. For RX channels, enabling a channel enables an interrupt, but the receiver is not started during this time, as the characteristics of the incoming signal have yet to be specified. The receiver is started in `rmt_receive()`. `rmt_disable()` does the opposite by disabling the interrupt and clearing any pending interrupts. The transmitter and receiver are disabled as well.
**ESP_ERROR_CHECK(rmt_enable(tx_chan));**
**ESP_ERROR_CHECK(rmt_enable(rx_chan));**

**Initiate TX Transaction**  
RMT is a special communication peripheral, as it is unable to transmit raw byte streams like SPI and I2C. RMT can only send data in its own format `rmt_symbol_word_t`. However, the hardware does not help to convert the user data into RMT symbols, this can only be done in software by the so-called RMT Encoder. The encoder is responsible for encoding user data into RMT symbols and then writing to the RMT memory block or the DMA buffer. For how to create an RMT encoder, please refer to RMT Encoder.  

Once we got an encoder, we can initiate a TX transaction by calling `rmt_transmit()`. This function takes several positional parameters like channel handle, encoder handle, and payload buffer. Besides, we also need to provide a transmission-specific configuration in `rmt_transmit_config_t`:

- `rmt_transmit_config_t::loop_count` sets the number of transmission loops. After the transmitter has finished one round of transmission, it can restart the same transmission again if this value is not set to zero. As the loop is controlled by hardware, the RMT channel can be used to generate many periodic sequences with minimal CPU intervention.
  - Setting `rmt_transmit_config_t::loop_count` to -1 means an infinite loop transmission. In this case, the channel does not stop until `rmt_disable()` is called. The "trans-done" event is not generated as well.
  - Setting `rmt_transmit_config_t::loop_count` to a positive number means finite number of iterations. In this case, the "trans-done" event is when the specified number of iterations have completed.

**Note:** The loop transmit feature is not supported on all ESP chips, please refer to [TRM] before you configure this option, or you might encounter ESP_ERR_NOT_SUPPORTED error.

- `rmt_transmit_config_t::eot_level` sets the output level when the transmitter finishes working or stops working by calling `rmt_disable()`.

**Note:** There is a limitation in the transmission size if the `rmt_transmit_config_t::loop_count` is set to non-zero, i.e., to enable the loop feature. The encoded RMT symbols should not exceed the capacity of the RMT hardware memory block size, or you might see an error message like encoding artifacts can't exceed hw memory block for loop transmission. If you have to start a large transaction by loop, you can try either of the following methods.

  - Increase the `rmt_tx_channel_config_t::mem_block_symbols`. This approach does not work if the DMA backend is also enabled.
  - Customize an encoder and construct an infinite loop in the encoding function. See also RMT Encoder.

Internally, `rmt_transmit()` constructs a transaction descriptor and sends it to a job queue, which is dispatched in the ISR. So it is possible that the transaction is not started yet when `rmt_transmit()` returns. To ensure all pending transactions to complete, the user can use `rmt_tx_wait_all_done()`.

**Multiple Channels Simultaneous Transmission**  
In some real-time control applications (e.g., to make two robotic arms move simultaneously), we do not want any time drift in between when startup multiple TX channels. The RMT driver can help to manage this by creating a so-called Sync Manager. The sync manager is represented by `rmt_sync_manager_handle_t` in the driver. The procedure of RMT sync transmission is shown as follows:

**Install RMT Sync Manager**  
To create a sync manager, the user needs to tell which channels are going to be managed in the `rmt_sync_manager_config_t`:

- `rmt_sync_manager_config_t::tx_channel_array` points to the array of TX channels to be managed.
- `rmt_sync_manager_config_t::array_size` sets the number of channels to be managed.
rmt_new_sync_manager() can return a manager handle on success. This function could also fail due to various errors such as invalid arguments, etc. Especially, when the sync manager has been installed before, and there are no hardware resources to create another manager, this function reports ESP_ERR_NOT_FOUND error. In addition, if the sync manager is not supported by the hardware, it reports a ESP_ERR_NOT_SUPPORTED error. Please refer to [TRM] before using the sync manager feature.

**Start Transmission Simultaneously** For any managed TX channel, it does not start the machine until rmt_transmit() has been called on all channels in rmt_sync_manager_config_t::tx_channel_array. Before that, the channel is just put in a waiting state. TX channels will usually complete their transactions at different times due to differing transactions, thus resulting in a loss of sync. So before restarting a simultaneous transmission, the user needs to call rmt_sync_reset() to synchronize all channels again.

Calling rmt_del_sync_manager() can recycle the sync manager and enable the channels to initiate transactions independently afterward.
Initiate RX Transaction  As also discussed in the Enable and Disable Channel, calling rmt_enable() does not prepare an RX to receive RMT symbols. The user needs to specify the basic characteristics of the incoming signals in rmt_receive_config_t:

- rmt_receive_config_t::signal_range_min_ns specifies the minimal valid pulse duration in either high or low logic levels. A pulse width that is smaller than this value is treated as a glitch, and ignored by the hardware.
- rmt_receive_config_t::signal_range_max_ns specifies the maximum valid pulse duration in either high or low logic levels. A pulse width that is bigger than this value is treated as Stop Signal, and the receiver generates receive-complete event immediately.

The RMT receiver starts the RX machine after the user calls rmt_receive() with the provided configuration above. Note that, this configuration is transaction specific, which means, to start a new round of reception, the user needs to set the rmt_receive_config_t again. The receiver saves the incoming signals into its internal memory block or DMA buffer, in the format of rmt_symbol_word_t.

Due to the limited size of the memory block, the RMT receiver can only save short frames whose length is not longer than the memory block capacity. Long frames are truncated by the hardware, and the driver reports an error message: hw buffer too small, received symbols truncated.

The copy destination should be provided in the buffer parameter of rmt_receive() function. If this buffer overflows due to an insufficient buffer size, the receiver can continue to work, but overflowed symbols are dropped and the following error message is reported: user buffer too small, received symbols truncated. Please take care of the lifecycle of the buffer parameter, ensuring that the buffer is not recycled before the receiver is finished or stopped.

The receiver is stopped by the driver when it finishes working, i.e., receive a signal whose duration is bigger than rmt_receive_config_t::signal_range_max_ns. The user needs to call rmt_receive() again to restart the receiver, if necessary. The user can get the received data in the rmt_rx_event_callbacks_t::on_recv_done callback. See also Register Event Callbacks for more information.

```c
static bool example_rmt_rx_done_callback(rmt_channel_handle_t channel, const rmt_rx_done_event_data_t *edata, void *user_data) {
    BaseType_t high_task_wakeup = pdFALSE;
    QueueHandle_t receive_queue = (QueueHandle_t)user_data;
    // send the received RMT symbols to the parser task
    xQueueSendFromISR(receive_queue, edata, &high_task_wakeup);
    // return whether any task is woken up
    return high_task_wakeup == pdTRUE;
}

QueueHandle_t receive_queue = xQueueCreate(1, sizeof(rmt_rx_done_event_data_t));
rmt_rx_event_callbacks_t cbs = {
    .on_recv_done = example_rmt_rx_done_callback,
};
ESP_ERROR_CHECK(rmt_rx_register_event_callbacks(rx_channel, &cbs, receive_queue));
```

// the following timing requirement is based on NEC protocol
rmt_receive_config_t receive_config = {
    .signal_range_min_ns = 1250,  // the shortest duration for NEC signal is...
    .signal_range_max_ns = 12000000,  // the longest duration for NEC signal is...
    .560 µs, 1250 ns < 560 µs, valid signal is not treated as noise
    .9000 µs, 12000000 ns > 9000 µs, the receive does not stop early

(continues on next page)
RMT Encoder An RMT encoder is part of the RMT TX transaction, whose responsibility is to generate and write the correct RMT symbols into hardware memory or DMA buffer at a specific time. There are some special restrictions for an encoding function:

- During a single transaction, the encoding function may be called multiple times. This is necessary because the target RMT memory block cannot hold all the artifacts at once. To overcome this limitation, we utilize a ping-pong approach, where the encoding session is divided into multiple parts. This means that the encoder needs to keep track of its state in order to continue encoding from where it left off in the previous part.
- The encoding function is running in the ISR context. To speed up the encoding session, it is highly recommended to put the encoding function into IRAM. This can also avoid the cache miss during encoding.

To help get started with the RMT driver faster, some commonly-used encoders are provided out-of-the-box. They can either work alone or be chained together into a new encoder. See also Composite Pattern for the principle behind it. The driver has defined the encoder interface in `rmt_encoder_t`, it contains the following functions:

- `rmt_encoder_t::encode` is the fundamental function of an encoder. This is where the encoding session happens.
  - The function might be called multiple times within a single transaction. The encode function should return the state of the current encoding session.
  - The supported states are listed in the `rmt_encode_state_t`. If the result contains `RMT_ENCODING_COMPLETE`, it means the current encoder has finished work.
  - If the result contains `RMT_ENCODING_MEM_FULL`, we need to yield from the current session, as there is no space to save more encoding artifacts.
- `rmt_encoder_t::reset` should reset the encoder state back to the initial state (the RMT encoder is stateful).
  - If the RMT transmitter is manually stopped without resetting its corresponding encoder, subsequent encoding session can be erroneous.
  - This function is also called implicitly in `rmt_disable()`.
- `rmt_encoder_t::del` should free the resources allocated by the encoder.

Copy Encoder A copy encoder is created by calling `rmt_new_copy_encoder()`. A copy encoder’s main functionality is to copy the RMT symbols from user space into the driver layer. It is usually used to encode `const` data, i.e., data does not change at runtime after initialization such as the leading code in the IR protocol.

A configuration structure `rmt_copy_encoder_config_t` should be provided in advance before calling `rmt_new_copy_encoder()`. Currently, this configuration is reserved for future expansion, and has no specific use or setting items for now.

Bytes Encoder A bytes encoder is created by calling `rmt_new_bytes_encoder()`. The bytes encoder’s main functionality is to convert the user space byte stream into RMT symbols dynamically. It is usually used to encode dynamic data, e.g., the address and command fields in the IR protocol.

A configuration structure `rmt_bytes_encoder_config_t` should be provided in advance before calling `rmt_new_bytes_encoder()`.

```c
};

rmt_symbol_word_t raw_symbols[64]; // 64 symbols should be sufficient for a
->standard NEC frame
// ready to receive
ESP_ERROR_CHECK(rmt_receive(rx_channel, raw_symbols, sizeof(raw_symbols), \n&receive_
->--config));
// wait for the RX-done signal
rmt_rx_done_event_data_t rx_data;
xQueueReceive(receive_queue, \n&rx_data, portMAX_DELAY);
// parse the received symbols
example_parse_nec_frame(rx_data.received_symbols, \nrx_data.num_symbols);
```
• `rmt_bytes_encoder_config_t::bit0` and `rmt_bytes_encoder_config_t::bit1` are necessary to specify the encoder how to represent bit zero and bit one in the format of `rmt_symbol_word_t`.

• `rmt_bytes_encoder_config_t::msb_first` sets the bit endianness of each byte. If it is set to true, the encoder encodes the **Most Significant Bit** first. Otherwise, it encodes the **Least Significant Bit** first.

Besides the primitive encoders provided by the driver, the user can implement his own encoder by chaining the existing encoders together. A common encoder chain is shown as follows:

![Encoder Chain Diagram](image)

**Fig. 20: RMT Encoder Chain**

**Customize RMT Encoder for NEC Protocol** In this section, we demonstrates how to write an NEC encoder. The NEC IR protocol uses pulse distance encoding of the message bits. Each pulse burst is 562.5 µs in length, logical bits are transmitted as follows. It is worth mentioning that the least significant bit of each byte is sent first.

- **Logical 0**: a 562.5 µs pulse burst followed by a 562.5 µs space, with a total transmit time of 1.125 ms
- **Logical 1**: a 562.5 µs pulse burst followed by a 1.6875 ms space, with a total transmit time of 2.25 ms

When a key is pressed on the remote controller, the transmitted message includes the following elements in the specified order:

![IR NEC Frame](image)

**Fig. 21: IR NEC Frame**

- 9 ms leading pulse burst, also called the "AGC pulse"
- 4.5 ms space
- 8-bit address for the receiving device
- 8-bit logical inverse of the address
- 8-bit command
- 8-bit logical inverse of the command
- a final 562.5 µs pulse burst to signify the end of message transmission

Then we can construct the NEC `rmt_encoder_t::encode` function in the same order, for example:
// IR NEC scan code representation

typedef struct {
    uint16_t address;
    uint16_t command;
} ir_nec_scan_code_t;

// construct an encoder by combining primitive encoders

typedef struct {
    rmt_encoder_t base;  // the base "class" declares the standard
    // encoder interface
    rmt_encoder_t *copy_encoder;  // use the copy_encoder to encode the leading
    // and ending pulse
    rmt_encoder_t *bytes_encoder;  // use the bytes_encoder to encode the address
    // and command data
    rmt_symbol_word_t nec_leading_symbol; // NEC leading code with RMT
    // representation
    rmt_symbol_word_t nec_ending_symbol; // NEC ending code with RMT
    // representation
    int state;  // record the current encoding state, i.e., we are in which
    // encoding phase
} rmt_ir_nec_encoder_t;

static size_t rmt_encode_ir_nec(rmt_encoder_t *encoder,
                                 rmt_channel_handle_t channel,
                                 const void *primary_data,
                                 size_t data_size,
                                 rmt_encode_state_t *ret_state) {
    rmt_ir_nec_encoder_t *nec_encoder = __containerof(encoder,
                                                      rmt_ir_nec_encoder_t,
                                                      base);
    rmt_encode_state_t session_state = RMT_ENCODING_RESET;
    rmt_encode_state_t state = RMT_ENCODING_RESET;
    size_t encoded_symbols = 0;
    ir_nec_scan_code_t *scan_code = (ir_nec_scan_code_t *)primary_data;
    rmt_encoder_handle_t copy_encoder = nec_encoder->copy_encoder;
    rmt_encoder_handle_t bytes_encoder = nec_encoder->bytes_encoder;
    switch (nec_encoder->state) {
    case 0: // send leading code
        encoded_symbols += copy_encoder->encode(copy_encoder, channel, &nec_encoder->nec_leading_symbol, sizeof(rmt_symbol_word_t), &session_state);
        if (session_state & RMT_ENCODING_COMPLETE) {
            nec_encoder->state = 1; // we can only switch to the next state when
            // the current encoder finished
        }
        if (session_state & RMT_ENCODING_MEM_FULL) {
            state = RMT_ENCODING_MEM_FULL;
            goto out; // yield if there is no free space to put other encoding artifacts
        }
        // fall-through
    case 1: // send address
        encoded_symbols += bytes_encoder->encode(bytes_encoder, channel, &scan_code->address, sizeof(uint16_t), &session_state);
        if (session_state & RMT_ENCODING_COMPLETE) {
            nec_encoder->state = 2; // we can only switch to the next state when
            // the current encoder finished
        }
        if (session_state & RMT_ENCODING_MEM_FULL) {
            state = RMT_ENCODING_MEM_FULL;
            goto out; // yield if there is no free space to put other encoding artifacts
        }
    }
}

(continues on next page)
// fall-through
    case 2: // send command
        encoded_symbols += bytes_encoder->encode(bytes_encoder, channel, &scan_-
        _code->command, sizeof(uint16_t), &session_state);
        if (session_state & RMT_ENCODING_COMPLETE) {
            nec_encoder->state = 3; // we can only switch to the next state when-
            _the current encoder finished
        }
        if (session_state & RMT_ENCODING_MEM_FULL) {
            state |= RMT_ENCODING_MEM_FULL;
            goto out; // yield if there is no free space to put other encoding-
            _artifacts
        }
    // fall-through
    case 3: // send ending code
        encoded_symbols += copy_encoder->encode(copy_encoder, channel, &nec_-
        _encoder->nec_ending_symbol, sizeof(rmt_symbol_word_t), &
        session_state);
        if (session_state & RMT_ENCODING_COMPLETE) {
            nec_encoder->state = RMT_ENCODING_RESET; // back to the initial-
            encoding session
            state |= RMT_ENCODING_COMPLETE; // telling the caller the NEC encoding-
            _has finished
        }
        if (session_state & RMT_ENCODING_MEM_FULL) {
            state |= RMT_ENCODING_MEM_FULL;
            goto out; // yield if there is no free space to put other encoding-
            _artifacts
        }
    out:
        *ret_state = state;
        return encoded_symbols;
    }

A full sample code can be found in peripherals/rmt/ir_nec_transceiver. In the above snippet, we use a
switch-case and several goto statements to implement a Finite-state machine. With this pattern, users can
construct much more complex IR protocols.

Power Management When power management is enabled, i.e., CONFIG_PM_ENABLE is on, the system adjusts
the APB frequency before going into Light-sleep, thus potentially changing the resolution of the RMT internal counter.
However, the driver can prevent the system from changing APB frequency by acquiring a power manage-
ment lock of type ESP_PM_APB_FREQ_MAX. Whenever the user creates an RMT channel that has selected
RMT_CLK_SRC_APB as the clock source, the driver guarantees that the power management lock is acquired af-
ter the channel enabled by rmt_enable(). Likewise, the driver releases the lock after rmt_disable() is
called for the same channel. This also reveals that the rmt_enable() and rmt_disable() should appear in
pairs.
If the channel clock source is selected to others like RMT_CLK_SRC_XTAL, then the driver does not install a power
management lock for it, which is more suitable for a low-power application as long as the source clock can still provide
sufficient resolution.

IRAM Safe By default, the RMT interrupt is deferred when the Cache is disabled for reasons like writing or erasing
the main Flash. Thus the transaction-done interrupt does not get handled in time, which is not acceptable in a real-
time application. What is worse, when the RMT transaction relies on ping-pong interrupt to successively encode or
copy RMT symbols, a delayed interrupt can lead to an unpredictable result.
There is a Kconfig option CONFIG_RMT_ISR_IRAM_SAFE that has the following features:
1. Enable the interrupt being serviced even when the cache is disabled
2. Place all functions used by the ISR into IRAM²
3. Place the driver object into DRAM in case it is mapped to PSRAM by accident

This Kconfig option allows the interrupt to run while the cache is disabled but comes at the cost of increased IRAM consumption.

**Thread Safety** The factory function `rmt_new_tx_channel()`, `rmt_new_rx_channel()` and `rmt_new_sync_manager()` are guaranteed to be thread-safe by the driver, which means, user can call them from different RTOS tasks without protection by extra locks. Other functions that take the `rmt_channel_handle_t` and `rmt_sync_manager_handle_t` as the first positional parameter, are not thread-safe, which means the user should avoid calling them from multiple tasks.

**Kconfig Options**

- `CONFIG_RMT_ISR_IRAM_SAFE` controls whether the default ISR handler can work when cache is disabled, see also IRAM Safe for more information.
- `CONFIG_RMT_ENABLE_DEBUG_LOG` is used to enable the debug log at the cost of increased firmware binary size.

**Application Examples**

- RMT-based RGB LED strip customized encoder: peripherals/rmt/led_strip
- RMT IR NEC protocol encoding and decoding: peripherals/rmt/ir_nec_transceiver
- RMT transactions in queue: peripherals/rmt/musical_buzzer
- RMT-based stepper motor with S-curve algorithm: peripherals/rmt/stepper_motor
- RMT infinite loop for driving DShot ESC: peripherals/rmt/dshot_esc
- RMT simulate 1-wire protocol (take DS18B20 as example): peripherals/rmt/onewire

**FAQ**

- Why the RMT encoder results in more data than expected?

The RMT encoding takes place in the ISR context. If your RMT encoding session takes a long time (e.g., by logging debug information) or the encoding session is deferred somehow because of interrupt latency, then it is possible the transmitting becomes faster than the encoding. As a result, the encoder can not prepare the next data in time, leading to the transmitter sending the previous data again. There is no way to ask the transmitter to stop and wait. You can mitigate the issue by combining the following ways:

  - Increase the `rmt_tx_channel_config_t::mem_block_symbols`, in steps of 64.
  - Place the encoding function in the IRAM.
  - Enables the `rmt_tx_channel_config_t::with_dma` if it is available for your chip.

**API Reference**

**Header File**

- components/driver/rmt/include/driver/rmt_tx.h

**Functions**

```c
esp_err_t rmt_new_tx_channel(const rmt_tx_channel_config_t *config, rmt_channel_handle_t *ret_chan)
```

Create a RMT TX channel.

**Parameters**

²The callback function, e.g., `rmt_tx_event_callbacks_t::on_trans_done`, and the functions invoked by itself should also reside in IRAM, users need to take care of this by themselves.
Chapter 2. API Reference

- **config** [in] TX channel configurations
- **ret_chan** [out] Returned generic RMT channel handle

**Returns**
- ESP_OK: Create RMT TX channel successfully
- ESP_ERR_INVALID_ARG: Create RMT TX channel failed because of invalid argument
- ESP_ERR_NO_MEM: Create RMT TX channel failed because out of memory
- ESP_ERR_NOT_FOUND: Create RMT TX channel failed because all RMT channels are used up and no more free one
- ESP_ERR_NOT_SUPPORTED: Create RMT TX channel failed because some feature is not supported by hardware, e.g. DMA feature is not supported by hardware
- ESP_FAIL: Create RMT TX channel failed because of other error

```c
esp_err_t rmt_transmit(rmt_channel_handle_t tx_channel, rmt_encoder_handle_t encoder, const void *payload, size_t payload_bytes, const rmt_transmit_config_t *config)
```

Transmit data by RMT TX channel.

**Note:** This function will construct a transaction descriptor and push to a queue. The transaction will not start immediately until it’s dispatched in the ISR. If there’re too many transactions pending in the queue, this function will block until the queue has free space.

**Parameters**
- **tx_channel** [in] RMT TX channel that created by `rmt_new_tx_channel()`
- **encoder** [in] RMT encoder that created by various factory APIs like `rmt_new_bytes_encoder()`
- **payload** [in] The raw data to be encoded into RMT symbols
- **payload_bytes** [in] Size of the payload in bytes
- **config** [in] Transmission specific configuration

**Returns**
- ESP_OK: Transmit data successfully
- ESP_ERR_INVALID_ARG: Transmit data failed because of invalid argument
- ESP_ERR_INVALID_STATE: Transmit data failed because channel is not enabled
- ESP_ERR_NOT_SUPPORTED: Transmit data failed because some feature is not supported by hardware, e.g. unsupported loop count
- ESP_FAIL: Transmit data failed because of other error

```c
esp_err_t rmt_tx_wait_all_done(rmt_channel_handle_t tx_channel, int timeout_ms)
```

Wait for all pending TX transactions done.

**Note:** This function will block forever if the pending transaction can’t be finished within a limited time (e.g. an infinite loop transaction). See also `rmt_disable()` for how to terminate a working channel.

**Parameters**
- **tx_channel** [in] RMT TX channel that created by `rmt_new_tx_channel()`

**Returns**
- ESP_OK: Flush transactions successfully
- ESP_ERR_INVALID_ARG: Flush transactions failed because of invalid argument
- ESP_ERR_TIMEOUT: Flush transactions failed because of timeout
- ESP_FAIL: Flush transactions failed because of other error

```c
esp_err_t rmt_tx_register_event_callbacks(rmt_channel_handle_t tx_channel, const rmt_tx_event_callbacks_t *cbs, void *user_data)
```

Note: The data to be transmitted will be encoded into RMT symbols by the specific encoder.
Set event callbacks for RMT TX channel.

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the `cbs` structure to NULL.

**Note:** When CONFIG_RMT_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well. The `user_data` should also reside in SRAM.

**Parameters**
- `tx_channel` [in] RMT generic channel that created by `rmt_new_tx_channel()`
- `cbs` [in] Group of callback functions
- `user_data` [in] User data, which will be passed to callback functions directly

**Returns**
- `ESP_OK`: Set event callbacks successfully
- `ESP_ERR_INVALID_ARG`: Set event callbacks failed because of invalid argument
- `ESP_FAIL`: Set event callbacks failed because of other error

```c
void rmt_set_event_callbacks(const rmt_channel_config_t *tx_channel, rmt_callback_t *cbs, void *user_data);
```

Create a synchronization manager for multiple TX channels, so that the managed channel can start transmitting at the same time.

**Note:** All the channels to be managed should be enabled by `rmt_enable()` before put them into sync manager.

**Parameters**
- `config` [in] Synchronization manager configuration
- `ret_synchro` [out] Returned synchronization manager handle

**Returns**
- `ESP_OK`: Create sync manager successfully
- `ESP_ERR_INVALID_ARG`: Create sync manager failed because of invalid argument
- `ESP_ERR_NOT_SUPPORTED`: Create sync manager failed because it is not supported by hardware
- `ESP_ERR_INVALID_STATE`: Create sync manager failed because not all channels are enabled
- `ESP_ERR_NO_MEM`: Create sync manager failed because out of memory
- `ESP_ERR_NOT_FOUND`: Create sync manager failed because all sync controllers are used up and no more free one
- `ESP_FAIL`: Create sync manager failed because of other error

```c
esp_err_t rmt_new_sync_manager(const rmt_sync_manager_config_t *config, rmt_sync_manager_handle_t *ret_synchro);
```

Delete synchronization manager.

**Parameters**
- `synchro` [in] Synchronization manager handle returned from `rmt_new_sync_manager()`

**Returns**
- `ESP_OK`: Delete the synchronization manager successfully
- `ESP_ERR_INVALID_ARG`: Delete the synchronization manager failed because of invalid argument
- `ESP_FAIL`: Delete the synchronization manager failed because of other error

```c
void rmt_del_sync_manager(rmt_sync_manager_handle_t synchro);
```
**esp_err_t rmt_sync_reset (rmt_sync_manager_handle_t synchro)**

Reset synchronization manager.

**Parameters synchro** [in] Synchronization manager handle returned from `rmt_new_sync_manager()`

**Returns**
- ESP_OK: Reset the synchronization manager successfully
- ESP_ERR_INVALID_ARG: Reset the synchronization manager failed because of invalid argument
- ESP_FAIL: Reset the synchronization manager failed because of other error

**Structures**

`struct rmt_tx_event_callbacks_t`

Group of RMT TX callbacks.

**Note:** The callbacks are all running under ISR environment

**Note:** When CONFIG_RMT_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well.

**Public Members**

`rmt_tx_done_callback_t on_trans_done`

Event callback, invoked when transmission is finished

`struct rmt_tx_channel_config_t`

RMT TX channel specific configuration.

**Public Members**

`gpio_num_t gpio_num`

GPIO number used by RMT TX channel. Set to -1 if unused

`rmt_clock_source_t clk_src`

Clock source of RMT TX channel, channels in the same group must use the same clock source

`uint32_t resolution_hz`

Channel clock resolution, in Hz

`size_t mem_block_symbols`

Size of memory block, in number of `rmt_symbol_word_t`, must be an even. In the DMA mode, this field controls the DMA buffer size, it can be set to a large value; In the normal mode, this field controls the number of RMT memory block that will be used by the channel.

`size_t trans_queue_depth`

Depth of internal transfer queue, increase this value can support more transfers pending in the background
uint32_t invert_out
    Whether to invert the RMT channel signal before output to GPIO pad

uint32_t with_dma
    If set, the driver will allocate an RMT channel with DMA capability

uint32_t io_loop_back
    The signal output from the GPIO will be fed to the input path as well

uint32_t io_od_mode
    Configure the GPIO as open-drain mode

struct rmt_tx_channel_config_t::[anonymous] flags
    TX channel config flags

int intr_priority
    RMT interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1,2,3)

struct rmt_transmit_config_t
    RMT transmit specific configuration.

Public Members

int loop_count
    Specify the times of transmission in a loop, -1 means transmitting in an infinite loop

uint32_t eot_level
    Set the output level for the “End Of Transmission”

struct rmt_transmit_config_t::[anonymous] flags
    Transmit config flags

struct rmt_sync_manager_config_t
    Synchronous manager configuration.

Public Members

const rmt_channel_handle_t *tx_channel_array
    Array of TX channels that are about to be managed by a synchronous controller

size_t array_size
    Size of the tx_channel_array

Header File

- components/driver/rmt/include/driver/rmt_rx.h
**Functions**

**esp_err_t rmt_new_rx_channel** (const rmt_rx_channel_config_t *config, rmt_channel_handle_t *ret_chan)

Create a RMT RX channel.

**Parameters**
- config: [in] RX channel configurations
- ret_chan: [out] Returned generic RMT channel handle

**Returns**
- ESP_OK: Create RMT RX channel successfully
- ESP_ERR_INVALID_ARG: Create RMT RX channel failed because of invalid argument
- ESP_ERR_NO_MEM: Create RMT RX channel failed because out of memory
- ESP_ERR_NOT_FOUND: Create RMT RX channel failed because all RMT channels are used up and no more free one
- ESP_ERR_NOT_SUPPORTED: Create RMT RX channel failed because some feature is not supported by hardware, e.g. DMA feature is not supported by hardware
- ESP_FAIL: Create RMT RX channel failed because of other error

**esp_err_t rmt_receive** (rmt_channel_handle_t rx_channel, void *buffer, size_t buffer_size, const rmt_receive_config_t *config)

Initiate a receive job for RMT RX channel.

**Note:** This function is non-blocking, it initiates a new receive job and then returns. User should check the received data from the on_recv_done callback that registered by rmt_rx_register_event_callbacks().

**Parameters**
- rx_channel: [in] RMT RX channel that created by rmt_new_rx_channel()
- buffer: [in] The buffer to store the received RMT symbols
- buffer_size: [in] size of the buffer, in bytes
- config: [in] Receive specific configurations

**Returns**
- ESP_OK: Initiate receive job successfully
- ESP_ERR_INVALID_ARG: Initiate receive job failed because of invalid argument
- ESP_ERR_INVALID_STATE: Initiate receive job failed because channel is not enabled
- ESP_FAIL: Initiate receive job failed because of other error

**esp_err_t rmt_rx_register_event_callbacks** (rmt_channel_handle_t rx_channel, const rmt_rx_event_callbacks_t *cbs, void *user_data)

Set callbacks for RMT RX channel.

**Note:** User can deregister a previously registered callback by calling this function and setting the callback member in the cbs structure to NULL.

**Note:** When CONFIG_RMT_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well. The user_data should also reside in SRAM.

**Parameters**
- rx_channel: [in] RMT generic channel that created by rmt_new_rx_channel()
- cbs: [in] Group of callback functions
- user_data: [in] User data, which will be passed to callback functions directly

**Returns**
- ESP_OK: Set event callbacks successfully
- ESP_ERR_INVALID_ARG: Set event callbacks failed because of invalid argument
• ESP_FAIL: Set event callbacks failed because of other error

**Structures**

```c
struct rmt_rx_event_callbacks_t
```

Group of RMT RX callbacks.

---

**Note:** The callbacks are all running under ISR environment

---

**Note:** When CONFIG_RMT_ISR_IRAM_SAFE is enabled, the callback itself and functions called by it should be placed in IRAM. The variables used in the function should be in the SRAM as well.

---

**Public Members**

```c
rmt_rx_done_callback_t on_recv_done
```

Event callback, invoked when one RMT channel receiving transaction completes

```c
struct rmt_rx_channel_config_t
```

RMT RX channel specific configuration.

---

**Public Members**

```c
gpio_num_t gpio_num
```

GPIO number used by RMT RX channel. Set to -1 if unused

```c
rmt_clock_source_t clk_src
```

Clock source of RMT RX channel, channels in the same group must use the same clock source

```c
uint32_t resolution_hz
```

Channel clock resolution, in Hz

```c
size_t mem_block_symbols
```

Size of memory block, in number of `rmt_symbol_word_t`, must be an even. In the DMA mode, this field controls the DMA buffer size, it can be set to a large value (e.g. 1024); In the normal mode, this field controls the number of RMT memory block that will be used by the channel.

```c
uint32_t invert_in
```

Whether to invert the incoming RMT channel signal

```c
uint32_t with_dma
```

If set, the driver will allocate an RMT channel with DMA capability

```c
uint32_t io_loop_back
```

For debug/test, the signal output from the GPIO will be fed to the input path as well

```c
struct rmt_rx_channel_config_t::[anonymous] flags
```

RX channel config flags
### Chapter 2. API Reference

#### int intr_priority
RMT interrupt priority, if set to 0, the driver will try to allocate an interrupt with a relative low priority (1,2,3)

#### struct rmt_receive_config_t
RMT receive specific configuration.

### Public Members

- `uint32_t signal_range_min_ns`
  A pulse whose width is smaller than this threshold will be treated as glitch and ignored

- `uint32_t signal_range_max_ns`
  RMT will stop receiving if one symbol level has kept more than `signal_range_max_ns`

### Header File
- `components/driver/rmt/include/driver/rmt_common.h`

### Functions

#### esp_err_t rmt_del_channel (rmt_channel_handle_t channel)
Delete an RMT channel.

- **Parameters**
  - `channel` [in] RMT generic channel that created by `rmt_new_tx_channel()` or `rmt_new_rx_channel()`

- **Returns**
  - ESP_OK: Delete RMT channel successfully
  - ESP_ERR_INVALID_ARG: Delete RMT channel failed because of invalid argument
  - ESP_ERR_INVALID_STATE: Delete RMT channel failed because it is still in working
  - ESP_FAIL: Delete RMT channel failed because of other error

#### esp_err_t rmt_apply_carrier (rmt_channel_handle_t channel, const rmt_carrier_config_t *config)
Apply modulation feature for TX channel or demodulation feature for RX channel.

- **Parameters**
  - `channel` [in] RMT generic channel that created by `rmt_new_tx_channel()` or `rmt_new_rx_channel()`
  - `config` [in] Carrier configuration. Specially, a NULL config means to disable the carrier modulation or demodulation feature

- **Returns**
  - ESP_OK: Apply carrier configuration successfully
  - ESP_ERR_INVALID_ARG: Apply carrier configuration failed because of invalid argument
  - ESP_FAIL: Apply carrier configuration failed because of other error

#### esp_err_t rmt_enable (rmt_channel_handle_t channel)
Enable the RMT channel.

- **Parameters**
  - `channel` [in] RMT generic channel that created by `rmt_new_tx_channel()` or `rmt_new_rx_channel()`

- **Returns**
  - ESP_OK: Enable RMT channel successfully

---

Note: This function will acquire a PM lock that might be installed during channel allocation
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG: Enable RMT channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Enable RMT channel failed because it’s enabled already
- ESP_FAIL: Enable RMT channel failed because of other error

`esp_err_t rmt_disable(rmt_channel_handle_t channel)`
Disable the RMT channel.

**Note:** This function will release a PM lock that might be installed during channel allocation

**Parameters**
channel - [in] RMT generic channel that created by `rmt_new_tx_channel()` or `rmt_new_rx_channel()`

**Returns**
- ESP_OK: Disable RMT channel successfully
- ESP_ERR_INVALID_ARG: Disable RMT channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Disable RMT channel failed because it’s not enabled yet
- ESP_FAIL: Disable RMT channel failed because of other error

**Structures**

```
struct rmt_carrier_config_t
RMT carrier wave configuration (for either modulation or demodulation)
```

**Public Members**

- `uint32_t frequency_hz`
  Carrier wave frequency, in Hz, 0 means disabling the carrier
- `float duty_cycle`
  Carrier wave duty cycle (0~100%)
- `uint32_t polarity_active_low`
  Specify the polarity of carrier, by default it’s modulated to base signal’s high level
- `uint32_t always_on`
  If set, the carrier can always exist even there’s not transfer undergoing

```
struct rmt_carrier_config_t::[anonymous] flags
Carrier config flags
```

**Header File**

- `components/driver/rmt/include/driver/rmt_encoder.h`

**Functions**

```
esp_err_t rmt_new_bytes_encoder(const rmt_bytes_encoder_config_t *config, rmt_encoder_handle_t *ret_encoder)
```
Create RMT bytes encoder, which can encode byte stream into RMT symbols.

**Parameters**
- `config` - [in] Bytes encoder configuration
- `ret_encoder` - [out] Returned encoder handle
Returns

- ESP_OK: Create RMT bytes encoder successfully
- ESP_ERR_INVALID_ARG: Create RMT bytes encoder failed because of invalid argument
- ESP_ERR_NO_MEM: Create RMT bytes encoder failed because out of memory
- ESP_FAIL: Create RMT bytes encoder failed because of other error

`esp_err_t rmt_new_copy_encoder(const rmt_copy_encoder_config_t *config, rmt_encoder_handle_t *ret_encoder)`

Create RMT copy encoder, which copies the given RMT symbols into RMT memory.

Parameters

- `config` - [in] Copy encoder configuration
- `ret_encoder` - [out] Returned encoder handle

Returns

- ESP_OK: Create RMT copy encoder successfully
- ESP_ERR_INVALID_ARG: Create RMT copy encoder failed because of invalid argument
- ESP_ERR_NO_MEM: Create RMT copy encoder failed because out of memory
- ESP_FAIL: Create RMT copy encoder failed because of other error

`esp_err_t rmt_del_encoder(rmt_encoder_handle_t encoder)`

Delete RMT encoder.

Parameters

- `encoder` - [in] RMT encoder handle, created by e.g. `rmt_new_bytes_encoder()`

Returns

- ESP_OK: Delete RMT encoder successfully
- ESP_ERR_INVALID_ARG: Delete RMT encoder failed because of invalid argument
- ESP_FAIL: Delete RMT encoder failed because of other error

`esp_err_t rmt_encoder_reset(rmt_encoder_handle_t encoder)`

Reset RMT encoder.

Parameters

- `encoder` - [in] RMT encoder handle, created by e.g. `rmt_new_bytes_encoder()`

Returns

- ESP_OK: Reset RMT encoder successfully
- ESP_ERR_INVALID_ARG: Reset RMT encoder failed because of invalid argument
- ESP_FAIL: Reset RMT encoder failed because of other error

Structures

`struct rmt_encoder_t`

Interface of RMT encoder.

Public Members

`size_t (*encode)(rmt_encoder_t *encoder, rmt_channel_handle_t tx_channel, const void *primary_data, size_t data_size, rmt_encode_state_t *ret_state)`

Encode the user data into RMT symbols and write into RMT memory.

Note: The encoding function will also be called from an ISR context, thus the function must not call any blocking API.
Note: It’s recommended to put this function implementation in the IRAM, to achieve a high performance and less interrupt latency.

**Param encoder** [in] Encoder handle

**Param tx_channel** [in] RMT TX channel handle, returned from `rmt_new_tx_channel()`

**Param primary_data** [in] App data to be encoded into RMT symbols

**Param data_size** [in] Size of `primary_data`, in bytes

**Param ret_state** [out] Returned current encoder’s state

**Return** Number of RMT symbols that the primary data has been encoded into

```c
esp_err_t (*reset)(rmt_encoder_t *encoder)
```

Reset encoding state.

**Param encoder** [in] Encoder handle

**Return**

- ESP_OK: reset encoder successfully
- ESP_FAIL: reset encoder failed

```c
esp_err_t (*del)(rmt_encoder_t *encoder)
```

Delete encoder object.

**Param encoder** [in] Encoder handle

**Return**

- ESP_OK: delete encoder successfully
- ESP_FAIL: delete encoder failed

```c
struct rmt_bytes_encoder_config_t
```

Bytes encoder configuration.

### Public Members

```c
rmt_symbol_word_t bit0
```

How to represent BIT0 in RMT symbol

```c
rmt_symbol_word_t bit1
```

How to represent BIT1 in RMT symbol

```c
uint32_t msb_first
```

Whether to encode MSB bit first

```c
struct rmt_bytes_encoder_config_t::[anonymous] flags
```

Encoder config flag

```c
struct rmt_copy_encoder_config_t
```

Copy encoder configuration.

### Enumerations
enum rmt_encode_state_t
  RMT encoding state.

  Values:

  enumerator RMT_ENCODING_RESET
      The encoding session is in reset state

  enumerator RMT_ENCODING_COMPLETE
      The encoding session is finished, the caller can continue with subsequent encoding

  enumerator RMT_ENCODING_MEM_FULL
      The encoding artifact memory is full, the caller should return from current encoding session

Header File
  • components/driver/rmt/include/driver/rmt_types.h

Structures

struct rmt_tx_done_event_data_t
  Type of RMT TX done event data.

  Public Members

  size_t num_symbols
      The number of transmitted RMT symbols, including one EOF symbol, which is appended by the driver to mark the end of a transmission. For a loop transmission, this value only counts for one round.

struct rmt_rx_done_event_data_t
  Type of RMT RX done event data.

  Public Members

  rmt_symbol_word_t *received_symbols
      Point to the received RMT symbols

  size_t num_symbols
      The number of received RMT symbols

Type Definitions

typedef struct rmt_channel_t *rmt_channel_handle_t
  Type of RMT channel handle.

typedef struct rmt_sync_manager_t *rmt_sync_manager_handle_t
  Type of RMT synchronization manager handle.
typedef struct rmt_encoder_t *rmt_encoder_handle_t
    Type of RMT encoder handle.

typedef bool (*rmt_tx_done_callback_t)(rmt_channel_handle_t tx_chan, const rmt_tx_done_event_data_t *edata, void *user_ctx)
    Prototype of RMT event callback.
    Param tx_chan [in] RMT channel handle, created from rmt_new_tx_channel()
    Param edata [in] Point to RMT event data. The lifecycle of this pointer memory is inside this function, user should copy it into static memory if used outside this function.
    Param user_ctx [in] User registered context, passed from rmt_tx_register_event_callbacks()
    Return Whether a high priority task has been waken up by this callback function

typedef bool (*rmt_rx_done_callback_t)(rmt_channel_handle_t rx_chan, const rmt_rx_done_event_data_t *edata, void *user_ctx)
    Prototype of RMT event callback.
    Param rx_chan [in] RMT channel handle, created from rmt_new_rx_channel()
    Param edata [in] Point to RMT event data. The lifecycle of this pointer memory is inside this function, user should copy it into static memory if used outside this function.
    Param user_ctx [in] User registered context, passed from rmt_rx_register_event_callbacks()
    Return Whether a high priority task has been waken up by this function

Header File

- components/hal/include/hal/rmt_types.h

Unions

union rmt_symbol_word_t
    #include <rmt_types.h> The layout of RMT symbol stored in memory, which is decided by the hardware design.

Public Members

uint16_t duration0
    Duration of level0

uint16_t level0
    Level of the first part

uint16_t duration1
    Duration of level1

uint16_t level1
    Level of the second part

struct rmt_symbol_word_t::[anonymous] [anonymous]

uint32_t val
    Equivalent unsigned value for the RMT symbol
Type Definitions

typedef soc_periph_rmt_clk_src_t rmt_clock_source_t
RMT group clock source.

Note: User should select the clock source based on the power and resolution requirement

2.6.15 SD Pull-up Requirements

Espressif hardware products are designed for multiple use cases which may require different pull states on pins. For this reason, the pull state of particular pins on certain products will need to be adjusted to provide the pull-ups required in the SD bus.

SD pull-up requirements apply to cases where ESP32 uses the SPI or SDMMC controller to communicate with SD cards. When an SD card is operating in SPI mode or 1-bit SD mode, the CMD and DATA (DAT0 - DAT3) lines of the SD bus must be pulled up by 10 kOhm resistors. SD cards and SDIO devices should also have pull-ups on all above-mentioned lines (regardless of whether these lines are connected to the host) in order to prevent them from entering a wrong state.

By default, the MTDI bootstrapping pin is incompatible with the DAT2 line pull-up if the flash voltage is 3.3 V. For more information, see MTDI Strapping Pin below.

This document has the following structure:

- Overview of compatibility between the default pull states on pins of Espressif’s products and the states required by the SD bus
- Solutions - ideas on how to resolve compatibility issues
- Related information - other relevant information

Overview of Compatibility

This section provides an overview of compatibility issues that might occur when using SDIO (secure digital input output). Since the SD bus needs to be connected to pull-ups, these issues should be resolved regardless of whether they are related to master (host) or slave (device). Each issue has links to its respective solution. A solution for a host and device may differ.

Systems on a Chip (SoCs)

- ESP32 (except for D2WD versions, see ESP32 datasheet):
  - No Pull-ups
  - Conflicts Between Bootstrap and SDIO on DAT2 for models with 3.3 V flash chip
- ESP32-D2WD:
  - No Pull-ups
  - No Pull-up on GPIO12

Systems in Packages (SIP)

- ESP32-PICO-D4:
  - No Pull-ups
  - Conflicts Between Bootstrap and SDIO on DAT2

Modules

  - No Pull-ups
Conflicts Between Bootstrap and SDIO on DAT2

- ESP32-WROVER Series, including ESP32-WROVER and ESP32-WROVER-I
  - No Pull-ups
- ESP32-WROVER-B Series, including ESP32-WROVER-B and ESP32-WROVER-IB
  - No Pull-ups
  - Conflicts Between Bootstrap and SDIO on DAT2

Development Boards

- ESP32-PICO-KIT, including PICO-KIT v4.1, v4.0, and v3
  - No Pull-ups
  - Conflicts Between Bootstrap and SDIO on DAT2
  - Download Mode Not Working (minor issue)
- ESP32-DevKitC, including ESP32-DevKitC v4 and v2
  - No Pull-ups
  - Conflicts Between Bootstrap and SDIO on DAT2
  - Download Mode Not Working (minor issue)
- ESP-WROVER-KIT
  - Required pull-ups are provided
  - Pull-up Conflicts on GPIO13 (v4.1, v3, v2, and v1)
  - Conflicts Between Bootstrap and SDIO on DAT2 (v4.1, v2, and v1)
  - Download Mode Not Working (minor issue) (v2, v1)

You can determine the version of your ESP32-WROVER-KIT by checking which module is mounted on it:
- ESP32-WROVER-B on v4.1
- ESP32-WROVER on v3
- ESP32-WROOM-32 on v1 and v2

- ESP32-LyraTD-MSC
  - Required pull-ups are provided
  - Conflicts Between Bootstrap and SDIO on DAT2
- ESP32-LyraT
  - Required pull-ups are provided
  - Pull-up Conflicts on GPIO13

Non-Espressif Hosts

Please make sure that your SDIO host provides necessary pull-ups for all SD bus signals.

Solutions

No Pull-ups

If you use a development board without pull-ups, you can do the following:
- If your host and slave device are on separate boards, replace one of them with a board that has pull-ups. For the list of Espressif’s development boards with pull-ups, go to Development Boards.
- Attach external pull-ups by connecting each pin which requires a pull-up to VDD via a 10 kOhm resistor.

Pull-up Conflicts on GPIO13

If DAT3 of your device is not properly pulled up, you have the following options:
- Use 1-bit SD mode and tie the device’s DAT3 to VDD
- Use SPI mode
- Perform one of the following actions on the GPIO13 pin:
  - Remove the pull-down resistors
  - Attach a pull-up resistor of less than 5 kOhm (2 kOhm suggested)
  - Pull it up or drive it high either by using the host or with 3.3 V on VDD in 1-bit SD mode

Conflicts Between Bootstrap and SDIO on DAT2

There is a conflict between the boot strapping requirements of the ESP32 and the SDIO protocol. For details, see MTDI Strapping Pin.

To resolve the conflict, you have the following options:
1. (Recommended) Burn the flash voltage selection eFuses. This will permanently configure the internal regulator’s output voltage to 3.3 V, and GPIO12 will not be used as a bootstrapping pin. After that, connect a pull-up resistor to GPIO12.

**Warning:** Burning eFuses is irreversible! The issue list above might be out of date, so please make sure that the module you are burning has a 3.3 V flash chip by checking the information on [https://www.espressif.com/](https://www.espressif.com/). If you burn the 3.3 V eFuses on a module with a 1.8 V flash chip, the module will stop functioning.

If you are sure that you need to irreversibly burn eFuses, go to your ESP-IDF directory and run the following command:

```
components/esptool_py/esptool/espefuse.py set_flash_voltage 3.3V
```

This command will burn the XPD_SDIO_TIEH, XPD_SDIO_FORCE, and XPD_SDIO_REG eFuses. After all the three eFuses are burned to value 1, the internal VDD_SDIO flash voltage regulator will be permanently set to 3.3 V. You will see the following log if the burning succeeds:

```
espefuse.py v2.6
Connecting....
Enable internal flash voltage regulator (VDD_SDIO) to 3.3 V.
The following eFuses are burned: XPD_SDIO_FORCE, XPD_SDIO_REG, XPD_SDIO_TIEH.
This is an irreversible operation.
Type 'BURN' (all capitals) to continue.
BURN
VDD_SDIO setting complete.
```

To check the status of the eFuses, run:

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If the above solutions do not work for you, please determine if it is the host or slave device that has pull-ups affecting their GPIO2, then locate these pull-ups and remove them.

Related Information

**MTDI Strapping Pin**  MTDI (GPIO12) is used as a bootstrapping pin to select the output voltage of an internal regulator (VDD_SDIO) which powers the flash chip. This pin has an internal pull-down, so, if left unconnected, it will read low level at startup, which will lead to selecting the default 3.3 V operation.

All ESP32-WROVER modules, excluding ESP32-WROVER-B, use 1.8 V flash and have internal pull-ups on GPIO12. Other modules that use 3.3 V flash have no pull-ups on the GPIO12 pin, and this pin is slightly pulled down internally.

When adding a pull-up to this pin for SD card operation, consider the following:
- For boards that do not use the internal regulator (VDD_SDIO) to power flash, GPIO12 can be pulled high.
- For boards using 1.8 V flash chips, GPIO12 needs to be pulled high at reset. This is fully compatible with the SD card operation.
- On boards using the internal regulator and a 3.3 V flash chip, GPIO12 must be pulled low at reset. This is incompatible with the SD card operation. For reference information on compatibility of Espressif’s boards with the SD card operation, see *Overview of Compatibility*.

**Internal Pull-ups and Strapping Requirements**  Using external resistors is always preferable. However, Espressif’s products have internal weak pull-up and pull-down resistors which can be enabled and used instead of external ones. Please keep in mind that this solution cannot guarantee reliable SDIO communication.

With that said, the information about these internal pull-ups and strapping requirements can still be useful. Espressif hardware products have different weak internal pull-ups / pull-downs connected to CMD and DATA pins. The table below shows the default pull-up and pull-down states of the CMD and DATA pins.

The following abbreviations are used in the table:
- **WPU**: Weak pull-up inside the SoC
- **WPD**: Weak pull-down inside the SoC
- **PU**: Pull-up inside Espressif modules but outside the SoC

<table>
<thead>
<tr>
<th>GPIO number</th>
<th>Pin Name</th>
<th>Startup State</th>
<th>Strapping Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>CMD</td>
<td>WPU</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>DAT0</td>
<td>WPD</td>
<td>Low for Download mode</td>
</tr>
<tr>
<td>4</td>
<td>DAT1</td>
<td>WPD</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>DAT2</td>
<td>PU for 1.8 V flash; WPD for 3.3 V flash</td>
<td>High for 1.8 V flash; Low for 3.3 V flash</td>
</tr>
<tr>
<td>13</td>
<td>DAT3</td>
<td>WPU</td>
<td></td>
</tr>
</tbody>
</table>

### 2.6.16 SDMMC Host Driver

**Overview**

ESP32’s SDMMC host peripheral has two slots. Each slot can be used independently to connect to an SD card, SDIO device or eMMC chip.

- Slot 0 (*SDMMC_HOST_SLOT_0*) is an 8-bit slot. It uses HS1_* signals in the PIN MUX.
- Slot 1 (*SDMMC_HOST_SLOT_1*) is a 4-bit slot. It uses HS2_* signals in the PIN MUX.

The slots are connected to ESP32 GPIOs using IO MUX. Pin mappings of these slots are given in the table below.
### Supported Speed Modes

SDMMC Host driver supports the following speed modes:

- Default Speed (20 MHz), 1/4-line (with SD cards), and 1/4/8-line (with 3.3 V eMMC)
- High Speed (40 MHz), 1/4-line (with SD cards), and 1/4/8-line (with 3.3 V eMMC)
- High Speed DDR (40 MHz), 4-line (with 3.3 V eMMC)

Speed modes not supported at present:

- High Speed DDR mode, 8-line eMMC
- UHS-I 1.8 V modes, 4-line SD cards

### Using the SDMMC Host Driver

Of all the functions listed below, only the following ones will be used directly by most applications:

- `sdmmc_host_init()`
- `sdmmc_host_init_slot()`
- `sdmmc_host_deinit()`

Other functions, such as the ones given below, will be called by the SD/MMC protocol layer via function pointers in the `sdmmc_host_t` structure:

- `sdmmc_host_set_bus_width()`
- `sdmmc_host_set_card_clk()`
- `sdmmc_host_do_transaction()`

### Configuring Bus Width and Frequency

With the default initializers for `sdmmc_host_t` and `sdmmc_slot_config_t` (`SDMMC_HOST_DEFAULT` and `SDMMC_SLOT_CONFIG_DEFAULT`), SDMMC Host driver will attempt to use the widest bus supported by the card (4 lines for SD, 8 lines for eMMC) and the frequency of 20 MHz.
In the designs where communication at 40 MHz frequency can be achieved, it is possible to increase the bus frequency by changing the max_freq_khz field of `sdmmc_host_t`:

```c
sdmmc_host_t host = SDMMC_HOST_DEFAULT();
host.max_freq_khz = SDMMC_FREQ_HIGHSPEED;
```

If you need a specific frequency other than standard speeds, you are free to use any value from within appropriate range of the SD interface given (SDMMC or SDSPI). However, the real clock frequency shall be calculated by the underlying driver and the value can be different from the one required. For the SDMMC, `max_freq_khz` works as the upper limit so the final frequency value shall be always lower or equal. For the SDSPI, the nearest fitting frequency is supplied and thus the value can be greater than/ equal to/ lower than `max_freq_khz`.

To configure the bus width, set the `width` field of `sdmmc_slot_config_t`. For example, to set 1-line mode:

```c
sdmmc_slot_config_t slot = SDMMC_SLOT_CONFIG_DEFAULT();
slot.width = 1;
```

### DDR Mode for eMMC chips

By default, DDR mode will be used if:

- SDMMC host frequency is set to `SDMMC_FREQ_HIGHSPEED` in `sdmmc_host_t` structure, and
- eMMC chip reports DDR mode support in its CSD register

DDRM mode places higher requirements for signal integrity. To disable DDR mode while keeping `SDMMC_FREQ_HIGHSPEED` frequency, clear `SDMMC_HOST_FLAG_DDR` bit in `flags` field of `sdmmc_host_t`:

```c
sdmmc_host_t host = SDMMC_HOST_DEFAULT();
host.max_freq_khz = SDMMC_FREQ_HIGHSPEED;
host.flags ^= SDMMC_HOST_FLAG_DDR;
```

### See also

See [SD/SDIO/MMC Driver](https://doc.espressif.com/espressif/system/components/driver/sdmmc) for the higher level driver which implements the protocol layer.

See [SD SPI Host Driver](https://doc.espressif.com/espressif/system/components/driver/sdmmc/sdspi_host) for a similar driver which uses the SPI controller and is limited to SD protocol’s SPI mode.

See [SD Pull-up Requirements](https://doc.espressif.com/espressif/system/components/driver/sdmmc/pullup) for pullup support and compatibilities of modules and development kits.

### API Reference

#### Header File

- `components/driver/sdmmc/include/driver/sdmmc_host.h`

#### Functions

- `esp_err_t sdmmc_host_init(void)`
  
  Initialize SDMMC host peripheral.

  **Note:** This function is not thread safe

  **Returns**

  - ESP_OK on success
  - ESP_ERR_INVALID_STATE if `sdmmc_host_init` was already called
  - ESP_ERR_NO_MEM if memory can not be allocated
**esp_err_t sdmmc_host_init_slot** (int slot, const sdmmc_slot_config_t *slot_config)

Initialize given slot of SDMMC peripheral.

On the ESP32, SDMMC peripheral has two slots:

- Slot 0: 8-bit wide, maps to HS1_* signals in PIN_MUX
- Slot 1: 4-bit wide, maps to HS2_* signals in PIN_MUX

Card detect and write protect signals can be routed to arbitrary GPIOs using GPIO matrix.

**Note:** This function is not thread safe

**Parameters**

- **slot** - slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **slot_config** - additional configuration for the slot

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_STATE if host has not been initialized using sdmmc_host_init

**esp_err_t sdmmc_host_set_bus_width** (int slot, size_t width)

Select bus width to be used for data transfer.

SD/MMC card must be initialized prior to this command, and a command to set bus width has to be sent to the card (e.g. SD_APP_SET_BUS_WIDTH)

**Note:** This function is not thread safe

**Parameters**

- **slot** - slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **width** - bus width (1, 4, or 8 for slot 0; 1 or 4 for slot 1)

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if slot number or width is not valid

**size_t sdmmc_host_get_slot_width** (int slot)

Get bus width configured in sdmmc_host_init_slot to be used for data transfer.

**Parameters**

- **slot** - slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)

**Returns**

- configured bus width of the specified slot.

**esp_err_t sdmmc_host_set_card_clk** (int slot, uint32_t freq_khz)

Set card clock frequency.

Currently only integer fractions of 40MHz clock can be used. For High Speed cards, 40MHz can be used. For Default Speed cards, 20MHz can be used.

**Note:** This function is not thread safe

**Parameters**

- **slot** - slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **freq_khz** - card clock frequency, in kHz

**Returns**

- ESP_OK on success
- other error codes may be returned in the future
**esp_err_t sdmmc_host_set_bus_ddr_mode** (int slot, bool ddr_enabled)

Enable or disable DDR mode of SD interface.

**Parameters**

- **slot** – slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **ddr_enabled** – enable or disable DDR mode

**Returns**

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if DDR mode is not supported on this slot

**esp_err_t sdmmc_host_set_cclk_always_on** (int slot, bool cclk_always_on)

Enable or disable always-on card clock. When cclk_always_on is false, the host controller is allowed to shut down the card clock between the commands. When cclk_always_on is true, the clock is generated even if no command is in progress.

**Parameters**

- **slot** – slot number
- **cclk_always_on** – enable or disable always-on clock

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if the slot number is invalid

**esp_err_t sdmmc_host_do_transaction** (int slot, sdmmc_command_t *cmdinfo)

Send command to the card and get response.

This function returns when command is sent and response is received, or data is transferred, or timeout occurs.

Attention Data buffer passed in cmdinfo->data must be in DMA capable memory

**Note:** This function is not thread safe w.r.t. init/deinit functions, and bus width-clock speed configuration functions. Multiple tasks can call sdmmc_host_do_transaction as long as other sdmmc_host_* functions are not called.

**Parameters**

- **slot** – slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **cmdinfo** – pointer to structure describing command and data to transfer

**Returns**

- ESP_OK on success
- ESP_ERR_TIMEOUT if response or data transfer has timed out
- ESP_ERR_INVALID_CRC if response or data transfer CRC check has failed
- ESP_ERR_INVALID_RESPONSE if the card has sent an invalid response
- ESP_ERR_INVALID_SIZE if the size of data transfer is not valid in SD protocol
- ESP_ERR_INVALID_ARG if the data buffer is not in DMA capable memory

**esp_err_t sdmmc_host_io_int_enable** (int slot)

Enable IO interrupts.

This function configures the host to accept SDIO interrupts.

**Parameters**

- **slot** – slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)

**Returns**

returns ESP_OK, other errors possible in the future

**esp_err_t sdmmc_host_io_int_wait** (int slot, TickType_t timeout_ticks)

Block until an SDIO interrupt is received, or timeout occurs.

**Parameters**

- **slot** – slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- **timeout_ticks** – number of RTOS ticks to wait for the interrupt

**Returns**

returns ESP_OK, other errors possible in the future
Chapter 2. API Reference

- ESP_OK on success (interrupt received)
- ESP_ERR_TIMEOUT if the interrupt did not occur within timeout_ticks

\texttt{esp_err_t sdmmc_host_deinit (void)}

Disable SDMMC host and release allocated resources.

\textbf{Note:} This function is not thread safe

\textbf{Returns}
- ESP_OK on success
- ESP_ERROR_INVALID_STATE if sdmmc_host_init function has not been called

\texttt{esp_err_t sdmmc_host_get_real_freq (int slot, int *real_freq_khz)}

Provides a real frequency used for an SD card installed on specific slot of SD/MMC host controller.

This function calculates real working frequency given by current SD/MMC host controller setup for required slot: it reads associated host and card dividers from corresponding SDMMC registers, calculates respective frequency and stores the value into the \textquote{real_freq_khz} parameter

\textbf{Parameters}
- \texttt{slot} - slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- \texttt{real_freq_khz} - [out] output parameter for the result frequency (in kHz)

\textbf{Returns}
- ESP_OK on success
- ESP_ERROR_INVALID_ARG on real_freq_khz == NULL or invalid slot number used

\textbf{Structures}

\texttt{struct sdmmc_slot_config_t}

Extra configuration for SDMMC peripheral slot

\textbf{Public Members}

\texttt{gpio_num_t gpio_cd}

GPIO number of card detect signal.

\texttt{gpio_num_t cd}

GPIO number of card detect signal; shorter name.

\texttt{gpio_num_t gpio_wp}

GPIO number of write protect signal.

\texttt{gpio_num_t wp}

GPIO number of write protect signal; shorter name.

\texttt{uint8_t width}

Bus width used by the slot (might be less than the max width supported)

\texttt{uint32_t flags}

Features used by this slot.
Macros

**SDMMC_HOST_SLOT_0**
SDMMC slot 0.

**SDMMC_HOST_SLOT_1**
SDMMC slot 1.

**SDMMC_HOST_DEFAULT**
Default `sdmmc_host_t` structure initializer for SDMMC peripheral.

- Uses SDMMC peripheral, with 4-bit mode enabled, and max frequency set to 20MHz

**SDMMC_SLOT_FLAG_INTERNAL_PULLUP**
Enable internal pullup on enabled pins. The internal pullups are insufficient however, please make sure external pullups are connected on the bus. This is for debug / example purpose only.

**SDMMC_SLOT_NO_CD**
indicates that card detect line is not used

**SDMMC_SLOT_NO_WP**
indicates that write protect line is not used

**SDMMC_SLOT_WIDTH_DEFAULT**
use the maximum possible width for the slot

**SDMMC_SLOT_CONFIG_DEFAULT**
Macro defining default configuration of SDMMC host slot

2.6.17 SD SPI Host Driver

Overview

The SD SPI host driver allows communication with one or more SD cards using the SPI Master driver, which utilizes the SPI host. Each card is accessed through an SD SPI device, represented by an SD SPI handle `sdspl_dev_handle_t`, which returns when the device is attached to an SPI bus by calling `sdspi_host_init_device()`. It is important to note that the SPI bus should be initialized beforehand by `spi_bus_initailize()`.

This driver’s naming pattern was adopted from the SDMMC Host Driver due to their similarity. Likewise, the APIs of both drivers are also very similar.

SD SPI driver that accesses the SD card in SPI mode offers lower throughput but makes pin selection more flexible. With the help of the GPIO matrix, an SPI peripheral’s signals can be routed to any ESP32 pin. Otherwise, if an SDMMC host driver is used (see SDMMC Host Driver) to access the card in SD 1-bit/4-bit mode, higher throughput can be reached while requiring routing the signals through their dedicated IO_MUX pins only.

With the help of SPI Master Driver the SD SPI host driver based on, the SPI bus can be shared among SD cards and other SPI devices. The SPI Master driver will handle exclusive access from different tasks.

The SD SPI driver uses software-controlled CS signal.
Chapter 2. API Reference

How to Use

Firstly, use the macro `SDSPI_DEVICE_CONFIG_DEFAULT` to initialize the structure `sdspi_device_config_t`, which is used to initialize an SD SPI device. This macro will also fill in the default pin mappings, which are the same as the pin mappings of the SDMMC host driver. Modify the host and pins of the structure to desired value. Then call `sdspi_host_init_device` to initialize the SD SPI device and attach to its bus.

Then use the `SDSPI_HOST_DEFAULT` macro to initialize the `sdmmc_host_t` structure, which is used to store the state and configurations of the upper layer (SD/SDIO/MMC driver). Modify the slot parameter of the structure to the SD SPI device SD SPI handle just returned from `sdspi_host_init_device`. Call `sdmmc_card_init` with the `sdmmc_host_t` to probe and initialize the SD card.

Now you can use SD/SDIO/MMC driver functions to access your card!

Other Details

Only the following driver’s API functions are normally used by most applications:

- `sdspi_host_init()`
- `sdspi_host_init_device()`
- `sdspi_host_remove_device()`
- `sdspi_host_deinit()`

Other functions are mostly used by the protocol level SD/SDIO/MMC driver via function pointers in the `sdmmc_host_t` structure. For more details, see *SD/SDIO/MMC Driver*.

**Note:** SD over SPI does not support speeds above `SDMMC_FREQ_DEFAULT` due to the limitations of the SPI driver.

**Warning:** If you want to share the SPI bus among SD card and other SPI devices, there are some restrictions, see *Sharing the SPI bus among SD card and other SPI devices*.

Related Docs

**Sharing the SPI bus among SD card and other SPI devices** The SD card has a SPI mode, which allows it to be communicated to as a SPI device. But there are some restrictions that we need to pay attention to.

**Pin loading of other devices** When adding more devices onto the same bus, the overall pin loading increases. The loading consists of AC loading (pin capacitor) and DC loading (pull-ups).

**AC loading** SD cards, which are designed for high-speed communications, have small pin capacitors (AC loading) to work until 50MHz. However, the other attached devices will increase the pin’s AC loading.

Heavy AC loading of a pin may prevent the pin from being toggled quickly. By using an oscilloscope, you will see the edges of the pin become smoother and not ideal any more (the gradient of the edge is smaller). The setup timing requirements of an SD card may be violated when the card is connected to such bus. Even worse, the clock from the host may not be recognized by the SD card and other SPI devices on the same bus.

This issue may be more obvious if other attached devices are not designed to work at the same frequency as the SD card, because they may have larger pin capacitors.

To see if your pin AC loading is too heavy, you can try the following tests:

(Terminology: **launch edge**: at which clock edge the data start to toggle; **latch edge**: at which clock edge the data is supposed to be sampled by the receiver, for SD card, it’s the rising edge.)
1. Use an oscilloscope to see the clock and compare the data line to the clock. - If you see the clock is not fast enough (for example, the rising/falling edge is longer than 1/4 of the clock cycle), it means the clock is skewed too much. - If you see the data line unstable before the latch edge of the clock, it means the load of the data line is too large.

You may also observed the corresponding phenomenon (data delayed largely from launching edge of clock) with logic analyzers. But it’s not as obvious as with an oscilloscope.

2. Try to use slower clock frequency.

If the lower frequency can work while the higher frequency can’t, it’s an indication of the AC loading on the pins is too large.

If the AC loading of the pins is too large, you can either use other faster devices (with lower pin load) or slow down the clock speed.

DC loading The pull-ups required by SD cards are usually around 10 kOhm to 50 kOhm, which may be too strong for some other SPI devices.

Check the specification of your device about its DC output current , it should be larger than 700uA, otherwise the device output may not be read correctly.

Initialization sequence

Note: If you see any problem in the following steps, please make sure the timing is correct first. You can try to slow down the clock speed (SDMMC_FREQ_PROBING = 400 KHz for SD card) to avoid the influence of pin AC loading (see above section).

When using a SD card with other SPI devices on the same SPI bus, due to the restrictions of the SD card startup flow, the following initialization sequence should be followed: (See also storage/sd_card)

1. Initialize the SPI bus properly by spi_bus_initialize.
2. Tie the CS lines of all other devices than the SD card to high. This is to avoid conflicts to the SD card in the following step.

You can do this by either:

1. Attach devices to the SPI bus by calling spi_bus_add_device. This function will initialize the GPIO that is used as CS to the idle level: high.
2. Initialize GPIO on the CS pin that needs to be tied up before actually adding a new device.
3. Rely on the internal/external pull-up (not recommended) to pull-up all the CS pins when the GPIOs of ESP are not initialized yet. You need to check carefully the pull-up is strong enough and there are no other pull-downs that will influence the pull-up (For example, internal pull-down should be enabled).
3. Mount the card to the filesystem by calling esp_vfs_fat_sdspi_mount.

This step will put the SD card into the SPI mode, which SHOULD be done before all other SPI communications on the same bus. Otherwise the card will stay in the SD mode, in which mode it may randomly respond to any SPI communications on the bus, even when its CS line is not addressed.

If you want to test this behavior, please also note that, once the card is put into SPI mode, it will not return to SD mode before next power cycle, i.e. powered down and powered up again.

4. Now you can talk to other SPI devices freely!

API Reference

Header File

* components/driver/spi/include/driver/sdspi_host.h

Functions

\texttt{esp_err_t sdspi_host_init (void)}

Initialize SD SPI driver.
**Note:** This function is not thread safe

**Returns**
- ESP_OK on success
- other error codes may be returned in future versions

```c
esp_err_t sdspi_host_init_device (const sdspi_device_config_t *dev_config, sdspi_dev_handle_t *out_handle)
```
Attach and initialize an SD SPI device on the specific SPI bus.

**Note:** This function is not thread safe

**Note:** Initialize the SPI bus by `spi_bus_initialize()` before calling this function.

**Note:** The SDIO overs despineeds an extra interrupt line. Call `gpio_install_isr_service()` before this function.

**Parameters**
- `dev_config` - pointer to device configuration structure
- `out_handle` - Output of the handle to the sdspi device.

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if `sdspi_host_init_device` has invalid arguments
- ESP_ERR_NO_MEM if memory cannot be allocated
- other errors from the underlying spi_master and gpio drivers

```c
esp_err_t sdspi_host_remove_device (sdspi_dev_handle_t handle)
```
Remove an SD SPI device.

**Parameters**
- `handle` - Handle of the SD SPI device

**Returns**
AlwayseSP_OK

```c
esp_err_t sdspi_host_do_transaction (sdspi_dev_handle_t handle, sdmmc_command_t *cmdinfo)
```
Send command to the card and get response.

This function returns when command is sent and response is received, or data is transferred, or timeout occurs.

**Note:** This function is not thread safe w.r.t. init/deinit functions, and bus width-clock speed configuration functions. Multiple tasks can call `sdspi_host_do_transaction` as long as other `sdspi_host_*` functions are not called.

**Parameters**
- `handle` - Handle of the sdspi device
- `cmdinfo` - pointer to structure describing command and data to transfer

**Returns**
- ESP_OK on success
- ESP_ERR_TIMEOUT if response or data transfer has timed out
- ESP_ERR_INVALID_CRC if response or data transfer CRC check has failed
- ESP_ERR_INVALID_RESPONSE if the card has sent an invalid response
**esp_err_t** `sdspi_host_set_card_clk` *(sdspi_dev_handle_t host, uint32_t freq_khz)*

Set card clock frequency.

Currently only integer fractions of 40MHz clock can be used. For High Speed cards, 40MHz can be used. For Default Speed cards, 20MHz can be used.

**Note:** This function is not thread safe

**Parameters**
- `host` – Handle of the sdspi device
- `freq_khz` – card clock frequency, in kHz

**Returns**
- ESP_OK on success
- other error codes may be returned in the future

**esp_err_t** `sdspi_host_get_real_freq` *(sdspi_dev_handle_t handle, int* real_freq_khz)*

Calculate working frequency for specific device.

**Parameters**
- `handle` – SDSPI device handle
- `real_freq_khz` – [out] output parameter to hold the calculated frequency (in kHz)

**Returns**
- ESP_ERR_INVALID_ARG : handle is NULL or invalid or real_freq_khz parameter is NULL
- ESP_OK : Success

**esp_err_t** `sdspi_host_deinit` *(void)*

Release resources allocated using sdspi_host_init.

**Note:** This function is not thread safe

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if sdspi_host_init function has not been called

**esp_err_t** `sdspi_host_io_int_enable` *(sdspi_dev_handle_t handle)*

Enable SDIO interrupt.

**Parameters**
- `handle` – Handle of the sdspi device

**Returns**
- ESP_OK on success

**esp_err_t** `sdspi_host_io_int_wait` *(sdspi_dev_handle_t handle, TickType_t timeout_ticks)*

Wait for SDIO interrupt until timeout.

**Parameters**
- `handle` – Handle of the sdspi device
- `timeout_ticks` – Ticks to wait before timeout.

**Returns**
- ESP_OK on success

**Structures**

**struct sdspi_device_config_t**

Extra configuration for SD SPI device.
Public Members

*spi_host_device_t* `host_id`
 SPI host to use, SPIx.Host (see spi_types.h).

*gpio_num_t* `gpio_cs`
 GPIO number of CS signal.

*gpio_num_t* `gpio_cd`
 GPIO number of card detect signal.

*gpio_num_t* `gpio_wp`
 GPIO number of write protect signal.

*gpio_num_t* `gpio_int`
 GPIO number of interrupt line (input) for SDIO card.

Macros

**SDSPI_DEFAULT_HOST**

**SDSPI_DEFAULT_DMA**

**SDSPI_HOST_DEFAULT()**
 Default `sdmmc_host_t` structure initializer for SD over SPI driver.
 Uses SPI mode and max frequency set to 20MHz
 ‘slot’ should be set to an sdspi device initialized by `sdspi_host_init_device()`.

**SDSPI_SLOT_NO_CS**
 indicates that card select line is not used

**SDSPI_SLOT_NO_CD**
 indicates that card detect line is not used

**SDSPI_SLOT_NO_WP**
 indicates that write protect line is not used

**SDSPI_SLOT_NO_INT**
 indicates that interrupt line is not used

**SDSPI_DEVICE_CONFIG_DEFAULT()**
 Macro defining default configuration of SD SPI device.

Type Definitions

typedef int *sdspi_dev_handle_t*
 Handle representing an SD SPI device.
2.6.18 SDIO Card Slave Driver

Overview

The ESP32 SDIO Card peripherals (Host, Slave) shares two sets of pins as below table. The first set is usually occupied by SPI0 bus which is responsible for the SPI flash holding the code to run. This means SDIO slave driver can only runs on the second set of pins while SDIO host is not using it.

The SDIO slave can run under 3 modes: SPI, 1-bit SD and 4-bit SD modes, which is detected automatically by the hardware. According to the SDIO specification, CMD and DAT0-3 lines should be pulled up no matter in 1-bit, 4-bit or SPI mode.

<table>
<thead>
<tr>
<th>Connections</th>
<th>Pin Name</th>
<th>Corresponding pins in SPI mode</th>
<th>Slot1</th>
<th>Slot2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CLK</td>
<td>SCLK</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>CMD</td>
<td>MOSI</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>DAT0</td>
<td>MISO</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>DAT1</td>
<td>Interrupt</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>DAT2</td>
<td>N.C. (pullup)</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>DAT3</td>
<td>#CS</td>
<td>10</td>
<td>13</td>
</tr>
</tbody>
</table>

- 1-bit SD mode: Connect CLK, CMD, DAT0, DAT1 pins and the ground.
- 4-bit SD mode: Connect all pins and the ground.
- SPI mode: Connect SCLK, MOSI, MISO, Interrupt, #CS pins and the ground.

Note: Please check if CMD and DATA lines D0-D3 of the card are properly pulled up by 10 KOhm resistors. This should be ensured even in 1-bit mode or SPI mode. Most official modules don’t offer these pullups internally. If you are using official development boards, check Overview of Compatibility to see whether your development boards have such pullups.

Note: Most official modules have conflicts on strapping pins with the SDIO slave function. If you are using a ESP32 module with 3.3 V flash inside, you have to burn the EFUSE when you are developing on the module for the first time. See Overview of Compatibility to see how to make your modules compatible with the SDIO.

Here is a list for modules/kits with 3.3 V flash:

- Kits: ESP32-PICO-KIT, ESP32-DevKitC (till v4), ESP32-WROVER-KIT (v4.1 (also known as ESP32-WROVER-KIT-VB), v2, v1 (also known as DevKitJ v1))

You can tell the version of your ESP32-WROVER-KIT version from the module on it: v4.1 are with ESP32-WROVER-B modules, v3 are with ESP32-WROVER modules, while v2 and v1 are with ESP32-WROOM-32 modules.

Refer to SD Pull-up Requirements for more technical details of the pullups.

The host initialize the slave into SD mode by first sending CMD0 with DAT3 pin high, or in SPI mode by sending CMD0 with CS pin (the same pin as DAT3) low.

After the initialization, the host can enable the 4-bit SD mode by writing CCCR register 0x07 by CMD52. All the bus detection process are handled by the slave peripheral.

The host has to communicate with the slave by an ESP-slave-specific protocol. The slave driver offers 3 services over Function 1 access by CMD52 and CMD53: (1) a sending FIFO and a receiving FIFO, (2) 52 8-bit R/W registers shared by host and slave, (3) 16 interrupt sources (8 from host to slave, and 8 from slave to host).
**Terminology**  The SDIO slave driver uses the following terms:

- **Transfer**: a transfer is always started by a command token from the host, and may contain a reply and several data blocks. ESP32 SDIO slave software is based on transfers.
- **Sending**: slave to host transfers.
- **Receiving**: host to slave transfers.

**Note**: Register names in ESP32 Technical Reference Manual > SDIO Slave Controller [PDF] are oriented from the point of view of the host, i.e. ‘rx’ registers refer to sending, while ‘tx’ registers refer to receiving. We’re not using tx or rx in the driver to avoid ambiguities.

- **FIFO**: specific address in Function 1 that can be access by CMD53 to read/write large amount of data. The address is related to the length requested to read from/write to the slave in a single transfer: \( \text{requested length} = 0x1F800-\text{address} \).
- **Ownership**: When the driver takes ownership of a buffer, it means the driver can randomly read/write the buffer (usually via DMA). The application should not read/write the buffer until the ownership is returned to the application. If the application reads from a buffer owned by a receiving driver, the data read can be random; if the application writes to a buffer owned by a sending driver, the data sent may be corrupted.
- **Requested length**: The length requested in one transfer determined by the FIFO address.
- **Transfer length**: The length requested in one transfer determined by the CMD53 byte/block count field.

**Note**: Requested length is different from the transfer length. ESP32 SDIO slave DMA base on the requested length rather than the transfer length. The transfer length should be no shorter than the requested length, and the rest part will be filled with 0 (sending) or discard (receiving).

- **Receiving buffer size**: The buffer size is pre-defined between the host and the slave before communication starts. Slave application has to set the buffer size during initialization by the recv_buffer_size member of sdio_slave_config_t.
- **Interrupts**: the ESP32 SDIO slave support interrupts in two directions: from host to slave (called slave interrupts below) and from slave to host (called host interrupts below). See more in Interrupts.
- **Registers**: specific address in Function 1 access by CMD52 or CMD53.

**Communication with ESP SDIO Slave**  The host should initialize the ESP32 SDIO slave according to the standard SDIO initialization process (Sector 3.1.2 of SDIO Simplified Specification), which is described briefly in ESP SDIO Slave Initialization.

Furthermore, there’s an ESP32-specific upper-level communication protocol upon the CMD52/CMD53 to Func 1. Please refer to ESP SDIO Slave Protocol. There is also a component ESP Serial Slave Link for ESP32 master to communicate with ESP32 SDIO slave, see example peripherals/sdio when programming your host.

**Interrupts**  There are interrupts from host to slave, and from slave to host to help communicating conveniently.

**Slave Interrupts**  The host can interrupt the slave by writing any one bit in the register 0x08D. Once any bit of the register is set, an interrupt is raised and the SDIO slave driver calls the callback function defined in the slave_intr_cb member in the sdio_slave_config_t structure.

**Note**: The callback function is called in the ISR, do not use any delay, loop or spinlock in the callback.

There’s another set of functions can be used. You can call sdio_slave_wait_int to wait for an interrupt within a certain time, or call sdio_slave_clear_int to clear interrupts from host. The callback function can work with the wait functions perfectly.
**Host Interrupts**  The slave can interrupt the host by an interrupt line (at certain time) which is level sensitive. When the host see the interrupt line pulled down, it may read the slave interrupt status register, to see the interrupt source. Host can clear interrupt bits, or choose to disable a interrupt source. The interrupt line will hold active until all the sources are cleared or disabled.

There are several dedicated interrupt sources as well as general purpose sources. see `sdio_slave_hostint_t` for more information.

**Shared Registers**  There are 52 8-bit R/W shared registers to share information between host and slave. The slave can write or read the registers at any time by `sdio_slave_read_reg` and `sdio_slave_write_reg`. The host can access (R/W) the register by CMD52 or CMD53.

**Receiving FIFO**  When the host is going to send the slave some packets, it has to check whether the slave is ready to receive by reading the buffer number of slave.

To allow the host sending data to the slave, the application has to load buffers to the slave driver by the following steps:

1. Register the buffer by calling `sdio_slave_recv_register_buf`, and get the handle of the registered buffer. The driver will allocate memory for the linked-list descriptor needed to link the buffer onto the hardware. The size of these buffers should equal to the Receiving buffer size.
2. Load buffers onto the driver by passing the buffer handle to `sdio_slave_recv_load_buf`.
3. Get the received data by calling `sdio_slave_recv` or `sdio_slave_recv_packet`. If non-blocking call is needed, set `wait=0`. The difference between two APIs is that, `sdio_slave_recv_packet` gives more information about packet, which can consist of several buffers. When `ESP_ERR_NOT_FINISHED` is returned by this API, you should call this API iteratively until the return value is `ESP_OK`. All the continuous buffers returned with `ESP_ERR_NOT_FINISHED`, together with the last buffer returned with `ESP_OK`, belong to one packet from the host. Call `sdio_slave_recv_get_buf` to get the address of the received data, and the actual length received in each buffer. The packet length is the sum of received length of all the buffers in the packet.
   If the host never send data longer than the Receiving buffer size, or you don’t care about the packet boundary (e.g. the data is only a byte stream), you can call the simpler version `sdio_slave_recv` instead.
4. Pass the handle of processed buffer back to the driver by `sdio_recv_load_buf` again.

**Note:** To avoid overhead from copying data, the driver itself doesn’t have any buffer inside, the application is responsible to offer new buffers in time. The DMA will automatically store received data to the buffer.

**Sending FIFO**  Each time the slave has data to send, it raises an interrupt and the host will request for the packet length. There are two sending modes:

- **Stream Mode:** when a buffer is loaded to the driver, the buffer length will be counted into the packet length requested by host in the incoming communications. Regardless previous packets are sent or not. This means the host can get data of several buffers in one transfer.
- **Packet Mode:** the packet length is updated packet by packet, and only when previous packet is sent. This means that the host can only get data of one buffer in one transfer.

**Note:** To avoid overhead from copying data, the driver itself doesn’t have any buffer inside. Namely, the DMA takes data directly from the buffer provided by the application. The application should not touch the buffer until the sending is finished.

The sending mode can be set in the `sending_mode` member of `sdio_slave_config_t`, and the buffer numbers can be set in the `send_queue_size`. All the buffers are restricted to be no larger than 4092 bytes. Though in the stream mode several buffers can be sent in one transfer, each buffer is still counted as one in the queue.
The application can call `sdio_slave_transmit` to send packets. In this case the function returns when the transfer is successfully done, so the queue is not fully used. When higher efficiency is required, the application can use the following functions instead:

1. Pass buffer information (address, length, as well as an `arg` indicating the buffer) to `sdio_slave_send_queue`. If non-blocking call is needed, set `wait=0`. If the wait is not `portMAX_DELAY` (wait until success), application has to check the result to know whether the data is put in to the queue or discard.
2. Call `sdio_slave_send_get_finished` to get and deal with a finished transfer. A buffer should be kept unmodified until returned from `sdio_slave_send_get_finished`. This means the buffer is actually sent to the host, rather than just staying in the queue.

There are several ways to use the `arg` in the queue parameter:

1. Directly point `arg` to a dynamic-allocated buffer, and use the `arg` to free it when transfer finished.
2. Wrap transfer informations in a transfer structure, and point `arg` to the structure. You can use the structure to do more things like:

```c
typedef struct {
    uint8_t* buffer;
    size_t size;
    int id;
} sdio_transfer_t;

// and send as:
sdio_transfer_t trans = {
    .buffer = ADDRESS_TO_SEND,
    .size = 8,
    .id = 3, // the 3rd transfer so far
};
sdio_slave_send_queue(trans.buffer, trans.size, &trans, portMAX_DELAY);

//... maybe more transfers are sent here

// and deal with finished transfer as:
sdio_transfer_t* arg = NULL;
sdio_slave_send_get_finished((void**)&arg, portMAX_DELAY);
ESP_LOGI("tag", "\n%d successfully send %d bytes of %p\n", arg->id, arg->size, ...
->arg->buffer);
some_post_callback(arg); // do more things
```

3. Working with the receiving part of this driver, point `arg` to the receive buffer handle of this buffer. So that we can directly use the buffer to receive data when it’s sent:

```c
uint8_t buffer[256] = {1, 2, 3, 4, 5, 6, 7, 8};
sdio_slave_buf_handle_t handle = sdio_slave_recv_register_buf(buffer);
sdio_slave_send_queue(buffer, 8, handle, portMAX_DELAY);

//... maybe more transfers are sent here

// and load finished buffer to receive as
sdio_slave_buf_handle_t handle = NULL;
sdio_slave_send_get_finished((void**)&handle, portMAX_DELAY);
sdio_slave_recv_load_buf(handle);
```

More about this, see `peripherals/sdio`.

**Application Example**

Slave/master communication: `peripherals/sdio`. 
API Reference

Header File

- components/hal/include/hal/sdio_slave_types.h

Enumerations

enum sdio_slave_hostint_t

Mask of interrupts sending to the host.

Values:

- enumerator SDIO_SLAVE_HOSTINT_BIT0
  General purpose interrupt bit 0.

- enumerator SDIO_SLAVE_HOSTINT_BIT1

- enumerator SDIO_SLAVE_HOSTINT_BIT2

- enumerator SDIO_SLAVE_HOSTINT_BIT3

- enumerator SDIO_SLAVE_HOSTINT_BIT4

- enumerator SDIO_SLAVE_HOSTINT_BIT5

- enumerator SDIO_SLAVE_HOSTINT_BIT6

- enumerator SDIO_SLAVE_HOSTINT_BIT7

- enumerator SDIO_SLAVE_HOSTINT_SEND_NEW_PACKET
  New packet available.

enum sdio_slave_timing_t

Timing of SDIO slave.

Values:

- enumerator SDIO_SLAVE_TIMING_PSEND_PSAMPLE
  Send at posedge, and sample at posedge. Default value for HS mode. If
  :macro:SDIO_SLAVE_FLAG_HIGH_SPEED is specified in :cpp:class:sdio_slave_config_t,
  this should be selected. Normally there’s no problem using this to work in DS mode.

- enumerator SDIO_SLAVE_TIMING_NSEND_PSAMPLE
  Send at negedge, and sample at posedge. Default value for DS mode and
  below. If :macro:SDIO_SLAVE_FLAG_DEFAULT_SPEED is specified in
  :cpp:class:sdio_slave_config_t, this should be selected.

- enumerator SDIO_SLAVE_TIMING_PSEND_NSAMPLE
  Send at posedge, and sample at negedge.
enumerator `SDIO_SLAVE_TIMING_NSEND_NSAMPLE`
   Send at negedge, and sample at negedge.

eenum `sdio_slave_sending_mode_t`
   Configuration of SDIO slave mode.
   
   Values:

   enumerator `SDIO_SLAVE_SEND_STREAM`
   Stream mode, all packets to send will be combined as one if possible.

   enumerator `SDIO_SLAVE_SEND_PACKET`
   Packet mode, one packets will be sent one after another (only increase packet_len if last packet sent).

**Header File**

- components/driver/sdio_slave/include/driver/sdio_slave.h

**Functions**

`esp_err_t sdio_slave_initialize (sdio_slave_config_t *config)`

Initialize the sdio slave driver

Parameters

- config - Configuration of the sdio slave driver.

Returns

- ESP_ERR_NOT_FOUND if no free interrupt found.
- ESP_ERR_INVALID_STATE if already initialized.
- ESP_ERR_NO_MEM if fail due to memory allocation failed.
- ESP_OK if success

void `sdio_slave_deinit` (void)

De-initialize the sdio slave driver to release the resources.

`esp_err_t sdio_slave_start` (void)

Start hardware for sending and receiving, as well as set the IREADY1 to 1.

**Note:** The driver will continue sending from previous data and PKT_LEN counting, keep data received as well as start receiving from current TOKEN1 counting. See `sdio_slave_reset`.

Returns

- ESP_ERR_INVALID_STATE if already started.
- ESP_OK otherwise.

void `sdio_slave_stop` (void)

Stop hardware from sending and receiving, also set IREADY1 to 0.

**Note:** this will not clear the data already in the driver, and also not reset the PKT_LEN and TOKEN1 counting. Call `sdio_slave_reset` to do that.

`esp_err_t sdio_slave_reset` (void)

Clear the data still in the driver, as well as reset the PKT_LEN and TOKEN1 counting.

Returns always return ESP_OK.
Chapter 2. API Reference

### sdio_slave_buf_handle_t sdio_slave_recv_register_buf (uint8_t* start)
Register buffer used for receiving. All buffers should be registered before used, and then can be used (again) in the driver by the handle returned.

**Note:** The driver will use and only use the amount of space specified in the `recv_buffer_size` member set in the `sdio_slave_config_t`. All buffers should be larger than that. The buffer is used by the DMA, so it should be DMA capable and 32-bit aligned.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>start</td>
<td>The start address of the buffer.</td>
</tr>
<tr>
<td>Returns</td>
<td>The buffer handle if success, otherwise NULL.</td>
</tr>
</tbody>
</table>

### esp_err_t sdio_slave_recv_unregister_buf (sdio_slave_buf_handle_t handle)
Unregister buffer from driver, and free the space used by the descriptor pointing to the buffer.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>handle</td>
<td>Handle to the buffer to release.</td>
</tr>
<tr>
<td>Returns</td>
<td>ESP_OK if success, ESP_ERR_INVALID_ARG if the handle is NULL or the buffer is being used.</td>
</tr>
</tbody>
</table>

### esp_err_t sdio_slave_recv_load_buf (sdio_slave_buf_handle_t handle)
Load buffer to the queue waiting to receive data. The driver takes ownership of the buffer until the buffer is returned by `sdio_slave_send_get_finished` after the transaction is finished.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>handle</td>
<td>Handle to the buffer ready to receive data.</td>
</tr>
<tr>
<td>Returns</td>
<td>* ESP_ERR_INVALID_ARG if invalid handle or the buffer is already in the queue. Only after the buffer is returned by <code>sdio_slave_recv</code> can you load it again. * ESP_OK if success</td>
</tr>
</tbody>
</table>

### esp_err_t sdio_slave_recv_packet (sdio_slave_buf_handle_t *handle_ret, TickType_t wait)
Get buffer of received data if exist with packet information. The driver returns the ownership of the buffer to the app.

When you see return value is ESP_ERR_NOT_FINISHED, you should call this API iteratively until the return value is ESP_OK. All the continuous buffers returned with ESP_ERR_NOT_FINISHED, together with the last buffer returned with ESP_OK, belong to one packet from the host.

You can call simpler `sdio_slave_recv` instead, if the host never send data longer than the Receiving buffer size, or you don’t care about the packet boundary (e.g. the data is only a byte stream).

**Note:** Call `sdio_slave_load_buf` with the handle to re-load the buffer onto the link list, and receive with the same buffer again. The address and length of the buffer got here is the same as got from `sdio_slave_get_buffer`.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>handle_ret</td>
<td>Handle of the buffer holding received data. Use this handle in <code>sdio_slave_recv_load_buf()</code> to receive in the same buffer again.</td>
</tr>
<tr>
<td>wait</td>
<td>Time to wait before data received.</td>
</tr>
<tr>
<td>Returns</td>
<td>* ESP_ERR_INVALID_ARG if handle_ret is NULL * ESP_ERR_TIMEOUT if timeout before receiving new data * ESP_ERR_NOT_FINISHED if returned buffer is not the end of a packet from the host, should call this API again until the end of a packet * ESP_OK if success</td>
</tr>
</tbody>
</table>

### esp_err_t sdio_slave_recv (sdio_slave_buf_handle_t *handle_ret, uint8_t **out_addr, size_t *out_len, TickType_t wait)

---

Espressif Systems 1315 Release v5.1.2

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Get received data if exist. The driver returns the ownership of the buffer to the app.

Note: Call `sdio_slave_load_buf` with the handle to re-load the buffer onto the link list, and receive with the same buffer again. The address and length of the buffer got here is the same as got from `sdio_slave_get_buffer`.

### Parameters
- **handle_ret** – Handle to the buffer holding received data. Use this handle in `sdio_slave_recv_load_buf` to receive in the same buffer again.
- **out_addr** [out] Output of the start address, set to NULL if not needed.
- **out_len** [out] Actual length of the data in the buffer, set to NULL if not needed.
- **wait** – Time to wait before data received.

### Returns
- ESP_ERR_INVALID_ARG if handle_ret is NULL
- ESP_ERR_TIMEOUT if timeout before receiving new data
- ESP_OK if success

```c
uint8_t* sdio_slave_recv_get_buf (sdio_slave_buf_handle_t handle, size_t* len_o)
```

Retrieve the buffer corresponding to a handle.

### Parameters
- **handle** – Handle to get the buffer.
- **len_o** – Output of buffer length

### Returns
buffer address if success, otherwise NULL.

```c
esp_err_t sdio_slave_send_queue (uint8_t* addr, size_t len, void* arg, TickType_t wait)
```

Put a new sending transfer into the send queue. The driver takes ownership of the buffer until the buffer is returned by `sdio_slave_send_get_finished` after the transaction is finished.

### Parameters
- **addr** – Address for data to be sent. The buffer should be DMA capable and 32-bit aligned.
- **len** – Length of the data, should not be longer than 4092 bytes (may support longer in the future).
- **arg** – Argument to returned in `sdio_slave_send_get_finished`. The argument can be used to indicate which transaction is done, or as a parameter for a callback. Set to NULL if not needed.
- **wait** – Time to wait if the buffer is full.

### Returns
- ESP_ERR_INVALID_ARG if the length is not greater than 0.
- ESP_ERR_TIMEOUT if the queue is still full until timeout.
- ESP_OK if success.

```c
esp_err_t sdio_slave_send_get_finished (void** out_arg, TickType_t wait)
```

Return the ownership of a finished transaction.

### Parameters
- **out_arg** – Argument of the finished transaction. Set to NULL if unused.
- **wait** – Time to wait if there’s no finished sending transaction.

### Returns
ESP_ERR_TIMEOUT if no transaction finished, or ESP_OK if succeed.

```c
esp_err_t sdio_slave_transmit (uint8_t* addr, size_t len)
```

Start a new sending transfer, and wait for it (blocked) to be finished.

### Parameters
- **addr** – Start address of the buffer to send
- **len** – Length of buffer to send.

### Returns
- ESP_ERR_INVALID_ARG if the length of descriptor is not greater than 0.
• ESP_ERR_TIMEOUT if the queue is full or host do not start a transfer before timeout.
• ESP_OK if success.

```c
uint8_t sdio_slave_read_reg (int pos)
Read the spi slave register shared with host.
```

**Note:** register 28 to 31 are reserved for interrupt vector.

**Parameters**
- `pos` - register address, 0-27 or 32-63.

**Returns**
- value of the register.

```c
esp_err_t sdio_slave_write_reg (int pos, uint8_t reg)
Write the spi slave register shared with host.
```

**Note:** register 29 and 31 are used for interrupt vector.

**Parameters**
- `pos` - register address, 0-11, 14-15, 18-19, 24-27 and 32-63, other address are reserved.
- `reg` - the value to write.

**Returns**
- ESP_ERR_INVALID_ARG if address wrong, otherwise ESP_OK.

```c
sdio_slave_hostint_t sdio_slave_get_host_intena (void)
Get the interrupt enable for host.
```

**Returns**
- the interrupt mask.

```c
void sdio_slave_set_host_intena (sdio_slave_hostint_t mask)
Set the interrupt enable for host.
```

**Parameters**
- `mask` - Enable mask for host interrupt.

```c
esp_err_t sdio_slave_send_host_int (uint8_t pos)
Interrupt the host by general purpose interrupt.
```

**Parameters**
- `pos` - Interrupt num, 0-7.

**Returns**
- ESP_ERR_INVALID_ARG if interrupt num error
- ESP_OK otherwise

```c
void sdio_slave_clear_host_int (sdio_slave_hostint_t mask)
Clear general purpose interrupt to host.
```

**Parameters**
- `mask` - Interrupt bits to clear, by bit mask.

```c
esp_err_t sdio_slave_wait_int (int pos, TickType_t wait)
Wait for general purpose interrupt from host.
```

**Note:** this clears the interrupt at the same time.

**Parameters**
- `pos` - Interrupt source number to wait for, is set.
- `wait` - Time to wait before interrupt triggered.

**Returns**
- ESP_OK if success, ESP_ERR_TIMEOUT if timeout.
Chapter 2. API Reference

Structures

struct **sdio_slave_config_t**

Configuration of SDIO slave.

Public Members

**sdio_slave_timing_t** *timing*

Timing of sdio_slave. See `sdio_slave_timing_t`.

**sdio_slave_sending_mode_t** *sending_mode*

Mode of sdio_slave. `SDIO_SLAVE_MODE_STREAM` if the data needs to be sent as much as possible; `SDIO_SLAVE_MODE_PACKET` if the data should be sent in packets.

**int** *send_queue_size*

Max buffers that can be queued before sending.

**size_t** *recv_buffer_size*

If buffer_size is too small, it costs more CPU time to handle larger number of buffers. If buffer_size is too large, the space larger than the transaction length is left blank but still counts a buffer, and the buffers are easily run out. Should be set according to length of data really transferred. All data that do not fully fill a buffer is still counted as one buffer. E.g. 10 bytes data costs 2 buffers if the size is 8 bytes per buffer. Buffer size of the slave pre-defined between host and slave before communication. All receive buffer given to the driver should be larger than this.

**sdio_event_cb_t** *event_cb*

When the host interrupts slave, this callback will be called with interrupt number (0-7).

**uint32_t** *flags*

Features to be enabled for the slave, combinations of `SDIO_SLAVE_FLAG_*`.

Macros

**SDIO_SLAVE_RECV_MAX_BUFFER**

**SDIO_SLAVE_FLAG_DAT2_DISABLED**

It is required by the SD specification that all 4 data lines should be used and pulled up even in 1-bit mode or SPI mode. However, as a feature, the user can specify this flag to make use of DAT2 pin in 1-bit mode. Note that the host cannot read CCCR registers to know we don’t support 4-bit mode anymore, please do this at your own risk.

**SDIO_SLAVE_FLAG_HOST_INTR_DISABLED**

The DAT1 line is used as the interrupt line in SDIO protocol. However, as a feature, the user can specify this flag to make use of DAT1 pin of the slave in 1-bit mode. Note that the host has to do polling to the interrupt registers to know whether there are interrupts from the slave. And it cannot read CCCR registers to know we don’t support 4-bit mode anymore, please do this at your own risk.

**SDIO_SLAVE_FLAG_INTERNAL_PULLUP**

Enable internal pullups for enabled pins. It is required by the SD specification that all the 4 data lines should be pulled up even in 1-bit mode or SPI mode. Note that the internal pull-ups are not sufficient for stable communication, please do connect external pull-ups on the bus. This is only for example and debug use.
**SDIO_SLAVE_FLAG_DEFAULT_SPEED**

Disable the highspeed support of the hardware.

**SDIO_SLAVE_FLAG_HIGH_SPEED**

Enable the highspeed support of the hardware. This is the default option. The host will see highspeed capability, but the mode actually used is determined by the host.

### Type Definitions

typedef void (*sdio_event_cb_t)(uint8_t event)

typedef void* sdio_slave_buf_handle_t

Handle of a receive buffer, register a handle by calling `sdio_slave_recv_register_buf`. Use the handle to load the buffer to the driver, or call `sdio_slave_recv_unregister_buf` if it is no longer used.

### 2.6.19 Sigma-Delta Modulation (SDM)

#### Introduction

ESP32 has a second-order sigma-delta modulator, which can generate independent PDM pulses to multiple channels. Please refer to the TRM to check how many hardware channels are available.\(^1\)

Delta-sigma modulation converts an analog voltage signal into a pulse frequency, or pulse density, which can be understood as pulse-density modulation (PDM) (refer to Delta-sigma modulation on Wikipedia). The main differences comparing to the PDM in I2S peripheral and DAC are:

1. SDM has no clock signal, it just like the DAC mode of PDM;
2. SDM has no DMA, and it can’t change its output density continuously. If you have to, you can update the density in a timer’s callback;
3. Base on the former two points, an external active or passive filter is required to restore the analog wave (See Convert to analog signal (Optional));

Typically, a Sigma-Delta modulated channel can be used in scenarios like:

- LED dimming
- Simple DAC (8-bit), with the help of an active RC low-pass filter
- Class D amplifier, with the help of a half-bridge or full-bridge circuit plus an LC low-pass filter

#### Functional Overview

The following sections of this document cover the typical steps to install and operate a SDM channel:

- **Resource Allocation** - covers which parameters should be set up to get a channel handle and how to recycle the resources when it finishes working.
- **Enable and Disable Channel** - covers how to enable and disable the channel.
- **Set Equivalent Duty Cycle** - describes how to set the equivalent duty cycle of the PDM pulses.
- **Power Management** - describes how different source clock selections can affect power consumption.
- **IRAM Safe** - lists which functions are supposed to work even when the cache is disabled.
- **Thread Safety** - lists which APIs are guaranteed to be thread safe by the driver.
- **Kconfig Options** - lists the supported Kconfig options that can be used to make a different effect on driver behavior.

\(^1\) Different ESP chip series might have different numbers of SDM channels. Please refer to Chapter GPIO and IOMUX in ESP32 Technical Reference Manual for more details. The driver won’t forbid you from applying for more channels, but it will return error when all available hardware resources are used up. Please always check the return value when doing resource allocation (e.g. `sdm_new_channel()`).
Resource Allocation  A SDM channel is represented by \textit{sdm\_channel\_handle\_t}. Each channel is capable to output the binary, hardware generated signal with the sigma-delta modulation. The driver manages all available channels in a pool, so that users don’t need to manually assign a fixed channel to a GPIO.

To install a SDM channel, you should call \textit{sdm\_new\_channel()} to get a channel handle. Channel specific configurations are passed in the \textit{sdm\_config\_t} structure:

- \textit{sdm\_config\_t::gpio\_num} sets the GPIO that the PDM pulses will output from.
- \textit{sdm\_config\_t::clk\_src} selects the source clock for the SDM module. Note that, all channels should select the same clock source.
- \textit{sdm\_config\_t::sample\_rate\_hz} sets the sample rate of the SDM module.
- \textit{sdm\_config\_t::invert\_out} sets whether to invert the output signal.
- \textit{sdm\_config\_t::io\_loop\_back} is for debugging purposes only. It enables both the GPIO’s input and output ability through the GPIO matrix peripheral.

The function \textit{sdm\_new\_channel()} can fail due to various errors such as insufficient memory, invalid arguments, etc. Specifically, when there are no more free channels (i.e. all hardware SDM channels have been used up), then \textit{ESP\_ERR\_NOT\_FOUND} will be returned.

If a previously created SDM channel is no longer required, you should recycle it by calling \textit{sdm\_del\_channel()}. It allows the underlying HW channel to be used for other purposes. Before deleting a SDM channel handle, you should disable it by \textit{sdm\_channel\_disable()} in advance or make sure it has not enabled yet by \textit{sdm\_channel\_enable()}.

### Creating a SDM Channel with Sample Rate of 1MHz

```c
sdm\_channel\_handle\_t chan = NULL;
sdm\_config\_t config = {
  .clk\_src = SDM\_CLK\_SRC\_DEFAULT,
  .sample\_rate\_hz = 1 * 1000 * 1000,
  .gpio\_num = 0,
};
ESP\_ERROR\_CHECK(sdm\_new\_channel(&config, &chan));
```

Enable and Disable Channel  Before doing further IO control to the SDM channel, you should enable it first, by calling \textit{sdm\_channel\_enable()}. Internally, this function will:

- switch the channel state from \texttt{init} to \texttt{enable}
- acquire a proper power management lock is a specific clock source (e.g. APB clock) is selected. See also \textit{Power management} for more information.

On the contrary, calling \textit{sdm\_channel\_disable()} will do the opposite, that is, put the channel back to the \texttt{init} state and release the power management lock.

Set Pulse Density  For the output PDM signals, the pulse density decides the output analog voltage that restored by a low-pass filter. The restored analog voltage from the channel is calculated by

\[ \text{Vout} = \frac{\text{VDD\_IO}}{256} \times \text{duty} + \frac{\text{VDD\_IO}}{2}. \]

The range of the quantized density input parameter of \textit{sdm\_channel\_set\_pulse\_density()} is from -128 to 127 (eight-bit signed integer). For example, if a zero value is set, then the output signal’s duty will be around 50%.

Power Management  When power management is enabled (i.e. \textit{CONFIG\_PM\_ENABLE} is on), the system will adjust the APB frequency before going into light sleep, thus potentially changing the sample rate of the sigma-delta modulator.

However, the driver can prevent the system from changing APB frequency by acquiring a power management lock of type \textit{ESP\_PM\_APB\_FREQ\_MAX}. Whenever the driver creates a SDM channel instance that has selected \textit{SDM\_CLK\_SRC\_APB} as its clock source, the driver will guarantee that the power management lock is acquired when enable the channel by \textit{sdm\_channel\_enable()}. Likewise, the driver releases the lock when \textit{sdm\_channel\_disable()} is called for that channel.
IRAM Safe  There’s a Kconfig option `CONFIG_SDM_CTRL_FUNC_IN_IRAM` that can put commonly used IO control functions into IRAM as well. So that these functions can also be executable when the cache is disabled. These IO control functions are listed as follows:

- `sdm_channel_set_pulse_density()`

Thread Safety  The factory function `sdm_new_channel()` is guaranteed to be thread safe by the driver, which means, user can call it from different RTOS tasks without protection by extra locks. The following functions are allowed to run under ISR context, the driver uses a critical section to prevent them being called concurrently in both task and ISR.

- `sdm_channel_set_pulse_density()`

Other functions that take the `sdm_channel_handle_t` as the first positional parameter, are not treated as thread safe. Which means the user should avoid calling them from multiple tasks.

Kconfig Options

- `CONFIG_SDM_CTRL_FUNC_IN_IRAM` controls where to place the SDM channel control functions (IRAM or Flash), see `IRAM Safe` for more information.
- `CONFIG_SDM_ENABLE_DEBUG_LOG` is used to enabled the debug log output. Enable this option will increase the firmware binary size.

Convert to analog signal (Optional)

Typically, if the sigma-delta signal is connected to an LED, you don’t have to add any filter between them (because our eyes are a low pass filter naturally). However, if you want to check the real voltage or watch the analog waveform, you need to design an analog low pass filter. Also, it is recommended to use an active filter instead of a passive filter to gain better isolation and not lose too much voltage.

For example, you can take the following Sallen-Key topology Low Pass Filter as a reference.

![Sallen-Key Low Pass Filter](image)

Fig. 22: Sallen-Key Low Pass Filter
Chapter 2. API Reference

Application Example

- 100 Hz sine wave that is modulated with Sigma-Delta: peripherals/sigma_delta/sdm_dac.
- LED driven by a GPIO that is modulated with Sigma-Delta: peripherals/sigma_delta/sdm_led.

API Reference

Header File

- components/driver/sigma_delta/include/driver/sdm.h

Functions

**esp_err_t sdm_new_channel** (const sdm_config_t *config, sdm_channel_handle_t *ret_chan)

Create a new Sigma Delta channel.

Parameters

- config - [in] SDM configuration
- ret_chan - [out] Returned SDM channel handle

Returns

- ESP_OK: Create SDM channel successfully
- ESP_ERR_INVALID_ARG: Create SDM channel failed because of invalid argument
- ESP_ERR_NO_MEM: Create SDM channel failed because out of memory
- ESP_ERR_NOT_FOUND: Create SDM channel failed because all channels are used up and no more free one
- ESP_FAIL: Create SDM channel failed because of other error

**esp_err_t sdm_del_channel** (sdm_channel_handle_t chan)

Delete the Sigma Delta channel.

Parameters

- chan - [in] SDM channel created by sdm_new_channel

Returns

- ESP_OK: Delete the SDM channel successfully
- ESP_ERR_INVALID_ARG: Delete the SDM channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Delete the SDM channel failed because the channel is not in init state
- ESP_FAIL: Delete the SDM channel failed because of other error

**esp_err_t sdm_channel_enable** (sdm_channel_handle_t chan)

Enable the Sigma Delta channel.

Parameters

- chan - [in] SDM channel created by sdm_new_channel

Returns

- ESP_OK: Enable SDM channel successfully
- ESP_ERR_INVALID_ARG: Enable SDM channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Enable SDM channel failed because the channel is already enabled
- ESP_FAIL: Enable SDM channel failed because of other error

Note: This function will transit the channel state from init to enable.

Note: This function will acquire a PM lock, if a specific source clock (e.g. APB) is selected in the sdm_config_t, while CONFIG_PM_ENABLE is enabled.
**esp_err_t sdm_channel_disable** *(sdm_channel_handle_t chan)*

Disable the Sigma Delta channel.

**Note:** This function will do the opposite work to the `sdm_channel_enable()` function.

**Parameters**
- `chan` [in] SDM channel created by `sdm_new_channel`

**Returns**
- ESP_OK: Disable SDM channel successfully
- ESP_ERR_INVALID_ARG: Disable SDM channel failed because of invalid argument
- ESP_ERR_INVALID_STATE: Disable SDM channel failed because the channel is not enabled yet
- ESP_FAIL: Disable SDM channel failed because of other error

**esp_err_t sdm_channel_set_pulse_density** *(sdm_channel_handle_t chan, int8_t density)*

Set the pulse density of the PDM output signal.

**Note:**
- The raw output signal requires a low-pass filter to restore it into analog voltage, the restored analog output voltage could be \( V_{out} = V_{DD\_IO} / 256 \times \text{density} + V_{DD\_IO} / 2 \)

**Note:**
- This function is allowed to run within ISR context

**Note:**
- This function will be placed into IRAM if `CONFIG_SDM_CTRL_FUNC_IN_IRAM` is on, so that it’s allowed to be executed when Cache is disabled

**Parameters**
- `chan` [in] SDM channel created by `sdm_new_channel`
- `density` [in] Quantized pulse density of the PDM output signal, ranges from -128 to 127. But the range of [-90, 90] can provide a better randomness.

**Returns**
- ESP_OK: Set pulse density successfully
- ESP_ERR_INVALID_ARG: Set pulse density failed because of invalid argument
- ESP_FAIL: Set pulse density failed because of other error

**esp_err_t sdm_channel_set_duty** *(sdm_channel_handle_t chan, int8_t duty)*

The alias function of `sdm_channel_set_pulse_density`, it decides the pulse density of the output signal.

**Note:** `sdm_channel_set_pulse_density` has a more appropriate name compared to this alias function, suggest to turn to `sdm_channel_set_pulse_density` instead

**Parameters**
- `chan` [in] SDM channel created by `sdm_new_channel`
- `duty` [in] Actually it’s the quantized pulse density of the PDM output signal

**Returns**
- ESP_OK: Set duty cycle successfully
- ESP_ERR_INVALID_ARG: Set duty cycle failed because of invalid argument
- ESP_FAIL: Set duty cycle failed because of other error
Chapter 2. API Reference

Structures

struct sdm_config_t
    Sigma Delta channel configuration.

Public Members

int gpio_num
    GPIO number

sdm_clock_source_t clk_src
    Clock source

uint32_t sample_rate_hz
    Over sample rate in Hz, it determines the frequency of the carrier pulses

uint32_t invert_out
    Whether to invert the output signal

uint32_t io_loop_back
    For debug/test, the signal output from the GPIO will be fed to the input path as well

struct sdm_config_t::[anonymous] flags
    Extra flags

Type Definitions

typedef struct sdm_channel_t *sdm_channel_handle_t
    Type of Sigma Delta channel handle.

Header File

- components/hal/include/hal/sdm_types.h

Type Definitions

typedef soc_periph_sdm_clk_src_t sdm_clock_source_t

2.6.20 SPI Flash API

Overview

The spi_flash component contains API functions related to reading, writing, erasing, memory mapping for data in the external flash.

For higher-level API functions which work with partitions defined in the partition table, see Partitions API

Note: esp_partition_* APIs are recommended to be used instead of the lower level esp_flash_* API functions when accessing the main SPI Flash chip, since they do bounds checking and are guaranteed to calculate
correct offsets in flash based on the information in the partition table. `esp_flash_*` functions can still be used directly when accessing an external (secondary) SPI flash chip.

Different from the API before ESP-IDF v4.0, the functionality of `esp_flash_*` APIs is not limited to the “main” SPI flash chip (the same SPI flash chip from which program runs). With different chip pointers, you can access external flash chips connected to not only SPI0/1 but also other SPI buses like SPI2.

**Note:** Instead of going through the cache connected to the SPI0 peripheral, most `esp_flash_*` APIs go through other SPI peripherals like SPI1, SPI2, etc. This makes them able to access not only the main flash, but also external (secondary) flash.

However, due to limitations of the cache, operations through the cache are limited to the main flash. The address range limitation for these operations are also on the cache side. The cache is not able to access external flash chips or address range above its capabilities. These cache operations include: `mmap`, encrypted read/write, executing code or access to variables in the flash.

**Note:** Flash APIs after ESP-IDF v4.0 are no longer **atomic**. If a write operation occurs during another on-going read operation, and the flash addresses of both operations overlap, the data returned from the read operation may contain both old data and new data (that was updated written by the write operation).

**Note:** Encrypted flash operations are only supported with the main flash chip (and not with other flash chips, that is on SPI1 with different CS, or on other SPI buses). Reading through cache is only supported on the main flash, which is determined by the HW.

### Support for Features of Flash Chips

**Quad/Dual Mode Chips** Features of different flashes are implemented in different ways and thus need special support. The fast/slow read and Dual mode (DOUT/DIO) of almost all flashes with 24-bit address are supported, because they don’t need any vendor-specific commands.

Quad mode (QIO/QOUT) is supported on following chip types:

1. ISSI
2. GD
3. MXIC
4. FM
5. Winbond
6. XMC
7. BOYA

**Note:** Only when one flash series listed above is supported by ESP32, this flash series is supported by the chip driver by default. You can use `Component config > SPI Flash driver > Auto-detect flash chips` in `menuconfig` to enable/disable a flash series.

### Optional Features

**Optional features for flash** Some features are not supported on all ESP chips and Flash chips. You can check the list below for more information.

- `Auto Suspend & Resume`
- `Flash unique ID`
Chapter 2. API Reference

- **High performance mode**
- **OPI flash support**
- **32-bit Address Flash Chips**

**Note:**
- The features listed above needs to be supported by both esp chips and flash chips.
- If you are using an official Espressif modules/SiP. Some of the modules/SiPs always support the feature, in this case you can see these features listed in the datasheet. Otherwise please contact Espressif’s business team to know if we can supply such products for you.
- If you are making your own modules with your own bought flash chips, and you need features listed above. Please contact your vendor if they support the those features, and make sure that the chips can be supplied continuously.

**Attention:** This document only shows that IDF code has supported the features of those flash chips. It’s not a list of stable flash chips certified by Espressif. If you build your own hardware from flash chips with your own bought flash chips (even with flash listed in this page), you need to validate the reliability of flash chips yourself.

**Auto Suspend & Resume**

ESP Chips List:
- ESP32C3

Flash Chips List:
- XM25QxxC series.

**Flash unique ID**

Unique ID is not flash id, which means flash has 64-Bit unique ID for each device. The instruction to read the unique ID (4Bh) accesses a factory-set read-only 64-bit number that is unique to each flash device. This ID number helps you to recognize each single device. Not all flash vendors support this feature. If you try to read the unique ID on a chip which does not have this feature, the behavior is not determined. The support list is as follows.

ESP Chips Lists:
- ALL

Flash Chips List:
- ISSI
- GD
- TH
- FM
- Winbond
- XMC
- BOYA

**High performance mode**

**Note:** This section is provided for Dual mode (DOUT/DIO) and Quad mode (QIO/QOUT) flash chips. Octal flash used on ESP-chips support High performance mode by default so far, you can refer to the octal flash support list below.

High performance mode (HPM) means that the SPI1 and flash chip works under high frequency. Usually, when the operating frequency of the flash is greater than 80MHz, it is considered that the flash works under HPM. As far as we acknowledged, flash chips have more than two different coping strategies when flash work under HPM. For some flash chips, HPM is controlled by high performance flag (HPF) in status register and for some flash chips, HPM is controlled by dummy cycle bit.

For following conditions, IDF start code deals with HPM internally.
Chapter 2. API Reference

ESP Chips List:
1. ESP32S3

Flash Chips (name & ID) List:
1. GD25Q64C (ID: 0xC84017)
2. GD25Q32C (ID: 0xC84016)

**Attention:** It is hard to create several strategies to cover all situations, so all flash chips using HPM need to be supported explicitly. Therefore, if you try to use a flash not listed as supported under high performance mode, it might cause some error. So, when you try to use the flash chip beyond supported list, please test properly.

**OPI flash support**  OPI flash means that the flash chip supports octal peripheral interface, which has octal I/O pins. Different octal flash has different configurations and different commands. Hence, it is necessary to carefully check the support list.

ESP Chips List:
1. ESP32S3

Flash Chips List:
1. MX25UM25645G

**32-bit Address Flash Chips**  Most NOR flash chips used by Espressif chips use 24-bits address, which can cover 16 MBytes memory. However, for larger memory (usually equal to or larger than 16 MBytes), flash uses a 32-bits address to address larger memory. Regrettfully, 32-bits address chips have vendor-specific commands, so we need to support the chips one by one.

ESP Chips List:
ALL ESP Chips support this.

Flash Chips List:
1. W25Q256
2. GD25Q256

There are some features that are not supported by all flash chips, or not supported by all Espressif chips. These features include:

- 32-bit address flash - usually means that the flash has higher capacity (equal to or larger than 16 MB) that needs longer addresses.
- Flash unique ID - means that flash supports its unique 64-bit ID.

If you want to use these features, please ensure both ESP32 and ALL flash chips in your product support these features. For more details, refer to Optional features for flash.

You may also customise your own flash chip driver. See Overriding Default Chip Drivers for more details.

**Warning:** Customizing SPI Flash Chip Drivers is considered an “expert” feature. Users should only do so at their own risk. (See the notes below)

**Overriding Default Chip Drivers**  During the SPI Flash driver’s initialization (i.e., `esp_flash_init()`), there is a chip detection step during which the driver will iterate through a Default Chip Driver List and determine which chip driver can properly support the currently connected flash chip. The Default Chip Drivers are provided by the IDF, thus are updated in together with each IDF version. However IDF also allows users to customize their own chip drivers.
Users should note the following when customizing chip drivers:

1. You may need to rely on some non-public IDF functions, which have slight possibility to change between IDF versions. On the one hand, these changes may be useful bug fixes for your driver, on the other hand, they may also be breaking changes (i.e., breaks your code).
2. Some IDF bug fixes to other chip drivers will not be automatically applied to your own custom chip drivers.
3. If the protection of flash is not handled properly, there may be some random reliability issues.
4. If you update to a newer IDF version that has support for more chips, you will have to manually add those new chip drivers into your custom chip driver list. Otherwise the driver will only search for the drivers in custom list you provided.

Steps For Creating Custom Chip Drivers and Overriding the IDF Default Driver List

1. Enable the `CONFIG_SPI_FLASH_OVERRIDE_CHIP_DRIVER_LIST` config option. This will prevent compilation and linking of the Default Chip Driver List (default_registered_chips) provided by IDF. Instead, the linker will search for the structure of the same name (default_registered_chips) that must be provided by the user.
2. Add a new component in your project, e.g. `custom_chip_driver`.
3. Copy the necessary chip driver files from the `spi_flash` component in IDF. This may include:
   - `spiFlash_chip_drivers.c` (to provide the default_registered_chips structure)
   - Any of the `spiFlash_chip_*.c` files that matches your own flash model best
   - `CMakeLists.txt` and `linker.lf` files

Modify the files above properly. Including:
   - Change the default_registered_chips variable to non-static and remove the #ifdef logic around it.
   - Update `linker.lf` file to rename the fragment header and the library name to match the new component.
   - If reusing other drivers, some header names need prefixing with `spi_flash/` when included from outside `spi_flash` component.

Note:

- When writing your own flash chip driver, you can set your flash chip capabilities through `spiFlash_chip_***(vendor)_get_caps` and points the function pointer `get_chip_caps` for protection to the `spiFlash_chip_***_get_caps` function. The steps are as follows.
  1. Please check whether your flash chip have the capabilities listed in `spiFlash_caps_t` by checking the flash datasheet.
  2. Write a function named `spiFlash_chip_***(vendor)_get_caps`. Take the example below as a reference. (if the flash support suspend and read unique id).
  3. Points the pointer `get_chip_caps` (in `spiFlash_chip_t`) to the function mentioned above.

```c
spiFlash_caps_t spiFlash_chip_*** (vendor)_get_caps (espFlash_t *chip)
{
    spiFlash_caps_t caps_flags = 0;
    // 32-bit-address flash is not supported
    flash_suspend is supported
    caps_flags |= SPI_FLASH_CHIP_CAP_SUSPEND;
    // flash read unique id.
    caps_flags |= SPI_FLASH_CHIP_CAP_UNIQUE_ID;
    return caps_flags;
}
```

```
const spiFlash_chip_t espFlash_chip_eon = {
    // Other function pointers
    .get_chip_caps = spiFlash_chip_eon_get_caps,
};
```

- You also can see how to implement this in the example `storage/custom_flash_driver`.

4. Write a new `CMakeLists.txt` file for the `custom_chip_driver` component, including an additional line to add a linker dependency from `spi_flash` to `custom_chip_driver`: 

---

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Release v5.1.2
idf_component_register(SRCS "spi_flash_chip_drivers.c"
    "spi_flash_chip_mychip.c"  # modify as needed
    REQUIRES hal
    PRIV_REQUIRES spi_flash
    LDFRAGMENTS linker.lf)

• An example of this component CMakeLists.txt can be found in storage/custom_flash_driver/components/custom_chip_driver/CMakeLists.txt

5. The linker.lf is used to put every chip driver that you are going to use whilst cache is disabled into internal RAM. See *Linker Script Generation* for more details. Make sure this file covers all the source files that you add.
6. Build your project, and you will see the new flash driver is used.

**Example**  See also storage/custom_flash_driver.

### Initializing a Flash Device

To use the *esp_flash_* APIs, you need to initialise a flash chip on a certain SPI bus, as shown below:

1. Call `spi_bus_initialize()` to properly initialize an SPI bus. This function initializes the resources (I/O, DMA, interrupts) shared among devices attached to this bus.
2. Call `spi_bus_add_flash_device()` to attach the flash device to the bus. This function allocates memory and fills the members for the `esp_flash_t` structure. The CS I/O is also initialized here.
3. Call `esp_flash_init()` to actually communicate with the chip. This will also detect the chip type, and influence the following operations.

---

**Note:** Multiple flash chips can be attached to the same bus now.

### SPI Flash Access API

This is the set of API functions for working with data in flash:

- `esp_flash_read()` reads data from flash to RAM
- `esp_flash_write()` writes data from RAM to flash
- `esp_flash_erase_region()` erases specific region of flash
- `esp_flash_erase_chip()` erases the whole flash
- `esp_flash_get_chip_size()` returns flash chip size, in bytes, as configured in menuconfig

Generally, try to avoid using the raw SPI flash functions to the “main” SPI flash chip in favour of *partition-specific functions*.

### SPI Flash Size

The SPI flash size is configured by writing a field in the software bootloader image header, flashed at offset 0x1000. By default, the SPI flash size is detected by esptool.py when this bootloader is written to flash, and the header is updated with the correct size. Alternatively, it is possible to generate a fixed flash size by setting `CONFIG_ESPTOOLPY_FLASHSIZE` in the project configuration.

If it is necessary to override the configured flash size at runtime, it is possible to set the `chip_size` member of the `g_rom_flashchip` structure. This size is used by `esp_flash_*` functions (in both software & ROM) to check the bounds.
Chapter 2. API Reference

Concurrency Constraints for Flash on SPI1

**Concurrency Constraints for Flash on SPI1** The SPI0/1 bus is shared between the instruction & data cache (for firmware execution) and the SPI1 peripheral (controlled by the drivers including this SPI Flash driver). Hence, operations to SPI1 will cause significant influence to the whole system. This kind of operations include calling SPI Flash API or other drivers on SPI1 bus, any operations like read/write/erase or other user defined SPI operations, regardless to the main flash or other SPI slave devices.

On ESP32, these caches must be disabled while reading/writing/erasing.

**When the Caches Are Disabled** Under this condition, all CPUs should always execute code and access data from internal RAM. The APIs documented in this file will disable the caches automatically and transparently.

The way that these APIs disable the caches will suspend all the other tasks. Besides, all non-IRAM-safe interrupts will be disabled. The other core will be polling in a busy loop. These will be restored until the Flash operation completes.

See also OS Functions and SPI Bus Lock.

There are no such constraints and impacts for flash chips on other SPI buses than SPI0/1.

For differences between internal RAM (e.g. IRAM, DRAM) and flash cache, please refer to the application memory layout documentation.

**IRAM-Safe Interrupt Handlers** For interrupt handlers which need to execute when the cache is disabled (e.g., for low latency operations), set the ESP_INTR_FLAG_IRAM flag when the interrupt handler is registered.

You must ensure that all data and functions accessed by these interrupt handlers, including the ones that handlers call, are located in IRAM or DRAM. See How to Place Code in IRAM.

If a function or symbol is not correctly put into IRAM/DRAM, and the interrupt handler reads from the flash cache during a flash operation, it will cause a crash due to Illegal Instruction exception (for code which should be in IRAM) or garbage data to be read (for constant data which should be in DRAM).

**Note:** When working with strings in ISRs, it is not advised to use printf and other output functions. For debugging purposes, use ESP_DRAM_LOGE() and similar macros when logging from ISRs. Make sure that both TAG and format string are placed into DRAM in that case.

**Non-IRAM-Safe Interrupt Handlers** If the ESP_INTR_FLAG_IRAM flag is not set when registering, the interrupt handler will not get executed when the caches are disabled. Once the caches are restored, the non-IRAM-safe interrupts will be re-enabled. After this moment, the interrupt handler will run normally again. This means that as long as caches are disabled, users won’t see the corresponding hardware event happening.

**Attention:** The SPI0/1 bus is shared between the instruction & data cache (for firmware execution) and the SPI1 peripheral (controlled by the drivers including this SPI flash driver). Hence, calling SPI Flash API on SPI1 bus (including the main flash) will cause significant influence to the whole system. See Concurrency Constraints for Flash on SPI1 for more details.

**SPI Flash Encryption**

It is possible to encrypt the contents of SPI flash and have it transparently decrypted by hardware.

Refer to the Flash Encryption documentation for more details.
Chapter 2. API Reference

Memory Mapping API

ESP32 features memory hardware which allows regions of flash memory to be mapped into instruction and data address spaces. This mapping works only for read operations. It is not possible to modify contents of flash memory by writing to a mapped memory region.

Mapping happens in 64 KB pages. Memory mapping hardware can map flash into the data address space and the instruction address space. See the technical reference manual for more details and limitations about memory mapping hardware.

Note that some pages are used to map the application itself into memory, so the actual number of available pages may be less than the capability of the hardware.

Reading data from flash using a memory mapped region is the only way to decrypt contents of flash when flash encryption is enabled. Decryption is performed at the hardware level.

Memory mapping API are declared in spi_flash_mmap.h and esp_partition.h:

- `spi_flash_mmap()` maps a region of physical flash addresses into instruction space or data space of the CPU.
- `spi_flash_munmap()` unmaps previously mapped region.
- `esp_partition_mmap()` maps part of a partition into the instruction space or data space of the CPU.

Differences between `spi_flash_mmap()` and `esp_partition_mmap()` are as follows:

- `spi_flash_mmap()` must be given a 64 KB aligned physical address.
- `esp_partition_mmap()` may be given any arbitrary offset within the partition. It will adjust the returned pointer to mapped memory as necessary.

Note that since memory mapping happens in pages, it may be possible to read data outside of the partition provided to `esp_partition_mmap`, regardless of the partition boundary.

Note: mmap is supported by cache, so it can only be used on main flash.

SPI Flash Implementation

The `esp_flash_t` structure holds chip data as well as three important parts of this API:

1. The host driver, which provides the hardware support to access the chip;
2. The chip driver, which provides compatibility service to different chips;
3. The OS functions, provide support of some OS functions (e.g. lock, delay) in different stages (1st/2nd boot, or the app).

**Host Driver** The host driver relies on an interface (`spi_flash_host_driver_t`) defined in the `spi_flash_types.h` (in the `hal/include/hal` folder). This interface provides some common functions to communicate with the chip.

In other files of the SPI HAL, some of these functions are implemented with existing ESP32 memory-spi functionalities. However, due to the speed limitations of ESP32, the HAL layer cannot provide high-speed implementations to some reading commands (so the support for it was dropped). The files (memspi_host_driver.h and .c) implement the high-speed version of these commands with the `common_command` function provided in the HAL, and wrap these functions as `spiFlashHostDriver_t` for upper layer to use.

You can also implement your own host driver, even with the GPIO. As long as all the functions in the `spiFlashHostDriver_t` are implemented, the `esp_flash` API can access the flash regardless of the low-level hardware.
Chip Driver  The chip driver, defined in `spi_flash_chip_driver.h`, wraps basic functions provided by the host driver for the API layer to use.

Some operations need some commands to be sent first, or read some status afterwards. Some chips need different commands or values, or need special communication ways.

There is a type of chip called generic chip which stands for common chips. Other special chip drivers can be developed on the base of the generic chip.

The chip driver relies on the host driver.

OS Functions  Currently the OS function layer provides entries of a lock and delay.

The lock (see SPI Bus Lock) is used to resolve the conflicts among the access of devices on the same SPI bus, and the SPI Flash chip access. E.g.

1. On SPI1 bus, the cache (used to fetch the data (code) in the Flash and PSRAM) should be disabled when the flash chip on the SPI0/1 is being accessed.
2. On the other buses, the flash driver needs to disable the ISR registered by SPI Master driver, to avoid conflicts.
3. Some devices of SPI Master driver may require to use the bus monopolized during a period (especially when the device doesn’t have a CS wire, or the wire is controlled by software like SDSPi driver).

The delay is used by some long operations which requires the master to wait or polling periodically.

The top API wraps these the chip driver and OS functions into an entire component, and also provides some argument checking.

OS functions can also help to avoid a watchdog timeout when erasing large flash areas. During this time, the CPU is occupied with the flash erasing task. This stops other tasks from being executed. Among these tasks is the idle task to feed the watchdog timer (WDT). If the configuration option `CONFIG_ESP_TASK_WDT_PANIC` is selected and the flash operation time is longer than the watchdog timeout period, the system will reboot.

It’s pretty hard to totally eliminate this risk, because the erasing time varies with different flash chips, making it hard to be compatible in flash drivers. Therefore, users need to pay attention to it. Please use the following guidelines:

1. It is recommended to enable the `CONFIG_SPI_FLASH_YIELD_DURING_ERASE` option to allow the scheduler to re-schedule during erasing flash memory. Besides, following parameters can also be used.
   - Increase `CONFIG_SPI_FLASH_ERASE_YIELD_TICKS` or decrease `CONFIG_SPI_FLASH_ERASE_YIELD_DURATION_MS` in menuconfig.
   - You can also increase `CONFIG_ESP_TASK_WDT_TIMEOUT_S` in menuconfig for a larger watchdog timeout period. However, with larger watchdog timeout period, previously detected timeouts may no longer be detected.
2. Please be aware of the consequences of enabling the `CONFIG_ESP_TASK_WDT_PANIC` option when doing long-running SPI flash operations which will trigger the panic handler when it times out. However, this option can also help dealing with unexpected exceptions in your application. Please decide whether this is needed to be enabled according to actual condition.
3. During your development, please carefully review the actual flash operation according to the specific requirements and time limits on erasing flash memory of your projects. Always allow reasonable redundancy based on your specific product requirements when configuring the flash erasing timeout threshold, thus improving the reliability of your product.

Implementation Details

In order to perform some flash operations, it is necessary to make sure that both CPUs are not running any code from flash for the duration of the flash operation: - In a single-core setup, the SDK needs to disable interrupts or scheduler before performing the flash operation. - In a dual-core setup, the SDK needs to make sure that both CPUs are not running any code from flash.

When SPI flash API is called on CPU A (can be PRO or APP), start the `spi_flash_op_block_func` function on CPU B using the `esp_ipc_call` API. This API wakes up a high priority task on CPU B and tells it to execute a given function, in this case, `spi_flash_op_block_func`. This function disables cache on CPU B and signals
that the cache is disabled by setting the `s_flash_op_can_start` flag. Then the task on CPU A disables cache as well and proceeds to execute flash operation.

While a flash operation is running, interrupts can still run on CPUs A and B. It is assumed that all interrupt code is placed into RAM. Once the interrupt allocation API is added, a flag should be added to request the interrupt to be disabled for the duration of a flash operations.

Once the flash operation is complete, the function on CPU A sets another flag, `s_flash_op_complete`, to let the task on CPU B know that it can re-enable cache and release the CPU. Then the function on CPU A re-enables the cache on CPU A as well and returns control to the calling code.

Additionally, all API functions are protected with a mutex (s_flash_op_mutex).

In a single core environment (`CONFIG_FREERTOS_UNICORE` enabled), you need to disable both caches, so that no inter-CPU communication can take place.

**SPI Flash API ESP-IDF version vs Chip-ROM version** There is a set of SPI Flash drivers in Chip-ROM which you can use by enabling `CONFIG_SPI_FLASH_ROM_IMPL`. Most of the ESP-IDF SPI Flash driver code are in internal RAM, therefore enabling this option will free some internal RAM usage. Note if you enable this option, this means some SPI Flash driver features and bugfixes that are done in ESP-IDF might not be included in the Chip-ROM version.

**Feature Supported by ESP-IDF but not in Chip-ROM**
- Octal Flash chip support. See [OPI flash support] for details.
- 32-bit-address support for GD25Q256. See [32-bit Address Flash Chips] for details.
- TH Flash chip support.
- Kconfig option `CONFIG_SPI_FLASH_CHECK_ERASE_TIMEOUT_DISABLED`.
- `CONFIG_SPI_FLASH_VERIFY_WRITE`, enabling this option helps you detect bad writing.
- `CONFIG_SPI_FLASH_LOG_FAILED_WRITE`, enabling this option will print the bad writing.
- `CONFIG_SPI_FLASH_WARN_SETTING_ZERO_TO_ONE`, enabling this option will check if you’re writing zero to one.
- `CONFIG_SPI_FLASH_DANGEROUS_WRITE`, enabling this option will check for flash programming to certain protected regions like bootloader, partition table or application itself.
- `CONFIG_SPI_FLASH_ENABLE_COUNTERS`, enabling this option to collect performance data for ESP-IDF SPI Flash driver APIs.

**Bugfixes Introduced in ESP-IDF but not in Chip-ROM**
- Detected Flash physical size correctly, for larger than 256MBit Flash chips. (Commit ID: b4964279d44f73c7c5c67f8456f7bd6f6d9e)

**API Reference - SPI Flash**

**Header File**
- `components/spi_flash/include/esp_flash_spi_init.h`

**Functions**

```c
esp_err_t spi_bus_add_flash_device(esp_flash_t **out_chip, const esp_flash_spi_device_config_t *config)
```

Add a SPI Flash device onto the SPI bus.

The bus should be already initialized by `spi_bus_initialization`.

**Parameters**
- `out_chip` - Pointer to hold the initialized chip.
- `config` - Configuration of the chips to initialize.

**Returns**
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG: out_chip is NULL, or some field in the config is invalid.
- ESP_ERR_NO_MEM: failed to allocate memory for the chip structures.
- ESP_OK: success.

```c
esp_err_t spi_bus_remove_flash_device(esp_flash_t *chip)
```

Remove a SPI Flash device from the SPI bus.

**Parameters**

- `chip` - The flash device to remove.

**Returns**

- ESP_ERR_INVALID_ARG: The chip is invalid.
- ESP_OK: success.

**Structures**

```c
struct esp_flash_spi_device_config_t
```

Configurations for the SPI Flash to init.

**Public Members**

```c
spi_host_device_t host_id
```

Bus to use.

```c
int cs_io_num
```

GPIO pin to output the CS signal.

```c
esp_flash_io_mode_t io_mode
```

IO mode to read from the Flash.

```c
enum esp_flash_speed_s speed
```

Speed of the Flash clock. Replaced by freq_mhz.

```c
int input_delay_ns
```

Input delay of the data pins, in ns. Set to 0 if unknown.

```c
int cs_id
```

CS line ID, ignored when not host_id is not SPI1_HOST, or CONFIG_SPI_FLASH_SHARE_SPI1_BUS is enabled. In this case, the CS line used is automatically assigned by the SPI bus lock.

```c
int freq_mhz
```

The frequency of flash chip(MHZ)

**Header File**

- components/spi_flash/include/esp_flash.h

**Functions**

```c
esp_err_t esp_flash_init(esp_flash_t *chip)
```

Initialise SPI flash chip interface.

This function must be called before any other API functions are called for this chip.
Chapter 2. API Reference

**Note:** Only the `host` and `read_mode` fields of the chip structure must be initialised before this function is called. Other fields may be auto-detected if left set to zero or NULL.

**Note:** If the chip->drv pointer is NULL, chip chip_drv will be auto-detected based on its manufacturer & product IDs. See `esp_flash_registered_flash_drivers` pointer for details of this process.

```
Parameters chip – Pointer to SPI flash chip to use. If NULL, esp_flash_default_chip is substituted.

Returns ESP_OK on success, or a flash error code if initialisation fails.
```

`bool esp_flash_chip_driver_initialized(const esp_flash_t *chip)`

Check if appropriate chip driver is set.

```
Parameters chip – Pointer to SPI flash chip to use. If NULL, esp_flash_default_chip is substituted.

Returns true if set, otherwise false.
```

```
esp_err_t esp_flash_read_id(esp_flash_t *chip, uint32_t*out_id)
```

Read flash ID via the common “RDID” SPI flash command.

ID is a 24-bit value. Lower 16 bits of ‘id’ are the chip ID, upper 8 bits are the manufacturer ID.

```
Parameters
  • chip – Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
  • out_id – [out] Pointer to receive ID value.

Returns ESP_OK on success, or a flash error code if operation failed.
```

```
esp_err_t esp_flash_get_size(esp_flash_t *chip, uint32_t*out_size)
```

Detect flash size based on flash ID.

**Note:** 1. Most flash chips use a common format for flash ID, where the lower 4 bits specify the size as a power of 2. If the manufacturer doesn’t follow this convention, the size may be incorrectly detected.

a. The out_size returned only stands for The out_size stands for the size in the binary image header. If you want to get the real size of the chip, please call `esp_flash_get_physical_size` instead.

```
Parameters
  • chip – Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
  • out_size – [out] Detected size in bytes, standing for the size in the binary image header.

Returns ESP_OK on success, or a flash error code if operation failed.
```

```
esp_err_t esp_flash_get_physical_size(esp_flash_t *chip, uint32_t*flash_size)
```

Detect flash size based on flash ID.

**Note:** Most flash chips use a common format for flash ID, where the lower 4 bits specify the size as a power of 2. If the manufacturer doesn’t follow this convention, the size may be incorrectly detected.

```
Parameters
  • chip – Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
  • flash_size – [out] Detected size in bytes.
```
Returns ESP_OK on success, or a flash error code if operation failed.

```c
esp_err_t esp_flash_read_unique_chip_id(esp_flash_t *chip, uint64_t *out_id)
```
Read flash unique ID via the common “RDUID” SPI flash command.

ID is a 64-bit value.

**Parameters**
- `chip` — Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init().
- `out_id` — [out] Pointer to receive unique ID value.

**Returns**
- ESP_OK on success, or a flash error code if operation failed.
- ESP_ERR_NOT_SUPPORTED if the chip doesn’t support read id.

```c
esp_err_t esp_flash_erase_chip(esp_flash_t *chip)
```
Erase flash chip contents.

**Parameters**
- `chip` — Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init().

**Returns**
- ESP_OK on success,
- ESP_ERR_NOT_SUPPORTED if the chip is not able to perform the operation. This is indicated by WREN = 1 after the command is sent.
- Other flash error code if operation failed.

```c
esp_err_t esp_flash_erase_region(esp_flash_t *chip, uint32_t start, uint32_t len)
```
Erase a region of the flash chip.

Sector size is specified in chip->drv->sector_size field (typically 4096 bytes.) ESP_ERR_INVALID_ARG will be returned if the start & length are not a multiple of this size.

Erase is performed using block (multi-sector) erases where possible (block size is specified in chip->drv->block_erase_size field, typically 65536 bytes). Remaining sectors are erased using individual sector erase commands.

**Parameters**
- `chip` — Pointer to identify flash chip. If NULL, esp_flash_default_chip is substituted. Must have been successfully initialised via esp_flash_init().
- `start` — Address to start erasing flash. Must be sector aligned.
- `len` — Length of region to erase. Must also be sector aligned.

**Returns**
- ESP_OK on success,
- ESP_ERR_NOT_SUPPORTED if the chip is not able to perform the operation. This is indicated by WREN = 1 after the command is sent.
- Other flash error code if operation failed.

```c
esp_err_t esp_flash_get_chip_write_protect(esp_flash_t *chip, bool *write_protected)
```
Read if the entire chip is write protected.

**Note:** A correct result for this flag depends on the SPI flash chip model and chip_driv in use (via the ‘chip->drv’ field).

**Parameters**
- `chip` — Pointer to identify flash chip. If NULL, esp_flash_default_chip is substituted. Must have been successfully initialised via esp_flash_init().
- `write_protected` — [out] Pointer to boolean, set to the value of the write protect flag.
Returns ESP_OK on success, or a flash error code if operation failed.

```c
esp_err_t esp_flash_set_chip_write_protect (esp_flash_t *chip, bool write_protect)
```

Set write protection for the SPI flash chip.

Some SPI flash chips may require a power cycle before write protect status can be cleared. Otherwise, write protection can be removed via a follow-up call to this function.

**Note:** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the `chip->drv` field).

**Parameters**
- `chip` - Pointer to identify flash chip. If NULL, esp_flash_default_chip is substituted. Must have been successfully initialised via esp_flash_init()
- `write_protect` - Boolean value for the write protect flag

**Returns** ESP_OK on success, or a flash error code if operation failed.

```c
esp_err_t esp_flash_get_protectable_regions (const esp_flash_t *chip, const esp_flash_region_t **out_regions, uint32_t *out_num_regions)
```

Read the list of individually protectable regions of this SPI flash chip.

**Note:** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the `chip->drv` field).

**Parameters**
- `chip` - Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
- `out_regions` - [out] Pointer to receive a pointer to the array of protectable regions of the chip.
- `out_num_regions` - [out] Pointer to an integer receiving the count of protectable regions in the array returned in `out_regions`.

**Returns** ESP_OK on success, or a flash error code if operation failed.

```c
esp_err_t esp_flash_get_protected_region (esp_flash_t *chip, const esp_flash_region_t *region, bool *out_protected)
```

Detect if a region of the SPI flash chip is protected.

**Note:** It is possible for this result to be false and write operations to still fail, if protection is enabled for the entire chip.

**Note:** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the `chip->drv` field).

**Parameters**
- `chip` - Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
- `region` - Pointer to a struct describing a protected region. This must match one of the regions returned from esp_flash_get_protectable_regions(...).
- `out_protected` - [out] Pointer to a flag which is set based on the protected status for this region.
**Returns** ESP_OK on success, or a flash error code if operation failed.

`esp_err_t esp_flash_set_protected_region(esp_flash_t *chip, const esp_flash_region_t *region, bool protect)`

Update the protected status for a region of the SPI flash chip.

**Note:** It is possible for the region protection flag to be cleared and write operations to still fail, if protection is enabled for the entire chip.

**Note:** Correct behaviour of this function depends on the SPI flash chip model and chip_drv in use (via the ‘chip->drv’ field).

**Parameters**
- `chip` – Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
- `region` – Pointer to a struct describing a protected region. This must match one of the regions returned from esp_flash_get_protectable_regions(…).
- `protect` – Write protection flag to set.

**Returns** ESP_OK on success, or a flash error code if operation failed.

`esp_err_t esp_flash_read(esp_flash_t *chip, void *buffer, uint32_t address, uint32_t length)`

Read data from the SPI flash chip.

There are no alignment constraints on buffer, address or length.

**Note:** If on-chip flash encryption is used, this function returns raw (ie encrypted) data. Use the flash cache to transparently decrypt data.

**Parameters**
- `chip` – Pointer to identify flash chip. If NULL, esp_flash_default_chip is substituted. Must have been successfully initialised via esp_flash_init()
- `buffer` – Pointer to a buffer where the data will be read. To get better performance, this should be in the DRAM and word aligned.
- `address` – Address on flash to read from. Must be less than chip->size field.
- `length` – Length (in bytes) of data to read.

**Returns**
- ESP_OK: success
- ESP_ERR_NO_MEM: Buffer is in external PSRAM which cannot be concurrently accessed, and a temporary internal buffer could not be allocated.
- or a flash error code if operation failed.

`esp_err_t esp_flash_write(esp_flash_t *chip, const void *buffer, uint32_t address, uint32_t length)`

Write data to the SPI flash chip.

There are no alignment constraints on buffer, address or length.

**Parameters**
- `chip` – Pointer to identify flash chip. If NULL, esp_flash_default_chip is substituted. Must have been successfully initialised via esp_flash_init()
- `address` – Address on flash to write to. Must be previously erased (SPI NOR flash can only write bits 1->0).
• **buffer** - Pointer to a buffer with the data to write. To get better performance, this should be in the DRAM and word aligned.
• **length** - Length (in bytes) of data to write.

**Returns**
- ESP_OK on success,
- ESP_FAIL, bad write, this will be detected only when CONFIG_SPI_FLASH_VERIFY_WRITE is enabled
- ESP_ERR_NOT_SUPPORTED if the chip is not able to perform the operation. This is indicated by WREN = 1 after the command is sent.
- Other flash error code if operation failed.

```c
esp_err_t esp_flash_write_encrypted(esp_flash_t *chip, uint32_t address, const void *buffer, uint32_t length)
```

Encrypted and write data to the SPI flash chip using on-chip hardware flash encryption.

**Note:** Both address & length must be 16 byte aligned, as this is the encryption block size

**Parameters**
- **chip** - Pointer to identify flash chip. Must be NULL (the main flash chip). For other chips, encrypted write is not supported.
- **address** - Address on flash to write to. 16 byte aligned. Must be previously erased (SPI NOR flash can only write bits 1->0).
- **buffer** - Pointer to a buffer with the data to write.
- **length** - Length (in bytes) of data to write. 16 byte aligned.

**Returns**
- ESP_OK: on success
- ESP_FAIL: bad write, this will be detected only when CONFIG_SPI_FLASH_VERIFY_WRITE is enabled
- ESP_ERR_NOT_SUPPORTED: encrypted write not supported for this chip.
- ESP_ERR_INVALID_ARG: Either the address, buffer or length is invalid.

```c
esp_err_t esp_flash_read_encrypted(esp_flash_t *chip, uint32_t address, void *out_buffer, uint32_t length)
```

Read and decrypt data from the SPI flash chip using on-chip hardware flash encryption.

**Parameters**
- **chip** - Pointer to identify flash chip. Must be NULL (the main flash chip). For other chips, encrypted read is not supported.
- **address** - Address on flash to read from.
- **out_buffer** - Pointer to a buffer for the data to read to.
- **length** - Length (in bytes) of data to read.

**Returns**
- ESP_OK: on success
- ESP_ERR_NOT_SUPPORTED: encrypted read not supported for this chip.

```c
static inline bool esp_flash_is_quad_mode(const esp_flash_t *chip)
```

Returns true if chip is configured for Quad I/O or Quad Fast Read.

**Parameters**
- **chip** - Pointer to SPI flash chip to use. If NULL, esp_flash_default_chip is substituted.

**Returns**
- true if flash works in quad mode, otherwise false

**Structures**

```c
struct esp_flash_region_t
```

Structure for describing a region of flash.
Public Members

uint32_t **offset**
Start address of this region.

uint32_t **size**
Size of the region.

struct **esp_flash_os_functions_t**
OS-level integration hooks for accessing flash chips inside a running OS.

It’s in the public header because some instances should be allocated statically in the startup code. May be updated according to hardware version and new flash chip feature requirements, shouldn’t be treated as public API.

For advanced developers, you may replace some of them with your implementations at your own risk.

Public Members

*esp_err_t (* start)(void *arg)*
Called before commencing any flash operation. Does not need to be recursive (ie is called at most once for each call to ‘end’).

*esp_err_t (* end)(void *arg)*
Called after completing any flash operation.

*esp_err_t (* region_protected)(void *arg, size_t start_addr, size_t size)*
Called before any erase/write operations to check whether the region is limited by the OS.

*esp_err_t (* delay_us)(void *arg, uint32_t us)*
Delay for at least ‘us’ microseconds. Called in between ‘start’ and ‘end’.

void *(get_temp_buffer)(void *arg, size_t request_size, size_t *out_size)*
Called for get temp buffer when buffer from application cannot be directly read into/write from.

void *(release_temp_buffer)(void *arg, void *temp_buf)*
Called for release temp buffer.

*esp_err_t (* check_yield)(void *arg, uint32_t chip_status, uint32_t[out_request]*
Yield to other tasks. Called during erase operations.

    Return ESP_OK means yield needs to be called (got an event to handle), while
    ESP_ERR_TIMEOUT means skip yield.

*esp_err_t (* yield)(void *arg, uint32_t *out_status)*
Yield to other tasks. Called during erase operations.

int64_t (* get_system_time)(void *arg)*
Called for get system time.
void (*set_flash_op_status)(uint32_t op_status)
    Call to set flash operation status

struct esp_flash_t
    Structure to describe a SPI flash chip connected to the system.
    Structure must be initialized before use (passed to esp_flash_init()). Its in the public header because some instances should be allocated statically in the startup code. May be updated according to hardware version and new flash chip feature requirements, shouldn’t be treated as public API.
    For advanced developers, you may replace some of them with your implementations at your own risk.

**Public Members**

*spi_flash_host_inst_t* `host`
    Pointer to hardware-specific “host_driver” structure. Must be initialized before used.

*const spi_flash_chip_t* `chip_drv`
    Pointer to chip-model-specific “adapter” structure. If NULL, will be detected during initialisation.

*const esp_flash_os_functions_t* `os_func`
    Pointer to os-specific hook structure. Call `esp_flash_init_os_functions()` to setup this field, after the host is properly initialized.

void *`os_func_data`
    Pointer to argument for os-specific hooks. Left NULL and will be initialized with `os_func`.

*esp_flash_io_mode_t* `read_mode`
    Configured SPI flash read mode. Set before `esp_flash_init` is called.

uint32_t `size`
    Size of SPI flash in bytes. If 0, size will be detected during initialisation. Note: this stands for the size in the binary image header. If you want to get the flash physical size, please call `esp_flash_get_physical_size`.

uint32_t `chip_id`
    Detected chip id.

uint32_t `busy`
    This flag is used to verify chip’s status.

uint32_t `hpm_dummy_ena`
    This flag is used to verify whether flash works under HPM status.

uint32_t `reserved_flags`
    reserved.

**Macros**

SPI_FLASH_YIELD_REQ_YIELD
SPI_FLASH_YIELD_REQ_SUSPEND

SPI_FLASH_YIELD_STA_RESUME

SPI_FLASH_OS_IS_ERASING_STATUS_FLAG

Type Definitions
typedef struct spi_flash_chip_t spi_flash_chip_t

Header File
- components/spi_flash/include/spi_flash_mmap.h

Functions

esp_err_t spi_flash_mmap(size_t src_addr, size_t size, spi_flash_mmap_memory_t memory, const void **out_ptr, spi_flash_mmap_handle_t *out_handle)

Map region of flash memory into data or instruction address space.

This function allocates sufficient number of 64kB MMU pages and configures them to map the requested region of flash memory into the address space. It may reuse MMU pages which already provide the required mapping.

As with any allocator, if mmap/munmap are heavily used then the address space may become fragmented. To troubleshoot issues with page allocation, use spi_flash_mmap_dump() function.

Parameters
- src_addr – Physical address in flash where requested region starts. This address must be aligned to 64kB boundary (SPI_FLASH_MMU_PAGE_SIZE)
- size – Size of region to be mapped. This size will be rounded up to a 64kB boundary
- memory – Address space where the region should be mapped (data or instruction)
- out_ptr – [out] Output, pointer to the mapped memory region
- out_handle – [out] Output, handle which should be used for spi_flash_munmap call

Returns
- ESP_OK on success
- ESP_ERR_NO_MEM if pages cannot be allocated

esp_err_t spi_flash_mmap_pages(const int *pages, size_t page_count, spi_flash_mmap_memory_t memory, const void **out_ptr, spi_flash_mmap_handle_t *out_handle)

Map sequences of pages of flash memory into data or instruction address space.

This function allocates sufficient number of 64kB MMU pages and configures them to map the indicated pages of flash memory contiguously into address space. In this respect, it works in a similar way as spi_flash_mmap() but it allows mapping a (maybe non-contiguous) set of pages into a contiguous region of memory.

Parameters
- pages – An array of numbers indicating the 64kB pages in flash to be mapped contiguously into memory. These indicate the indexes of the 64kB pages, not the byte-size addresses as used in other functions. Array must be located in internal memory.
- page_count – Number of entries in the pages array
- memory – Address space where the region should be mapped (instruction or data)
- out_ptr – [out] Output, pointer to the mapped memory region
- out_handle – [out] Output, handle which should be used for spi_flash_munmap call

Returns
- ESP_OK on success
- ESP_ERR_NO_MEM if pages can not be allocated
- ESP_ERR_INVALID_ARG if pagecount is zero or pages array is not in internal memory
void `spi_flash_munmap` (`spi_flash_mmap_handle_t` handle)
Release region previously obtained using `spi_flash_mmap`.

**Note:** Calling this function will not necessarily unmmap memory region. Region will only be unmapped when there are no other handles which reference this region. In case of partially overlapping regions it is possible that memory will be unmapped partially.

**Parameters handle** – Handle obtained from `spi_flash_mmap`

void `spi_flash_mmap_dump` (void)
Display information about mapped regions.
This function lists handles obtained using `spi_flash_mmap`, along with range of pages allocated to each handle. It also lists all non-zero entries of MMU table and corresponding reference counts.

`uint32_t` `spi_flash_mmap_get_free_pages` (`spi_flash_mmap_memory_t` memory)
get free pages number which can be mmap
This function will return number of free pages available in mmu table. This could be useful before calling actual `spi_flash_mmap` (maps flash range to DCache or ICache memory) to check if there is sufficient space available for mapping.

**Parameters memory** – memory type of MMU table free page
**Returns** number of free pages which can be mmaped

`size_t` `spi_flash_cache2phys` (const void *cached)
Given a memory address where flash is mapped, return the corresponding physical flash offset.
Cache address does not have have been assigned via `spi_flash_mmap()`, any address in memory mapped flash space can be looked up.

**Parameters cached** – Pointer to flashed cached memory.
**Returns**
- SPI_FLASH_CACHE2PHYS_FAIL If cache address is outside flash cache region, or the address is not mapped.
- Otherwise, returns physical offset in flash

const void *`spi_flash_phys2cache` (size_t phys_offs, `spi_flash_mmap_memory_t` memory)
Given a physical offset in flash, return the address where it is mapped in the memory space.
Physical address does not have to have been assigned via `spi_flash_mmap()`, any address in flash can be looked up.

**Note:** Only the first matching cache address is returned. If MMU flash cache table is configured so multiple entries point to the same physical address, there may be more than one cache address corresponding to that physical address. It is also possible for a single physical address to be mapped to both the IROM and DROM regions.

**Note:** This function doesn’t impose any alignment constraints, but if memory argument is SPI_FLASH_MMAP_INST and phys_offs is not 4-byte aligned, then reading from the returned pointer will result in a crash.

**Parameters**
- **phys_offs** – Physical offset in flash memory to look up.
- **memory** – Address space type to look up a flash cache address mapping for (instruction or data)
**Returns**
• NULL if the physical address is invalid or not mapped to flash cache of the specified memory type.
• Cached memory address (in IROM or DROM space) corresponding to phys_offs.

Macros

ESP_ERR_FLASH_OP_FAIL
This file contains spi_flash_mmap_xx APIs, mainly for doing memory mapping to an SPI0-connected external Flash, as well as some helper functions to convert between virtual and physical address

ESP_ERR_FLASH_OP_TIMEOUT

SPI_FLASH_SEC_SIZE
SPI Flash sector size

SPI_FLASH_MMU_PAGE_SIZE
Flash cache MMU mapping page size

SPI_FLASH_CACHE2PHYS_FAIL

Type Definitions
typedef uint32_t spi_flash_mmap_handle_t
Opaque handle for memory region obtained from spi_flash_mmap.

Enumerations
enum spi_flash_mmap_memory_t
Enumeration which specifies memory space requested in an mmap call.
Values:

enumerator SPI_FLASH_MMAP_DATA
map to data memory, allows byte-aligned access

enumerator SPI_FLASH_MMAP_INST
map to instruction memory, allows only 4-byte-aligned access

Header File
• components/hal/include/hal/spi_flash_types.h

Structures
struct spi_flash_trans_t
Definition of a common transaction. Also holds the return value.

Public Members

uint8_t reserved
Reserved, must be 0.
Chapter 2. API Reference

uint8_t mosi_len
   Output data length, in bytes.

uint8_t miso_len
   Input data length, in bytes.

uint8_t address_bitlen
   Length of address in bits, set to 0 if command does not need an address.

uint32_t address
   Address to perform operation on.

const uint8_t *mosi_data
   Output data to salve.

uint8_t *miso_data
   [out] Input data from slave, little endian

uint32_t flags
   Flags for this transaction. Set to 0 for now.

uint16_t command
   Command to send.

uint8_t dummy_bitlen
   Basic dummy bits to use.

uint32_t io_mode
   Flash working mode when SPI_FLASH_IGNORE_BASEIO is specified.

struct spi_flash_sus_cmd_conf
   Configuration structure for the flash chip suspend feature.

Public Members

uint32_t sus_mask
   SUS/SUS1/SUS2 bit in flash register.

uint32_t cmd_rdsr
   Read flash status register(2) command.

uint32_t sus_cmd
   Flash suspend command.

uint32_t res_cmd
   Flash resume command.

uint32_t reserved
   Reserved, set to 0.
struct spi_flash_encryption_t
Structure for flash encryption operations.

Public Members

void (*flash_encryption_enable)(void)
Enable the flash encryption.

void (*flash_encryption_disable)(void)
Disable the flash encryption.

void (*flash_encryption_data_prepare)(uint32_t address, const uint32_t* buffer, uint32_t size)
Prepare flash encryption before operation.

Note: address and buffer must be 8-word aligned.

Param address  The destination address in flash for the write operation.
Param buffer  Data for programming
Param size  Size to program.

void (*flash_encryption_done)(void)
flash data encryption operation is done.

void (*flash_encryption_destroy)(void)
Destroy encrypted result

bool (*flash_encryption_check)(uint32_t address, uint32_t length)
Check if is qualified to encrypt the buffer

Param address  the address of written flash partition.
Param length  Buffer size.

struct spi_flash_host_inst_t
SPI Flash Host driver instance

Public Members

const struct spi_flash_host_driver_s *driver
Pointer to the implementation function table.

struct spi_flash_host_driver_s
Host driver configuration and context structure.

Public Members


**esp_err_t (**\*dev_config\**) (spi_flash_host_inst_t *host)**
Configure the device-related register before transactions. This saves some time to re-configure those registers when we send continuously

**esp_err_t (**\*common_command\**) (spi_flash_host_inst_t *host, spi_flash_trans_t *t)**
Send an user-defined spi transaction to the device.

**esp_err_t (**\*read_id\**) (spi_flash_host_inst_t *host, uint32_t *id)**
Read flash ID.

**void (**\*erase_chip\**) (spi_flash_host_inst_t *host)**
Erase whole flash chip.

**void (**\*erase_sector\**) (spi_flash_host_inst_t *host, uint32_t start_address)**
Erase a specific sector by its start address.

**void (**\*erase_block\**) (spi_flash_host_inst_t *host, uint32_t start_address)**
Erase a specific block by its start address.

**esp_err_t (**\*read_status\**) (spi_flash_host_inst_t *host, uint8_t *out_sr)**
Read the status of the flash chip.

**esp_err_t (**\*set_write_protect\**) (spi_flash_host_inst_t *host, bool wp)**
Disable write protection.

**void (**\*program_page\**) (spi_flash_host_inst_t *host, const void *buffer, uint32_t address, uint32_t length)**
Program a page of the flash. Check max_write_bytes for the maximum allowed writing length.

**bool (**\*supports_direct_write\**) (spi_flash_host_inst_t *host, const void *p)**
Check whether the SPI host supports direct write.
When cache is disabled, SPI1 doesn’t support directly write when buffer isn’t internal.

**int (**\*write_data_slicer\**) (spi_flash_host_inst_t *host, uint32_t address, uint32_t len, uint32_t *align_addr, uint32_t page_size)**
Slicer for write data. The program_page should be called iteratively with the return value of this function.

- **Param address**  Beginning flash address to write
- **Param len**  Length request to write
- **Param align_addr**  Output of the aligned address to write to
- **Param page_size**  Physical page size of the flash chip
- **Return**  Length that can be actually written in one program_page call

**esp_err_t (**\*read\**) (spi_flash_host_inst_t *host, void *buffer, uint32_t address, uint32_t read_len)**
Read data from the flash. Check max_read_bytes for the maximum allowed reading length.

**bool (**\*supports_direct_read\**) (spi_flash_host_inst_t *host, const void *p)**
Check whether the SPI host supports direct read.
When cache is disabled, SPI1 doesn’t support directly read when the given buffer isn’t internal.
Chapter 2. API Reference

```c
int (*read_data_slicer)(spi_flash_host_inst_t *host, uint32_t address, uint32_t len, uint32_t *align_addr, uint32_t page_size)

Slicer for read data. The read should be called iteratively with the return value of this function.

- **Param address** Beginning flash address to read
- **Param len** Length request to read
- **Param align_addr** Output of the aligned address to read
- **Param page_size** Physical page size of the flash chip

Return Length that can be actually read in one read call
```

```c
uint32_t (*host_status)(spi_flash_host_inst_t *host)

Check the host status, 0: busy, 1: idle, 2: suspended.
```

```c
esp_err_t (*configure_host_io_mode)(spi_flash_host_inst_t *host, uint32_t command, uint32_t addr_bitlen, int dummy_bitlen_base, esp_flash_io_mode_t io_mode)

Configure the host to work at different read mode. Responsible to compensate the timing and set IO mode.
```

```c
void (*poll_cmd_done)(spi.flash_host_inst_t *host)

Internal use, poll the HW until the last operation is done.
```

```c
esp_err_t (*flush_cache)(spi.flash_host_inst_t *host, uint32_t addr, uint32_t size)

For some host (SPI1), they are shared with a cache. When the data is modified, the cache needs to be flushed. Left NULL if not supported.
```

```c
void (*check_suspend)(spi.flash_host_inst_t *host)

Suspend check erase/program operation, reserved for ESP32-C3 and ESP32-S3 spi flash ROM IMPL.
```

```c
void (*resume)(spi.flash_host_inst_t *host)

Resume flash from suspend manually
```

```c
void (*suspend)(spi.flash_host_inst_t *host)

Set flash in suspend status manually
```

```c
esp_err_t (*sus_setup)(spi.flash_host_inst_t *host, const spi_flash_sus_cmd_conf *sus_conf)

Suspend feature setup for setting cmd and status register mask.
```

### Macros

**SPI_FLASH_TRANS_FLAG_CMD16**

Send command of 16 bits.

**SPI_FLASH_TRANS_FLAG_IGNORE_BASEIO**

Not applying the basic io mode configuration for this transaction.

**SPI_FLASH_TRANS_FLAG_BYTE_SWAP**

Used for DTR mode, to swap the bytes of a pair of rising/falling edge.

**SPI_FLASH_CONFIG_CONF_BITS**

OR the io_mode with this mask, to enable the dummy output feature or replace the first several dummy bits into address to meet the requirements of conf bits. (Used in DIO/QIO/OIO mode)
**SPI_FLASH_OPI_FLAG**

A flag for flash work in opi mode, the io mode below are opi, above are SPI/QSPI mode. DO NOT use this value in any API.

**SPI_FLASH_READ_MODE_MIN**

Slowest io mode supported by ESP32, currently SlowRd.

**Type Definitions**

typedef enum esp_flash_speed_s esp_flash_speed_t

SPI flash clock speed values, always refer to them by the enum rather than the actual value (more speed may be appended into the list).

A strategy to select the maximum allowed speed is to enumerate from the ESP_FLASH_SPEED_MAX-1 or highest frequency supported by your flash, and decrease the speed until the probing success.

typedef struct spi_flash_host_driver_s spi_flash_host_driver_t

**Enumerations**

enum esp_flash_speed_s

SPI flash clock speed values, always refer to them by the enum rather than the actual value (more speed may be appended into the list).

A strategy to select the maximum allowed speed is to enumerate from the ESP_FLASH_SPEED_MAX-1 or highest frequency supported by your flash, and decrease the speed until the probing success.

Values:

enumerator ESP_FLASH_5MHZ

The flash runs under 5MHz.

enumerator ESP_FLASH_10MHZ

The flash runs under 10MHz.

enumerator ESP_FLASH_20MHZ

The flash runs under 20MHz.

enumerator ESP_FLASH_26MHZ

The flash runs under 26MHz.

enumerator ESP_FLASH_40MHZ

The flash runs under 40MHz.

enumerator ESP_FLASH_80MHZ

The flash runs under 80MHz.

enumerator ESP_FLASH_120MHZ

The flash runs under 120MHz, 120MHZ can only be used by main flash after timing tuning in system. Do not use this directly in any API.

enumerator ESP_FLASH_SPEED_MAX

The maximum frequency supported by the host is ESP_FLASH_SPEED_MAX-1.
enum esp_flash_io_mode_t

Mode used for reading from SPI flash.

Values:

enumerator SPI_FLASH_SLOWRD
    Data read using single I/O, some limits on speed.

enumerator SPI_FLASH_FASTRD
    Data read using single I/O, no limit on speed.

enumerator SPI_FLASH_DOUT
    Data read using dual I/O.

enumerator SPI_FLASH_DIO
    Both address & data transferred using dual I/O.

enumerator SPI_FLASH_QOUT
    Data read using quad I/O.

enumerator SPI_FLASH_QIO
    Both address & data transferred using quad I/O.

enumerator SPI_FLASH_OPI_STR
    Only support on OPI flash, flash read and write under STR mode.

enumerator SPI_FLASH_OPI_DTR
    Only support on OPI flash, flash read and write under DTR mode.

enumerator SPI_FLASH_READ_MODE_MAX
    The fastest io mode supported by the host is ESP_FLASH_READ_MODE_MAX-1.

Header File

- components/hal/include/hal/esp_flash_err.h

Macros

ESP_ERR_FLASH_NOTInicialised
    esp_flash_chip_t structure not correctly initialised by esp_flash_init().

ESP_ERR_FLASH_UNSUPPORTED_HOST
    Requested operation isn’t supported via this host SPI bus (chip->spi field).

ESP_ERR_FLASH_UNSUPPORTED_CHIP
    Requested operation isn’t supported by this model of SPI flash chip.

ESP_ERR_FLASH_PROTECTED
    Write operation failed due to chip’s write protection being enabled.
Enumerations

enum [anonymous]

Values:

enumerator ESP_ERR_FLASH_SIZE_NOT_MATCH
    The chip doesn’t have enough space for the current partition table.

enumerator ESP_ERR_FLASH_NO_RESPONSE
    Chip did not respond to the command, or timed out.

API Reference - Flash Encrypt

Header File

- components/bootloader_support/include/esp_flash_encrypt.h

Functions

- bool esp_flash_encryption_enabled (void)
  Is flash encryption currently enabled in hardware?
  Flash encryption is enabled if the FLASH_CRYPT_CNT efuse has an odd number of bits set.
  Returns true if flash encryption is enabled.

- esp_err_t esp_flash_encrypt_check_and_update (void)

- bool esp_flash_encrypt_state (void)
  Returns the Flash Encryption state and prints it.
  Returns True - Flash Encryption is enabled False - Flash Encryption is not enabled

- bool esp_flash_encrypt_initialized_once (void)
  Checks if the first initialization was done.
  If the first initialization was done then FLASH_CRYPT_CNT != 0
  Returns true - the first initialization was done false - the first initialization was NOT done

- esp_err_t esp_flash_encrypt_init (void)
  The first initialization of Flash Encryption key and related eFuses.
  Returns ESP_OK if all operations succeeded

- esp_err_t esp_flash_encrypt_contents (void)
  Encrypts flash content.
  Returns ESP_OK if all operations succeeded

- esp_err_t esp_flash_encrypt_enable (void)
  Activates Flash encryption on the chip.
  It burns FLASH_CRYPT_CNT eFuse based on the CONFIG_SECURE_FLASH_ENCRYPTION_MODE_RELEASE option.
  Returns ESP_OK if all operations succeeded

- bool esp_flash_encrypt_is_write_protected (bool print_error)
  Returns True if the write protection of FLASH_CRYPT_CNT is set.
  Parameters print_error - Print error if it is write protected
  Returns true - if FLASH_CRYPT_CNT is write protected
**esp_err_t esp_flash_encrypt_region (uint32_t src_addr, size_t data_length)**

Encrypt-in-place a block of flash sectors.

**Note:** This function resets RTC_WDT between operations with sectors.

**Parameters**
- **src_addr** - Source offset in flash. Should be multiple of 4096 bytes.
- **data_length** - Length of data to encrypt in bytes. Will be rounded up to next multiple of 4096 bytes.

**Returns**
ESP_OK if all operations succeeded, ESP_ERR_FLASH_OP_FAIL if SPI flash fails, ESP_ERR_FLASH_OP_TIMEOUT if flash times out.

**void esp_flash_write_protect_crypt_cnt (void)**

Write protect FLASH_CRYPT_CNT. Intended to be called as a part of boot process if flash encryption is enabled but secure boot is not used. This should protect against serial re-flash of an unauthorised code in absence of secure boot.

**Note:** On ESP32 V3 only, write protecting FLASH_CRYPT_CNT will also prevent disabling UART Download Mode. If both are wanted, call esp_efuse_disable_rom_download_mode() before calling this function.

**esp_flash_enc_mode_t esp_get_flash_encryption_mode (void)**

Return the flash encryption mode.

The API is called during boot process but can also be called by application to check the current flash encryption mode of ESP32

**Returns**

**void esp_flash_encryption_init_checks (void)**

Check the flash encryption mode during startup.

Verifies the flash encryption config during startup:

- Correct any insecure flash encryption settings if hardware Secure Boot is enabled.
- Log warnings if the efuse config doesn’t match the project config in any way

**Note:** This function is called automatically during app startup, it doesn’t need to be called from the app.

**esp_err_t esp_flash_encryption_enable_secure_features (void)**

Set all secure eFuse features related to flash encryption.

**Returns**
- ESP_OK - Successfully

**bool esp_flash_encryption_cfg_verify_release_mode (void)**

Returns the verification status for all physical security features of flash encryption in release mode.

If the device has flash encryption feature configured in the release mode, then it is highly recommended to call this API in the application startup code. This API verifies the sanity of the eFuse configuration against the release (production) mode of the flash encryption feature.

**Returns**
- True - all eFuses are configured correctly
- False - not all eFuses are configured correctly.
void esp_flash_encryption_set_release_mode (void)

Switches Flash Encryption from “Development” to “Release”.

If already in “Release” mode, the function will do nothing. If flash encryption efuse is not enabled yet then abort. It burns:

• ” disable encrypt in dl mode”
• set FLASH_CRYPT_CNT efuse to max

Enumerations

enum esp_flash_enc_mode_t

Values:

enumerator ESP_FLASH_ENC_MODE_DISABLED
enumerator ESP_FLASH_ENC_MODE_DEVELOPMENT
enumerator ESP_FLASH_ENC_MODE_RELEASE

2.6.21 SPI Master Driver

SPI Master driver is a program that controls ESP32’s SPI peripherals while they function as masters.

Overview of ESP32’s SPI peripherals

ESP32 integrates 3 SPI peripherals.

• SPI0 and SPI1 are used internally to access the ESP32’s attached flash memory. Both controllers share the same SPI bus signals, and there is an arbiter to determine which can access the bus. There are quite a few limitations when using SPI Master driver on the SPI1 bus, see Notes on Using the SPI Master driver on SPI1 Bus.

• SPI2 and SPI3 are general purpose SPI controllers, sometimes referred to as HSPI and VSPI, respectively. They are open to users. SPI2 and SPI3 have independent bus signals with the same respective names. Each bus has three CS lines to drive up to same number of SPI slaves.

Terminology

The terms used in relation to the SPI master driver are given in the table below.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host</td>
<td>The SPI controller peripheral inside ESP32 that initiates SPI transmissions over the bus, and acts as an SPI Master.</td>
</tr>
<tr>
<td>Device</td>
<td>SPI slave device. An SPI bus may be connected to one or more Devices. Each Device shares the MOSI, MISO and SCLK signals but is only active on the bus when the Host asserts the Device’s individual CS line.</td>
</tr>
<tr>
<td>Bus</td>
<td>A signal bus, common to all Devices connected to one Host. In general, a bus includes the following lines: MOSI, MOSI, SCLK, one or more CS lines, and, optionally, QUADWP and QUADHD. So Devices are connected to the same lines, with the exception that each Device has its own CS line. Several Devices can also share one CS line if connected in the daisy-chain manner.</td>
</tr>
<tr>
<td>MOSI</td>
<td>Master Out, Slave In, a.k.a. D. Data transmission from a Host to Device. Also data0 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>MISO</td>
<td>Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host. Also data1 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>SCLK</td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td>CS</td>
<td>Chip Select. Allows a Host to select individual Device(s) connected to the bus in order to send or receive data.</td>
</tr>
<tr>
<td>QUADWP</td>
<td>Protect signal. Used for 4-bit (qio/qout) transactions. Also for data2 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>QUADHD</td>
<td>signal. Used for 4-bit (qio/qout) transactions. Also for data3 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA4</td>
<td>Data4 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA5</td>
<td>Data5 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA6</td>
<td>Data6 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>DATA7</td>
<td>Data7 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td>Assert</td>
<td>The action of activating a line.</td>
</tr>
<tr>
<td>Deassert</td>
<td>The action of returning the line back to inactive (back to idle) status.</td>
</tr>
<tr>
<td>Transaction</td>
<td>One instance of a Host asserting a CS line, transferring data to and from a Device, and de-asserting the CS line. Transactions are atomic, which means they can never be interrupted by another transaction.</td>
</tr>
<tr>
<td>Latch edge</td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td>Latch edge</td>
<td>Edge of the clock at which the destination register latches in the signal.</td>
</tr>
</tbody>
</table>

**Driver Features**

The SPI master driver governs communications of Hosts with Devices. The driver supports the following features:

- Multi-threaded environments
- Transparent handling of DMA transfers while reading and writing data
- Automatic time-division multiplexing of data coming from different Devices on the same signal bus, see SPI Bus Lock.

**Warning:** The SPI master driver has the concept of multiple Devices connected to a single bus (sharing a single ESP32 SPI peripheral). As long as each Device is accessed by only one task, the driver is thread-safe. However, if multiple tasks try to access the same SPI Device, the driver is not thread-safe. In this case, it is recommended to either:

- Refactor your application so that each SPI peripheral is only accessed by a single task at a time. You can use `spi_bus_config_t::isr_cpu_id` to register the SPI ISR to the same core as SPI peripheral related tasks to ensure thread safety.
- Add a mutex lock around the shared Device using `xSemaphoreCreateMutex`.
**SPI Features**

**SPI Master**

**SPI Bus Lock** To realize the multiplexing of different devices from different drivers, including SPI Master, SPI Flash, etc., an SPI bus lock is applied on each SPI bus. Drivers can attach their devices to the bus with the arbitration of the lock.

Each bus lock is initialized with a BG (background) service registered. All devices that request transactions on the bus should wait until the BG is successfully disabled.

- For the SPI1 bus, the BG is the cache. The bus lock will disable the cache before device operations start, and enable it again after the device releases the lock. No devices on SPI1 are allowed to use ISR, since it is meaningless for the task to yield to other tasks when the cache is disabled. There are quite a few limitations when using the SPI Master driver on the SPI1 bus. See *Notes on Using the SPI Master driver on SPI1 Bus*.
- For other buses, the driver can register the ISR as a BG. If a device task requests exclusive bus access, the bus lock will block the task, disable the ISR, and then unblock the task. After the task releases the lock, the lock will try to re-enable the ISR if there are still pending transactions in the ISR.

**SPI Transactions**

An SPI bus transaction consists of five phases which can be found in the table below. Any of these phases can be skipped.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command</td>
<td>In this phase, a command (0-16 bit) is written to the bus by the Host.</td>
</tr>
<tr>
<td>Address</td>
<td>In this phase, an address (0-64 bit) is transmitted over the bus by the Host.</td>
</tr>
<tr>
<td>Dummy</td>
<td>This phase is configurable and is used to meet the timing requirements.</td>
</tr>
<tr>
<td>Write</td>
<td>Host sends data to a Device. This data follows the optional command and address phases and is indistinguishable from them at the electrical level.</td>
</tr>
<tr>
<td>Read</td>
<td>Device sends data to its Host.</td>
</tr>
</tbody>
</table>

The attributes of a transaction are determined by the bus configuration structure `spi_bus_config_t`, device configuration structure `spi_device_interface_config_t`, and transaction configuration structure `spi_transaction_t`.

An SPI Host can send full-duplex transactions, during which the read and write phases occur simultaneously. The total transaction length is determined by the sum of the following members:

- `spi_device_interface_config_t::command_bits`
- `spi_device_interface_config_t::address_bits`
- `spi_transaction_t::length`

While the member `spi_transaction_t::rxlength` only determines the length of data received into the buffer.

In half-duplex transactions, the read and write phases are not simultaneous (one direction at a time). The lengths of the write and read phases are determined by `spi_transaction_t::length` and `spi_transaction_t::rxlength` respectively.

The command and address phases are optional, as not every SPI device requires a command and/or address. This is reflected in the Device’s configuration: if `spi_device_interface_config_t::command_bits` and/or `spi_device_interface_config_t::address_bits` are set to zero, no command or address phase will occur.
The read and write phases can also be optional, as not every transaction requires both writing and reading data. If `spi_transaction_t::rx_buffer` is NULL and `SPI_TRANS_USE_RXDATA` is not set, the read phase is skipped. If `spi_transaction_t::tx_buffer` is NULL and `SPI_TRANS_USE_TXDATA` is not set, the write phase is skipped.

The driver supports two types of transactions: the interrupt transactions and polling transactions. The programmer can choose to use a different transaction type per Device. If your Device requires both transaction types, see **Notes on Sending Mixed Transactions to the Same Device**.

**Interrupt Transactions** Interrupt transactions will block the transaction routine until the transaction completes, thus allowing the CPU to run other tasks.

An application task can queue multiple transactions, and the driver will automatically handle them one-by-one in the interrupt service routine (ISR). It allows the task to switch to other procedures until all the transactions complete.

**Polling Transactions** Polling transactions do not use interrupts. The routine keeps polling the SPI Host’s status bit until the transaction is finished.

All the tasks that use interrupt transactions can be blocked by the queue. At this point, they will need to wait for the ISR to run twice before the transaction is finished. Polling transactions save time otherwise spent on queue handling and context switching, which results in smaller transaction duration. The disadvantage is that the CPU is busy while these transactions are in progress.

The `spi_device_polling_end()` routine needs an overhead of at least 1 us to unblock other tasks when the transaction is finished. It is strongly recommended to wrap a series of polling transactions using the functions `spi_device_acquire_bus()` and `spi_device_release_bus()` to avoid the overhead. For more information, see **Bus Acquiring**.

**Transaction Line Mode** Supported line modes for ESP32 are listed as follows, to make use of these modes, set the member `flags` in the struct `spi_transaction_t` as shown in the **Transaction Flag** column. If you want to check if corresponding IO pins are set or not, set the member `flags` in the `spi_bus_config_t` as shown in the **Bus IO setting Flag** column.

<table>
<thead>
<tr>
<th>Mode name</th>
<th>Command Line Width</th>
<th>Address Line Width</th>
<th>Data Line Width</th>
<th>Transaction Flag</th>
<th>Bus IO setting Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal SPI</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dual Output</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>SPI_TRANS_MODE_DIO</td>
<td>SPICOM-MON_BUSFLAG_DUAL</td>
</tr>
<tr>
<td>Dual I/O</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>SPI_TRANS_MODE_DIO</td>
<td>SPICOM-MON_BUSFLAG_DUAL</td>
</tr>
<tr>
<td>Quad Output</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>SPI_TRANS_MODE_QIO</td>
<td>SPICOM-MON_BUSFLAG_QUAD</td>
</tr>
<tr>
<td>Quad I/O</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>SPI_TRANS_MODE_QIO</td>
<td>SPICOM-MON_BUSFLAG_QUAD</td>
</tr>
</tbody>
</table>

**Command and Address Phases** During the command and address phases, the members `spi_transaction_t::cmd` and `spi_transaction_t::addr` are sent to the bus, nothing is read at this time. The default lengths of the command and address phases are set in `spi_device_interface_config_t` by calling `spi_bus_add_device()`. If the flags `SPI_TRANS_VARIABLE_CMD` and `SPI_TRANS_VARIABLE_ADDR` in the member `spi_transaction_t::flags` are not set, the driver automatically sets the length of these phases to default values during Device initialization.

If the lengths of the command and address phases need to be variable, declare the struct `spi_transaction_ext_t`, set the flags `SPI_TRANS_VARIABLE_CMD` and/or
SPI_TRANS_VARIABLE_ADDR in the member spi_transaction_ext_t::base and configure the rest of base as usual. Then the length of each phase will be equal to spi_transaction_ext_t::command_bits and spi_transaction_ext_t::address_bits set in the struct spi_transaction_ext_t.

If the command and address phase need to be as the same number of lines as data phase, you need to set SPI_TRANS_MULTILINE_CMD and/or SPI_TRANS_MULTILINE_ADDR to the flags member in the struct spi_transaction_t. Also see Transaction Line Mode.

Write and Read Phases Normally, the data that needs to be transferred to or from a Device will be read from or written to a chunk of memory indicated by the members spi_transaction_t::rx_buffer and spi_transaction_t::tx_buffer. If DMA is enabled for transfers, the buffers are required to be:

1. Allocated in DMA-capable internal memory. If external PSRAM is enabled, this means using pvPortMallocCaps(size, MALLOC_CAP_DMA).
2. 32-bit aligned (starting from a 32-bit boundary and having a length of multiples of 4 bytes).

If these requirements are not satisfied, the transaction efficiency will be affected due to the allocation and copying of temporary buffers.

If using more than one data lines to transmit, please set SPI_DEVICE_HALFDUPLEX flag for the member flags in the struct spi_device_interface_config_t. And the member flags in the struct spi_transaction_t should be set as described in Transaction Line Mode.

Note: Half-duplex transactions with both read and write phases are not supported when using DMA. For details and workarounds, see Known Issues.

Bus Acquiring Sometimes you might want to send SPI transactions exclusively and continuously so that it takes as little time as possible. For this, you can use bus acquiring, which helps to suspend transactions (both polling or interrupt) to other devices until the bus is released. To acquire and release a bus, use the functions spi_device_acquire_bus() and spi_device_release_bus().

Driver Usage

- Initialize an SPI bus by calling the function spi_bus_initialize(). Make sure to set the correct I/O pins in the struct spi_bus_config_t. Set the signals that are not needed to -1.
- Register a Device connected to the bus with the driver by calling the function spi_bus_add_device(). Make sure to configure any timing requirements the device might need with the parameter dev_config. You should now have obtained the Device’s handle which will be used when sending a transaction to it.
- To interact with the Device, fill one or more spi_transaction_t structs with any transaction parameters required. Then send the structs either using a polling transaction or an interrupt transaction:
  - Interrupt Either queue all transactions by calling the function spi_device_queue_trans() and, at a later time, query the result using the function spi_device_get_trans_result(), or handle all requests synchronously by feeding them into spi_device_transmit().
  - Polling Call the function spi_device_polling_transmit() to send polling transactions. Alternatively, if you want to insert something in between, send the transactions by using spi_device_polling_start() and spi_device_polling_end().
- (Optional) To perform back-to-back transactions with a Device, call the function spi_device_acquire_bus() before sending transactions and spi_device_release_bus() after the transactions have been sent.
- (Optional) To unload the driver for a certain Device, call spi_bus_remove_device() with the Device handle as an argument.
- (Optional) To remove the driver for a bus, make sure no more drivers are attached and call spi_bus_free().

The example code for the SPI master driver can be found in the peripherals/spi_master directory of ESP-IDF examples.
Transactions with Data Not Exceeding 32 Bits When the transaction data size is equal to or less than 32 bits, it will be sub-optimal to allocate a buffer for the data. The data can be directly stored in the transaction struct instead. For transmitted data, it can be achieved by using the `spi_transaction_t::tx_data` member and setting the `SPI_TRANS_USE_TXDATA` flag on the transmission. For received data, use `spi_transaction_t::rx_data` and set `SPI_TRANS_USE_RXDATA`. In both cases, do not touch the `spi_transaction_t::tx_buffer` or `spi_transaction_t::rx_buffer` members, because they use the same memory locations as `spi_transaction_t::tx_data` and `spi_transaction_t::rx_data`.

Transactions with Integers Other Than `uint8_t` An SPI Host reads and writes data into memory byte by byte. By default, data is sent with the most significant bit (MSB) first, as LSB first used in rare cases. If a value less than 8 bits needs to be sent, the bits should be written into memory in the MSB first manner.

For example, if `0b00010` needs to be sent, it should be written into a `uint8_t` variable, and the length for reading should be set to 5 bits. The Device will still receive 8 bits with 3 additional “random” bits, so the reading must be performed correctly.

On top of that, ESP32 is a little-endian chip, which means that the least significant byte of `uint16_t` and `uint32_t` variables is stored at the smallest address. Hence, if `uint16_t` is stored in memory, bits [7:0] are sent first, followed by bits [15:8].

For cases when the data to be transmitted has the size differing from `uint8_t` arrays, the following macros can be used to transform data to the format that can be sent by the SPI driver directly:

- `SPI_SWAP_DATA_TX` for data to be transmitted
- `SPI_SWAP_DATA_RX` for data received

Notes on Sending Mixed Transactions to the Same Device To reduce coding complexity, send only one type of transactions (interrupt or polling) to one Device. However, you still can send both interrupt and polling transactions alternately. The notes below explain how to do this.

The polling transactions should be initiated only after all the polling and interrupt transactions are finished.

Since an unfinished polling transaction blocks other transactions, please do not forget to call the function `spi_device_polling_end()` after `spi_device_polling_start()` to allow other transactions or to allow other Devices to use the bus. Remember that if there is no need to switch to other tasks during your polling transaction, you can initiate a transaction with `spi_device_polling_transmit()` so that it will be ended automatically.

In-flight polling transactions are disturbed by the ISR operation to accommodate interrupt transactions. Always make sure that all the interrupt transactions sent to the ISR are finished before you call `spi_device_polling_start()`. To do that, you can keep calling `spi_device_get_trans_result()` until all the transactions are returned.

To have better control of the calling sequence of functions, send mixed transactions to the same Device only within a single task.

Notes on Using the SPI Master driver on SPI1 Bus

Note: Though the SPI Bus Lock feature makes it possible to use SPI Master driver on the SPI1 bus, it’s still tricky and needs a lot of special treatment. It’s a feature for advanced developers.

To use SPI Master driver on SPI1 bus, you have to take care of two problems:

1. The code and data, required at the meanwhile the driver is operating SPI1 bus, should be in the internal memory. SPI1 bus is shared among devices and the cache for data (code) in the Flash as well as the PSRAM. The cache should be disabled during the other drivers are operating the SPI1 bus. Hence the data (code) in the flash as well as the PSRAM cannot be fetched at the meanwhile the driver acquires the SPI1 bus by:
   - Explicit bus acquiring between `spi_device_acquire_bus()` and `spi_device_release_bus()`.
Implicit bus acquiring between `spi_device_polling_start()` and `spi_device_polling_end()` (or inside `spi_device_polling_transmit()`).

During the time above, all other tasks and most ISRs will be disabled (see *IRAM-Safe Interrupt Handlers*).

Application code and data used by current task should be placed in internal memory (DRAM or IRAM), or already in the ROM. Access to external memory (flash code, const data in the flash, and static/heap data in the PSRAM) will cause a *Cache disabled but cached memory region accessed* exception. For differences between IRAM, DRAM, and flash cache, please refer to the *application memory layout* documentation.

To place functions into the IRAM, you can either:

1. Add `IRAM_ATTR` (include “esp_attr.h”) to the function like:
   ```c
   IRAM_ATTR void foo(void) {}  
   ```
   Please note that when a function is inlined, it will follow its caller’s segment, and the attribute will not take effect. You may need to use `NOLINE_ATTR` to avoid this.

2. Use the `noflash` placement in the `linker.lf`. See more in *Linker Script Generation*. Please note that, some code may be transformed into lookup table in the const data by the compiler, so `noflash_text` is not safe.

Please do take care that the optimization level may affect the compiler behavior of inline, or transforming some code into lookup table in the const data, etc.

To place data into the DRAM, you can either:

1. Add `DRAM_ATTR` (include “esp_attr.h”) to the data definition like:
   ```c
   DRAM_ATTR int g_foo = 3;  
   ```

2. Use the `noflash` placement in the `linker.lf`. See more in *Linker Script Generation*.

Please also see the example `peripherals/spi_master/hd_eeprom`.

---

**GPIO Matrix and IO_MUX**  
Most of ESP32’s peripheral signals have direct connection to their dedicated IO_MUX pins. However, the signals can also be routed to any other available pins using the less direct GPIO matrix. If at least one signal is routed through the GPIO matrix, then all signals will be routed through it.

The GPIO matrix introduces flexibility of routing but also brings the following disadvantages:

- Increases the input delay of the MISO signal, which makes MISO setup time violations more likely. If SPI needs to operate at high speeds, use dedicated IO_MUX pins.
- Allows signals with clock frequencies only up to 40 MHz, as opposed to 80 MHz if IO_MUX pins are used.

**Note:** For more details about the influence of the MISO input delay on the maximum clock frequency, see *Timing Considerations*.

The IO_MUX pins for SPI buses are given below.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>SPI2</th>
<th>SPI3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS0</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>SCLK</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>MISO</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>MOSI</td>
<td>13</td>
<td>23</td>
</tr>
<tr>
<td>QUADWP</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>QUADHD</td>
<td>4</td>
<td>21</td>
</tr>
</tbody>
</table>

**Transfer Speed Considerations**

There are three factors limiting the transfer speed:

- Transaction interval
- SPI clock frequency
- Cache miss of SPI functions, including callbacks

---

1 Only the first Device attached to the bus can use the CS0 pin.
The main parameter that determines the transfer speed for large transactions is clock frequency. For multiple small transactions, the transfer speed is mostly determined by the length of transaction intervals.

**Transaction Duration**  Transaction duration includes setting up SPI peripheral registers, copying data to FIFOs or setting up DMA links, and the time for SPI transaction.

Interrupt transactions allow appending extra overhead to accommodate the cost of FreeRTOS queues and the time needed for switching between tasks and the ISR.

For **interrupt transactions**, the CPU can switch to other tasks when a transaction is in progress. This saves the CPU time but increases the transaction duration. See *Interrupt Transactions*. For **polling transactions**, it does not block the task but allows to do polling when the transaction is in progress. For more information, see *Polling Transactions*.

If DMA is enabled, setting up the linked list requires about 2 us per transaction. When a master is transferring data, it automatically reads the data from the linked list. If DMA is not enabled, the CPU has to write and read each byte from the FIFO by itself. Usually, this is faster than 2 us, but the transaction length is limited to 64 bytes for both write and read.

Typical transaction duration for one byte of data are given below.

- Interrupt Transaction via DMA: 28 µs.
- Interrupt Transaction via CPU: 25 µs.
- Polling Transaction via DMA: 10 µs.
- Polling Transaction via CPU: 8 µs.

Note that these data are tested with `CONFIG_SPI_MASTER_ISR_IN_IRAM` enabled. SPI transaction related code are placed in the internal memory. If this option is turned off (for example, for internal memory optimization), the transaction duration may be affected.

**SPI Clock Frequency**  Clock source of the GPSPI peripherals can be selected by setting `spi_device_handle_t::cfg::clock_source`. You can refer to `spi_clock_source_t` to know the supported clock sources. By default driver will set `spi_device_handle_t::cfg::clock_source` to `SPI_CLK_SRC_DEFAULT`. This usually stands for the highest frequency among GPSPI clock sources. Its value will be different among chips.

Actual clock frequency of a device may not be exactly equal to the number you set, it will be re-calculated by the driver to the nearest hardware compatible number, and not larger than the clock frequency of the clock source. You can call `spi_device_get_actual_freq()` to know the actual frequency computed by the driver.

Theoretical maximum transfer speed of Write or Read phase can be calculated according to the table below:

<table>
<thead>
<tr>
<th>Line Width of Write/Read phase</th>
<th>Speed (Bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Line</td>
<td>SPI Frequency / 8</td>
</tr>
<tr>
<td>2-Line</td>
<td>SPI Frequency / 4</td>
</tr>
<tr>
<td>4-Line</td>
<td>SPI Frequency / 2</td>
</tr>
</tbody>
</table>

The transfer speed calculation of other phases(command, address, dummy) are similar.

If the clock frequency is too high, the use of some functions might be limited. See *Timing Considerations*.

**Cache Miss**  The default config puts only the ISR into the IRAM. Other SPI related functions, including the driver itself and the callback, might suffer from cache misses and will need to wait until the code is read from flash. Select `CONFIG_SPI_MASTER_IN_IRAM` to put the whole SPI driver into IRAM and put the entire callback(s) and its callee functions into IRAM to prevent cache misses.

**Note:**  SPI driver implementation is based on FreeRTOS APIs, to use `CONFIG_SPI_MASTER_IN_IRAM`, you should not enable `CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH`.
For an interrupt transaction, the overall cost is $20 + 8n/F_{spi}[MHz][us]$ for $n$ bytes transferred in one transaction. Hence, the transferring speed is: $n/(20 + 8n/F_{spi})$. An example of transferring speed at 8 MHz clock speed is given in the following table.

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Transaction Interval (us)</th>
<th>Transaction Length (bytes)</th>
<th>Total Time (us)</th>
<th>Total Speed (KBps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>25</td>
<td>1</td>
<td>26</td>
<td>38.5</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>8</td>
<td>33</td>
<td>242.4</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>16</td>
<td>41</td>
<td>490.2</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>64</td>
<td>89</td>
<td>719.1</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>128</td>
<td>153</td>
<td>836.6</td>
</tr>
</tbody>
</table>

When a transaction length is short, the cost of transaction interval is high. If possible, try to squash several short transactions into one transaction to achieve a higher transfer speed.

Please note that the ISR is disabled during flash operation by default. To keep sending transactions during flash operations, enable `CONFIG_SPI_MASTER_ISR_IN_IRAM` and set `ESP_INTR_FLAG_IRAM` in the member `spi_bus_config_t::intr_flags`. In this case, all the transactions queued before starting flash operations will be handled by the ISR in parallel. Also note that the callback of each Device and their callee functions should be in IRAM, or your callback will crash due to cache miss. For more details, see `IRAM-Safe Interrupt Handlers`.

**Timing Considerations**

As shown in the figure below, there is a delay on the MISO line after the SCLK launch edge and before the signal is latched by the internal register. As a result, the MISO pin setup time is the limiting factor for the SPI clock speed. When the delay is too long, the setup slack is < 0, which means the setup timing requirement is violated and the reading might be incorrect.

The maximum allowed frequency is dependent on:

- `spi_device_interface_config_t::input_delay_ns` - maximum data valid time on the MISO bus after a clock cycle on SCLK starts
- If the IO_MUX pin or the GPIO Matrix is used

When the GPIO matrix is used, the maximum allowed frequency is reduced to about 33~77% in comparison to the existing `input_delay`. To retain a higher frequency, you have to use the IO_MUX pins or the `dummy bit workaround`. You can obtain the maximum reading frequency of the master by using the function `spi_get_freq_limit()`.
**Dummy bit workaround**: Dummy clocks, during which the Host does not read data, can be inserted before the read phase begins. The Device still sees the dummy clocks and sends out data, but the Host does not read until the read phase comes. This compensates for the lack of the MISO setup time required by the Host and allows the Host to do reading at a higher frequency.

In the ideal case, if the Device is so fast that the input delay is shorter than an APB clock cycle - 12.5 ns - the maximum frequency at which the Host can read (or read and write) in different conditions is as follows:

<table>
<thead>
<tr>
<th>Frequency Limit (MHz)</th>
<th>Dummy Bits Used By Driver</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO matrix</td>
<td>IO_MUX pins</td>
<td></td>
</tr>
<tr>
<td>26.6</td>
<td>80</td>
<td>No</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>Yes, Half-duplex, no DMA allowed</td>
</tr>
</tbody>
</table>

If the Host only writes data, the *dummy bit workaround* and the frequency check can be disabled by setting the bit `SPI_DEVICE_NO_DUMMY` in the member `spi_device_interface_config_t::flags`. When disabled, the output frequency can be 80MHz, even if the GPIO matrix is used.

`spi_device_interface_config_t::flags`

The SPI master driver still works even if the `spi_device_interface_config_t::input_delay_ns` in the structure `spi_device_interface_config_t` is set to 0. However, setting an accurate value helps to:

- Calculate the frequency limit for full-duplex transactions
- Compensate the timing correctly with dummy bits for half-duplex transactions

You can approximate the maximum data valid time after the launch edge of SPI clocks by checking the statistics in the AC characteristics chapter of your Device’s specification or measure the time using an oscilloscope or logic analyzer.

Please note that the actual PCB layout design and excessive loads may increase the input delay. It means that non-optimal wiring and/or a load capacitor on the bus will most likely lead to input delay values exceeding the values given in the Device specification or measured while the bus is floating.

Some typical delay values are shown in the following table. (These data are retrieved when the slave device is on a different physical chip)

<table>
<thead>
<tr>
<th>Device</th>
<th>Input delay (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal Device</td>
<td>0</td>
</tr>
<tr>
<td>ESP32 slave using IO_MUX*</td>
<td>50</td>
</tr>
<tr>
<td>ESP32 slave using GPIO_MUX*</td>
<td>75</td>
</tr>
</tbody>
</table>

The MISO path delay (valid time) consists of a slave’s *input delay* plus master’s *GPIO matrix delay*. This delay determines the frequency limit above which full-duplex transfers will not work as well as the dummy bits used in the half-duplex transactions. The frequency limit is:

$$\text{Freq limit [MHz]} = \frac{80}{\text{floor(MISO delay[ns]/12.5) + 1}}$$

The figure below shows the relationship between frequency limit and input delay. Two extra APB clock cycle periods should be added to the MISO delay if the master uses the GPIO matrix.
Corresponding frequency limits for different Devices with different input delay times are shown in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Input delay (ns)</th>
<th>MISO path delay (ns)</th>
<th>Freq. limit (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO_MUX (0ns)</td>
<td>0</td>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>50</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>75</td>
<td>11.43</td>
</tr>
<tr>
<td>GPIO (25ns)</td>
<td>0</td>
<td>25</td>
<td>26.67</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>75</td>
<td>11.43</td>
</tr>
<tr>
<td></td>
<td>75</td>
<td>100</td>
<td>8.89</td>
</tr>
</tbody>
</table>

**Known Issues**

1. Half-duplex transactions are not compatible with DMA when both writing and reading phases are used. If such transactions are required, you have to use one of the alternative solutions:
   1. Use full-duplex transactions instead.
   2. **Disable DMA by setting the bus initialization function’s last parameter to 0 as follows:**
      ```c
      ret=spi_bus_initialize(VSPI_HOST, &buscfg, 0);
      ```
      This can prohibit you from transmitting and receiving data longer than 64 bytes.
   3. Try using the command and address fields to replace the write phase.

2. Full-duplex transactions are not compatible with the dummy bit workaround, hence the frequency is limited. See **dummy bit speed-up workaround**.

3. **dummy_bits** in `spi_device_interface_config_t` and `spi_transaction_ext_t` are not available when SPI read and write phases are both enabled (regardless of full duplex or half duplex mode).

4. `cs_ena_pretrans` is not compatible with the command and address phases of full-duplex transactions.
Application Example

The code example for using the SPI master half duplex mode to read/write a AT93C46D EEPROM (8-bit mode) can be found in the `peripherals/spi_master/hd_eeprom` directory of ESP-IDF examples.

API Reference - SPI Common

Header File

- components/hal/include/hal/spi_types.h

Structures

```c
struct spi_line_mode_t
```

Line mode of SPI transaction phases: CMD, ADDR, DOUT/DIN.

Public Members

```c
uint8_t cmd_lines
```

The line width of command phase, e.g. 2-line-cmd-phase.

```c
uint8_t addr_lines
```

The line width of address phase, e.g. 1-line-addr-phase.

```c
uint8_t data_lines
```

The line width of data phase, e.g. 4-line-data-phase.

Type Definitions

```c
typedef soc_periph_spi_clk_src_t spi_clock_source_t
```

Type of SPI clock source.

Enumerations

```c
enum spi_host_device_t
```

Enum with the three SPI peripherals that are software-accessible in it.

Values:

```c
enumerator SPI1_HOST
```

SPI1.

```c
enumerator SPI2_HOST
```

SPI2.

```c
enumerator SPI3_HOST
```

SPI3.

```c
enumerator SPI_HOST_MAX
```

invalid host value
enum spi_event_t
SPI Events.

Values:

enumerator SPI_EV_BUF_TX
The buffer has sent data to master.

enumerator SPI_EV_BUF_RX
The buffer has received data from master.

enumerator SPI_EV_SEND_DMA_READY
Slave has loaded its TX data buffer to the hardware (DMA).

enumerator SPI_EV_SEND
Master has received certain number of the data, the number is determined by Master.

enumerator SPI_EV_RECV_DMA_READY
Slave has loaded its RX data buffer to the hardware (DMA).

enumerator SPI_EV_RECV
Slave has received certain number of data from master, the number is determined by Master.

enumerator SPI_EV_CMD9
Received CMD9 from master.

enumerator SPI_EV_CMDA
Received CMDA from master.

enumerator SPI_EV_TRANS
A transaction has done.

enum spi_command_t
SPI command.

Values:

enumerator SPI_CMD_HD_WRBUF

enumerator SPI_CMD_HD_RDBUF

enumerator SPI_CMD_HD_WRDMA

enumerator SPI_CMD_HD_RDDMA

enumerator SPI_CMD_HD_SEG_END

enumerator SPI_CMD_HD_EN_QPI
enumerator SPI_CMD_HD_WR_END
enumerator SPI_CMD_HD_INT0
enumerator SPI_CMD_HD_INT1
enumerator SPI_CMD_HD_INT2

Header File
- components/driver/spi/include/driver/spi_common.h

Functions

```c
esp_err_t spi_bus_initialize(spi_host_device_t host_id, const spi_bus_config_t *bus_config, spi_dma_chan_t dma_chan)
```

Initialize a SPI bus.

**Warning:** SPI0/1 is not supported

**Warning:** If a DMA channel is selected, any transmit and receive buffer used should be allocated in DMA-capable memory.

**Warning:** The ISR of SPI is always executed on the core which calls this function. Never starve the ISR on this core or the SPI transactions will not be handled.

**Parameters**
- `host_id` - SPI peripheral that controls this bus
- `bus_config` - Pointer to a `spi_bus_config_t` struct specifying how the host should be initialized
- `dma_chan` - Selecting a DMA channel for an SPI bus allows transactions on the bus with size only limited by the amount of internal memory.
  - Selecting SPI_DMA_DISABLED limits the size of transactions.
  - Set to SPI_DMA_DISABLED if only the SPI flash uses this bus.
  - Set to SPI_DMA_CH_AUTO to let the driver to allocate the DMA channel.

**Returns**
- ESP_ERR_INVALID_ARG if configuration is invalid
- ESP_ERR_INVALID_STATE if host already is in use
- ESP_ERR_NOT_FOUND if there is no available DMA channel
- ESP_ERR_NO_MEM if out of memory
- ESP_OK on success

```c
esp_err_t spi_bus_free(spi_host_device_t host_id)
```

Free a SPI bus.

**Warning:** In order for this to succeed, all devices have to be removed first.

**Parameters**
- `host_id` - SPI peripheral to free

**Returns**
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_INVALID_STATE if bus hasn’t been initialized before, or not all devices on the bus are freed
- ESP_OK on success

Structures

struct spi_bus_config_t
This is a configuration structure for a SPI bus.

You can use this structure to specify the GPIO pins of the bus. Normally, the driver will use the GPIO matrix to route the signals. An exception is made when all signals either can be routed through the IO_MUX or are -1. In that case, the IO_MUX is used, allowing for >40MHz speeds.

<table>
<thead>
<tr>
<th>Public Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>int mosi_io_num</td>
</tr>
<tr>
<td>GPIO pin for Master Out Slave In (=spi_d) signal, or -1 if not used.</td>
</tr>
<tr>
<td>int data0_io_num</td>
</tr>
<tr>
<td>GPIO pin for spi data0 signal in quad/octal mode, or -1 if not used.</td>
</tr>
<tr>
<td>int miso_io_num</td>
</tr>
<tr>
<td>GPIO pin for Master In Slave Out (=spi_q) signal, or -1 if not used.</td>
</tr>
<tr>
<td>int data1_io_num</td>
</tr>
<tr>
<td>GPIO pin for spi data1 signal in quad/octal mode, or -1 if not used.</td>
</tr>
<tr>
<td>int sclk_io_num</td>
</tr>
<tr>
<td>GPIO pin for SPI Clock signal, or -1 if not used.</td>
</tr>
<tr>
<td>int quadwp_io_num</td>
</tr>
<tr>
<td>GPIO pin for WP (Write Protect) signal, or -1 if not used.</td>
</tr>
<tr>
<td>int data2_io_num</td>
</tr>
<tr>
<td>GPIO pin for spi data2 signal in quad/octal mode, or -1 if not used.</td>
</tr>
<tr>
<td>int quadhd_io_num</td>
</tr>
<tr>
<td>GPIO pin for HD (Hold) signal, or -1 if not used.</td>
</tr>
<tr>
<td>int data3_io_num</td>
</tr>
<tr>
<td>GPIO pin for spi data3 signal in quad/octal mode, or -1 if not used.</td>
</tr>
<tr>
<td>int data4_io_num</td>
</tr>
<tr>
<td>GPIO pin for spi data4 signal in octal mode, or -1 if not used.</td>
</tr>
</tbody>
</table>

Note: Be advised that the slave driver does not use the quadwp/quadhd lines and fields in spi_bus_config_t refering to these lines will be ignored and can thus safely be left uninitialized.
int **data5_io_num
    GPIO pin for spi data5 signal in octal mode, or -1 if not used.

int **data6_io_num
    GPIO pin for spi data6 signal in octal mode, or -1 if not used.

int **data7_io_num
    GPIO pin for spi data7 signal in octal mode, or -1 if not used.

int **max_transfer_sz
    Maximum transfer size, in bytes. Defaults to 4092 if 0 when DMA enabled, or to
    SOC_SPI_MAXIMUM_BUFFER_SIZE if DMA is disabled.

uint32_t **flags
    Abilities of bus to be checked by the driver. Or-ed value of SPICOMMON_BUSFLAG_* flags.

intr_cpu_id_t **isr_cpu_id
    Select cpu core to register SPI ISR.

int **intr_flags
    Interrupt flag for the bus to set the priority, and IRAM attribute, see esp_intr_alloc.h. Note that
    the EDGE, INTRDISABLED attribute are ignored by the driver. Note that if ESP_INTR_FLAG_IRAM
    is set, ALL the callbacks of the driver, and their callee functions, should be put in the IRAM.

Macros

SPI_MAX_DMA_LEN

SPI_SWAP_DATA_TX (DATA, LEN)
    Transform unsigned integer of length <= 32 bits to the format which can be sent by the SPI driver directly.
    E.g. to send 9 bits of data, you can:

    uint16_t data = SPI_SWAP_DATA_TX(0x145, 9);

Then points tx_buffer to &data.

Parameters
  • DATA - Data to be sent, can be uint8_t, uint16_t or uint32_t.
  • LEN - Length of data to be sent, since the SPI peripheral sends from the MSB, this helps
    to shift the data to the MSB.

SPI_SWAP_DATA_RX (DATA, LEN)
    Transform received data of length <= 32 bits to the format of an unsigned integer.
    E.g. to transform the data of 15 bits placed in a 4-byte array to integer:

    uint16_t data = SPI_SWAP_DATA_RX((uint32_t*)t->rx_data, 15);

Parameters
  • DATA - Data to be rearranged, can be uint8_t, uint16_t or uint32_t.
  • LEN - Length of data received, since the SPI peripheral writes from the MSB, this helps
    to shift the data to the LSB.
Chapter 2. API Reference

**SPICOMMON_BUSFLAG_SLAVE**
Initialize I/O in slave mode.

**SPICOMMON_BUSFLAG_MASTER**
Initialize I/O in master mode.

**SPICOMMON_BUSFLAG_IOMUX_PINS**
Check using iomux pins. Or indicates the pins are configured through the IO mux rather than GPIO matrix.

**SPICOMMON_BUSFLAG_GPIO_PINS**
Force the signals to be routed through GPIO matrix. Or indicates the pins are routed through the GPIO matrix.

**SPICOMMON_BUSFLAG_SCLK**
Check existing of SCLK pin. Or indicates CLK line initialized.

**SPICOMMON_BUSFLAG_MISO**
Check existing of MISO pin. Or indicates MISO line initialized.

**SPICOMMON_BUSFLAG_MOSI**
Check existing of MOSI pin. Or indicates MOSI line initialized.

**SPICOMMON_BUSFLAG_DUAL**
Check MOSI and MISO pins can output. Or indicates bus able to work under DIO mode.

**SPICOMMON_BUSFLAG_WPHD**
Check existing of WP and HD pins. Or indicates WP & HD pins initialized.

**SPICOMMON_BUSFLAG_QUAD**
Check existing of MOSI/MISO/ WP/HD pins as output. Or indicates bus able to work under QIO mode.

**SPICOMMON_BUSFLAG_IO4_IO7**
Check existing of IO4~IO7 pins. Or indicates IO4~IO7 pins initialized.

**SPICOMMON_BUSFLAG_OCTAL**
Check existing of MOSI/MISO/WP/HD/SPIIO4/SPIIO5/SPIIO6/SPIIO7 pins as output. Or indicates bus able to work under octal mode.

**SPICOMMON_BUSFLAG_NATIVE_PINS**

**Type Definitions**

typedef `spi_common_dma_t` spi_dma_chan_t

**Enumerations**

enum `spi_common_dma_t`
SPA DMA channels.

Values:
enumerator **SPI_DMA_DISABLED**

Do not enable DMA for SPI.

enumerator **SPI_DMA_CH1**

Enable DMA, select DMA Channel 1.

enumerator **SPI_DMA_CH2**

Enable DMA, select DMA Channel 2.

enumerator **SPI_DMA_CH_AUTO**

Enable DMA, channel is automatically selected by driver.

---

**API Reference - SPI Master**

**Header File**

- components/driver/spi/include/driver/spi_master.h

**Functions**

```c
esp_err_t spi_bus_add_device(spi_host_device_t host_id, const spi_device_interface_config_t *dev_config, spi_device_handle_t *handle)
```

Allocate a device on a SPI bus.

This initializes the internal structures for a device, plus allocates a CS pin on the indicated SPI master peripheral and routes it to the indicated GPIO. All SPI master devices have three CS pins and can thus control up to three devices.

**Note:** While in general, speeds up to 80MHz on the dedicated SPI pins and 40MHz on GPIO-matrix-routed pins are supported, full-duplex transfers routed over the GPIO matrix only support speeds up to 26MHz.

**Parameters**

- **host_id** - SPI peripheral to allocate device on
- **dev_config** - SPI interface protocol config for the device
- **handle** - Pointer to variable to hold the device handle

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid or configuration combination is not supported (e.g. dev_config->post_cb isn’t set while flag SPI_DEVICE_NO_RETURN_RESULT is enabled)
- ESP_ERR_INVALID_STATE if selected clock source is unavailable or spi bus not initialized
- ESP_ERR_NOT_FOUND if host doesn’t have any free CS slots
- ESP_ERR_NO_MEM if out of memory
- ESP_OK on success

```c
esp_err_t spi_bus_remove_device(spi_device_handle_t handle)
```

Remove a device from the SPI bus.

**Parameters**

- **handle** - Device handle to free

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_INVALID_STATE if device already is freed
- ESP_OK on success
**esp_err_t** `spi_device_queue_trans` *(spi_device_handle_t handle, spi_transaction_t *trans_desc, TickType_t ticks_to_wait)*

Queue a SPI transaction for interrupt transaction execution. Get the result by `spi_device_get_trans_result`.

**Note:** Normally a device cannot start (queue) polling and interrupt transactions simultaneously.

**Parameters**
- **handle** - Device handle obtained using `spi_host_add_dev`
- **trans_desc** - Description of transaction to execute
- **ticks_to_wait** - Ticks to wait until there’s room in the queue; use `portMAX_DELAY` to never time out.

**Returns**
- **ESP_ERR_INVALID_ARG** if parameter is invalid. This can happen if `SPI_TRANS_CS_KEEP_ACTIVE` flag is specified while the bus was not acquired (`spi_device_acquire_bus()` should be called first)
- **ESP_ERR_TIMEOUT** if there was no room in the queue before `ticks_to_wait` expired
- **ESP_ERR_NO_MEM** if allocating DMA-capable temporary buffer failed
- **ESP_ERR_INVALID_STATE** if previous transactions are not finished
- **ESP_OK** on success

**esp_err_t** `spi_device_get_trans_result` *(spi_device_handle_t handle, spi_transaction_t **trans_desc, TickType_t ticks_to_wait)*

Get the result of a SPI transaction queued earlier by `spi_device_queue_trans`.

This routine will wait until a transaction to the given device successfully completed. It will then return the description of the completed transaction so software can inspect the result and e.g. free the memory or re-use the buffers.

**Parameters**
- **handle** - Device handle obtained using `spi_host_add_dev`
- **trans_desc** - Pointer to variable able to contain a pointer to the description of the transaction that is executed. The descriptor should not be modified until the descriptor is returned by `spi_device_get_trans_result`.
- **ticks_to_wait** - Ticks to wait until there’s a returned item; use `portMAX_DELAY` to never time out.

**Returns**
- **ESP_ERR_INVALID_ARG** if parameter is invalid
- **ESP_ERR_NOT_SUPPORTED** if flag `SPI_DEVICE_NO_RETURN_RESULT` is set
- **ESP_ERR_TIMEOUT** if there was no completed transaction before `ticks_to_wait` expired
- **ESP_OK** on success

**esp_err_t** `spi_device_transmit` *(spi_device_handle_t handle, spi_transaction_t *trans_desc)*

Send a SPI transaction, wait for it to complete, and return the result.

This function is the equivalent of calling `spi_device_queue_trans()` followed by `spi_device_get_trans_result()`. Do not use this when there is still a transaction separately queued (started) from `spi_device_queue_trans()` or polling_start/transmit that hasn’t been finalized.

**Note:** This function is not thread safe when multiple tasks access the same SPI device. Normally a device cannot start (queue) polling and interrupt transactions simultaneously.

**Parameters**
- **handle** - Device handle obtained using `spi_host_add_dev`
- **trans_desc** - Description of transaction to execute

**Returns**
• ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_OK on success

```c
esp_err_t spi_device_polling_start(spi_device_handle_t handle, spi_transaction_t *trans_desc, TickType_t ticks_to_wait)
```

Immediately start a polling transaction.

**Note:** Normally a device cannot start (queue) polling and interrupt transactions simultaneously. Moreover, a device cannot start a new polling transaction if another polling transaction is not finished.

**Parameters**

- `handle` - Device handle obtained using `spi_host_add_dev`
- `trans_desc` - Description of transaction to execute
- `ticks_to_wait` - Ticks to wait until there’s room in the queue; currently only port-MAX_DELAY is supported.

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid. This can happen if `SPI_TRANS_CS_KEEP_ACTIVE` flag is specified while the bus was not acquired (`spi_device_acquire_bus()` should be called first)
- ESP_ERR_TIMEOUT if the device cannot get control of the bus before `ticks_to_wait` expired
- ESP_ERR_NO_MEM if allocating DMA-capable temporary buffer failed
- ESP_ERR_INVALID_STATE if previous transactions are not finished
- ESP_OK on success

```c
esp_err_t spi_device_polling_end(spi_device_handle_t handle, TickType_t ticks_to_wait)
```

Poll until the polling transaction ends.

This routine will not return until the transaction to the given device has successfully completed. The task is not blocked, but actively busy-spins for the transaction to be completed.

**Parameters**

- `handle` - Device handle obtained using `spi_host_add_dev`
- `ticks_to_wait` - Ticks to wait until there’s a returned item; use portMAX_DELAY to never time out.

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_TIMEOUT if the transaction cannot finish before `ticks_to_wait` expired
- ESP_OK on success

```c
esp_err_t spi_device_polling_transmit(spi_device_handle_t handle, spi_transaction_t *trans_desc)
```

Send a polling transaction, wait for it to complete, and return the result.

This function is the equivalent of calling `spi_device_polling_start()` followed by `spi_device_polling_end()`. Do not use this when there is still a transaction that hasn’t been finalized.

**Note:** This function is not thread safe when multiple tasks access the same SPI device. Normally a device cannot start (queue) polling and interrupt transactions simultaneously.

**Parameters**

- `handle` - Device handle obtained using `spi_host_add_dev`
- `trans_desc` - Description of transaction to execute

**Returns**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_TIMEOUT if the device cannot get control of the bus
- ESP_ERR_NO_MEM if allocating DMA-capable temporary buffer failed

---

Submit Document Feedback
• ESP_ERR_INVALID_STATE if previous transactions of same device are not finished
• ESP_OK on success

`esp_err_t spi_device_acquire_bus (spi_device_handle_t device, TickType_t wait)`

Occupy the SPI bus for a device to do continuous transactions.

Transactions to all other devices will be put off until `spi_device_release_bus` is called.

**Note:** The function will wait until all the existing transactions have been sent.

**Parameters**
- `device` - The device to occupy the bus.
- `wait` - Time to wait before the the bus is occupied by the device. Currently MUST set to `portMAX_DELAY`.

**Returns**
- ESP_ERR_INVALID_ARG : `wait` is not set to `portMAX_DELAY`.
- ESP_OK : Success.

`void spi_device_release_bus (spi_device_handle_t dev)`

Release the SPI bus occupied by the device. All other devices can start sending transactions.

**Parameters**
- `dev` - The device to release the bus.

`esp_err_t spi_device_get_actual_freq (spi_device_handle_t handle, int* freq_khz)`

Calculate working frequency for specific device.

**Parameters**
- `handle` - SPI device handle
- `freq_khz` - [out] output parameter to hold calculated frequency in kHz

**Returns**
- ESP_ERR_INVALID_ARG : handle or `freq_khz` parameter is NULL
- ESP_OK : Success

`int spi_get_actual_clock (int fapb, int hz, int duty_cycle)`

Calculate the working frequency that is most close to desired frequency.

**Parameters**
- `fapb` - The frequency of apb clock, should be `APB_CLK_FREQ`.
- `hz` - Desired working frequency
- `duty_cycle` - Duty cycle of the spi clock

**Returns** Actual working frequency that most fit.

`void spi_get_timing (bool gpio_is_used, int input_delay_ns, int eff_clk, int *dummy_o, int *cycles_remain_o)`

Calculate the timing settings of specified frequency and settings.

**Note:** If `*dummy_o` is not zero, it means dummy bits should be applied in half duplex mode, and full duplex mode may not work.

**Parameters**
- `gpio_is_used` - True if using GPIO matrix, or False if iomux pins are used.
- `input_delay_ns` - Input delay from SCLK launch edge to MISO data valid.
- `eff_clk` - Effective clock frequency (in Hz) from `spi_get_actual_clock()`.
- `dummy_o` - Address of dummy bits used output. Set to NULL if not needed.
- `cycles_remain_o` - Address of cycles remaining (after dummy bits are used) output.
  - -1 If too many cycles remaining, suggest to compensate half a clock.
  - 0 If no remaining cycles or dummy bits are not used.
positive value: cycles suggest to compensate.

```c
int spi_get_freq_limit (bool gpio_is_used, int input_delay_ns)
```
Get the frequency limit of current configurations. SPI master working at this limit is OK, while above the limit, full duplex mode and DMA will not work, and dummy bits will be applied in the half duplex mode.

**Parameters**
- **gpio_is_used** True if using GPIO matrix, or False if native pins are used.
- **input_delay_ns** Input delay from SCLK launch edge to MISO data valid.

**Returns** Frequency limit of current configurations.

```c
esp_err_t spi_bus_get_max_transaction_len (spi_host_device_t host_id, size_t *max_bytes)
```
Get max length (in bytes) of one transaction.

**Parameters**
- **host_id** SPI peripheral
- **max_bytes** [out] Max length of one transaction, in bytes

**Returns**
- ESP_OK: On success
- ESP_ERR_INVALID_ARG: Invalid argument

**Structures**

```c
struct spi_device_interface_config_t
```
This is a configuration for a SPI slave device that is connected to one of the SPI buses.

**Public Members**

```c
uint8_t command_bits
```
Default amount of bits in command phase (0-16), used when SPI_TRANS_VARIABLE_CMD is not used, otherwise ignored.

```c
uint8_t address_bits
```
Default amount of bits in address phase (0-64), used when SPI_TRANS_VARIABLE_ADDR is not used, otherwise ignored.

```c
uint8_t dummy_bits
```
Amount of dummy bits to insert between address and data phase.

```c
uint8_t mode
```
SPI mode, representing a pair of (CPOL, CPHA) configuration:
- 0: (0, 0)
- 1: (0, 1)
- 2: (1, 0)
- 3: (1, 1)

```c
spi_clock_source_t clock_source
```
Select SPI clock source, SPI_CLK_SRC_DEFAULT by default.

```c
uint16_t duty_cycle_pos
```
Duty cycle of positive clock, in 1/256th increments (128 = 50%/50% duty). Setting this to 0 (=not setting it) is equivalent to setting this to 128.
Chapter 2. API Reference

uint16_t cs_ena_pretrans
Amount of SPI bit-cycles the cs should be activated before the transmission (0-16). This only works on half-duplex transactions.

uint8_t cs_ena_posttrans
Amount of SPI bit-cycles the cs should stay active after the transmission (0-16)

int clock_speed_hz
Clock speed, divisors of the SPI clock_source, in Hz.

int input_delay_ns
Maximum data valid time of slave. The time required between SCLK and MISO valid, including the possible clock delay from slave to master. The driver uses this value to give an extra delay before the MISO is ready on the line. Leave at 0 unless you know you need a delay. For better timing performance at high frequency (over 8MHz), it’s suggest to have the right value.

int spics_io_num
CS GPIO pin for this device, or -1 if not used.

uint32_t flags
Bitwise OR of SPI_DEVICE_* flags.

int queue_size
Transaction queue size. This sets how many transactions can be ‘in the air’ (queued using spi_device_queue_trans but not yet finished using spi_device_get_trans_result) at the same time.

transaction_cb_t pre_cb
Callback to be called before a transmission is started.
This callback is called within interrupt context should be in IRAM for best performance, see “Transferring Speed” section in the SPI Master documentation for full details. If not, the callback may crash during flash operation when the driver is initialized with ESP_INTR_FLAG_IRAM.

transaction_cb_t post_cb
Callback to be called after a transmission has completed.
This callback is called within interrupt context should be in IRAM for best performance, see “Transferring Speed” section in the SPI Master documentation for full details. If not, the callback may crash during flash operation when the driver is initialized with ESP_INTR_FLAG_IRAM.

struct spi_transaction_t
This structure describes one SPI transaction. The descriptor should not be modified until the transaction finishes.

Public Members

uint32_t flags
Bitwise OR of SPI_TRANS_* flags.

uint16_t cmd
Command data, of which the length is set in the command_bits of spi_device_interface_config_t.
NOTE: this field, used to be “command” in ESP-IDF 2.1 and before, is re-written to be used in a new way in ESP-IDF 3.0.

Example: write 0x0123 and command_bits=12 to send command 0x12, 0x3_ (in previous version, you may have to write 0x3_12).

```c
uint64_t addr
```
Address data, of which the length is set in the `address_bits` of `spi_device_interface_config_t`.

NOTE: this field, used to be “address” in ESP-IDF 2.1 and before, is re-written to be used in a new way in ESP-IDF 3.0.

Example: write 0x123400 and address_bits=24 to send address of 0x12, 0x34, 0x00 (in previous version, you may have to write 0x12340000).

```c
size_t length
```
Total data length, in bits.

```c
size_t rxlength
```
Total data length received, should be not greater than `length` in full-duplex mode (0 defaults this to the value of `length`).

```c
void *user
```
User-defined variable. Can be used to store eg transaction ID.

```c
const void *tx_buffer
```
Pointer to transmit buffer, or NULL for no MOSI phase.

```c
uint8_t tx_data[4]
```
If SPI_TRANS_USE_TXDATA is set, data set here is sent directly from this variable.

```c
void *rx_buffer
```
Pointer to receive buffer, or NULL for no MISO phase. Written by 4 bytes-unit if DMA is used.

```c
uint8_t rx_data[4]
```
If SPI_TRANS_USE_RXDATA is set, data is received directly to this variable.

```c
struct spi_transaction_ext_t
```
This struct is for SPI transactions which may change their address and command length. Please do set the flags in base to `SPI_TRANS_VARIABLE_CMD_ADR` to use the bit length here.

**Public Members**

```c
struct spi_transaction_t base
```
Transaction data, so that pointer to `spi_transaction_t` can be converted into `spi_transaction_ext_t`.

```c
uint8_t command_bits
```
The command length in this transaction, in bits.

```c
uint8_t address_bits
```
The address length in this transaction, in bits.
uint8_t dummy_bits

The dummy length in this transaction, in bits.

**Macros**

**SPI_MASTER_FREQ_8M**

SPI common used frequency (in Hz)

**Note:** SPI peripheral only has an integer divider, and the default clock source can be different on other targets, so the actual frequency may be slightly different from the desired frequency. 8MHz

**SPI_MASTER_FREQ_9M**

8.89MHz

**SPI_MASTER_FREQ_10M**

10MHz

**SPI_MASTER_FREQ_11M**

11.43MHz

**SPI_MASTER_FREQ_13M**

13.33MHz

**SPI_MASTER_FREQ_16M**

16MHz

**SPI_MASTER_FREQ_20M**

20MHz

**SPI_MASTER_FREQ_26M**

26.67MHz

**SPI_MASTER_FREQ_40M**

40MHz

**SPI_MASTER_FREQ_80M**

80MHz

**SPI_DEVICE_TXBIT_LSBFIRST**

Transmit command/address/data LSB first instead of the default MSB first.

**SPI_DEVICE_RXBIT_LSBFIRST**

Receive data LSB first instead of the default MSB first.

**SPI_DEVICE_BIT_LSBFIRST**

Transmit and receive LSB first.

**SPI_DEVICE_3WIRE**

Use MOSI (=spid) for both sending and receiving data.
Chapter 2. API Reference

**SPI_DEVICE_POSITIVE_CS**
Make CS positive during a transaction instead of negative.

**SPI_DEVICE_HALFDUPLEX**
Transmit data before receiving it, instead of simultaneously.

**SPI_DEVICE_CLK_AS_CS**
Output clock on CS line if CS is active.

**SPI_DEVICE_NO_DUMMY**
There are timing issue when reading at high frequency (the frequency is related to whether iomux pins are used, valid time after slave sees the clock).
- In half-duplex mode, the driver automatically inserts dummy bits before reading phase to fix the timing issue. Set this flag to disable this feature.
- In full-duplex mode, however, the hardware cannot use dummy bits, so there is no way to prevent data being read from getting corrupted. Set this flag to confirm that you’re going to work with output only, or read without dummy bits at your own risk.

**SPI_DEVICE_DDRCLK**

**SPI_DEVICE_NO_RETURN_RESULT**
Don’t return the descriptor to the host on completion (use post_cb to notify instead)

**SPI_TRANS_MODE_DIO**
Transmit/receive data in 2-bit mode.

**SPI_TRANS_MODE_QIO**
Transmit/receive data in 4-bit mode.

**SPI_TRANS_USE_RXDATA**
Receive into rx_data member of *spi_transaction_t* instead into memory at rx_buffer.

**SPI_TRANS_USE_TXDATA**
Transmit tx_data member of *spi_transaction_t* instead of data at tx_buffer. Do not set tx_buffer when using this.

**SPI_TRANS_MODE_DIOQIO_ADDR**
Also transmit address in mode selected by SPI_MODE_DIO/SPI_MODE_QIO.

**SPI_TRANS_VARIABLE_CMD**
Use the command_bits in *spi_transaction_ext_t* rather than default value in *spi_device_interface_config_t*.

**SPI_TRANS_VARIABLE_ADDR**
Use the address_bits in *spi_transaction_ext_t* rather than default value in *spi_device_interface_config_t*.

**SPI_TRANS_VARIABLE_DUMMY**
Use the dummy_bits in *spi_transaction_ext_t* rather than default value in *spi_device_interface_config_t*. 
**SPI_TRANS_CS_KEEP_ACTIVE**
Keep CS active after data transfer.

**SPI_TRANS_MULTILINE_CMD**
The data lines used at command phase is the same as data phase (otherwise, only one data line is used at command phase)

**SPI_TRANS_MODE_OCT**
Transmit/receive data in 8-bit mode.

**SPI_TRANS_MULTILINE_ADDR**
The data lines used at address phase is the same as data phase (otherwise, only one data line is used at address phase)

**Type Definitions**

typedef void (*transaction_cb_t)(spi_transaction_t *trans)

typedef struct spi_device_t *spi_device_handle_t

Handle for a device on a SPI bus.

### 2.6.22 SPI Slave Driver

SPI Slave driver is a program that controls ESP32’s SPI peripherals while they function as slaves.

**Overview of ESP32’s SPI peripherals**

On ESP32, 2 SPI controllers are available for general purpose usage. A certain SPI controller has an independent signal bus with the same name.

**Note:** On ESP32, HSPI refers to SPI2, VSPI refers to SPI3.

**Terminology**

The terms used in relation to the SPI slave driver are given in the table below.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host</td>
<td>The SPI controller peripheral external to ESP32 that initiates SPI transmissions over the bus, and acts as an SPI Master.</td>
</tr>
<tr>
<td>Device</td>
<td>SPI slave device (general purpose SPI controller). Each Device shares the MOSI, MISO and SCLK signals but is only active on the bus when the Host asserts the Device’s individual CS line.</td>
</tr>
<tr>
<td>Bus</td>
<td>A signal bus, common to all Devices connected to one Host. In general, a bus includes the following lines: MISO, MOSI, SCLK, one or more CS lines, and, optionally, QUADWP and QUADHD. So Devices are connected to the same lines, with the exception that each Device has its own CS line. Several Devices can also share one CS line if connected in the daisy-chain manner.</td>
</tr>
<tr>
<td>MISO</td>
<td>Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host.</td>
</tr>
<tr>
<td>MOSI</td>
<td>Master Out, Slave In, a.k.a. D. Data transmission from a Host to Device.</td>
</tr>
<tr>
<td>SCLK</td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td>CS</td>
<td>Chip Select. Allows a Host to select individual Device(s) connected to the bus in order to send or receive data.</td>
</tr>
<tr>
<td>QUADWP</td>
<td>Write Protect signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td>QUADHD</td>
<td>Hold signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td>Assertion</td>
<td>The action of activating a line. The opposite action of returning the line back to inactive (back to idle) is called de-assertion.</td>
</tr>
<tr>
<td>Transaction</td>
<td>One instance of a Host asserting a CS line, transferring data to and from a Device, and de-asserting the CS line. Transactions are atomic, which means they can never be interrupted by another transaction.</td>
</tr>
<tr>
<td>Launch Edge</td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td>Latch Edge</td>
<td>Edge of the clock at which the destination register latches in the signal.</td>
</tr>
</tbody>
</table>

**Driver Features**

The SPI slave driver allows using the SPI peripherals as full-duplex Devices. The driver can send/receive transactions up to 64 bytes in length, or utilize DMA to send/receive longer transactions. However, there are some known issues related to DMA.

The SPI slave driver supports registering the SPI ISR to a certain CPU core. If multiple tasks try to access the same SPI Device simultaneously, it is recommended that your application be refactored so that each SPI peripheral is only accessed by a single task at a time. Please also use `spi_bus_config_t::isr_cpu_id` to register the SPI ISR to the same core as SPI peripheral related tasks to ensure thread safety.

**SPI Transactions**

A full-duplex SPI transaction begins when the Host asserts the CS line and starts sending out clock pulses on the SCLK line. Every clock pulse, a data bit is shifted from the Host to the Device on the MOSI line and back on the MISO line at the same time. At the end of the transaction, the Host de-asserts the CS line.

The attributes of a transaction are determined by the configuration structure for an SPI peripheral acting as a slave device `spi_slave_interface_config_t`, and transaction configuration structure `spi_slave_transaction_t`.

As not every transaction requires both writing and reading data, you can choose to configure the `spi_slave_transaction_t` structure for TX only, RX only, or TX and RX transactions. If `spi_slave_transaction_t::rx_buffer` is set to NULL, the read phase will be skipped. Similarly, if `spi_slave_transaction_t::tx_buffer` is set to NULL, the write phase will be skipped.

**Note:** A Host should not start a transaction before its Device is ready for receiving data. It is recommended to use another GPIO pin for a handshake signal to sync the Devices. For more details, see Transaction Interval.
Driver Usage

• Initialize an SPI peripheral as a Device by calling the function `spi_slave_initialize()`. Make sure to set the correct I/O pins in the struct `bus_config`. Set the unused signals to -1.

If transactions are expected to be longer than 32 bytes, set the parameter `dma_chan` to 1 or 2 to allow a DMA channel 1 or 2 respectively. Otherwise, set `dma_chan` to 0.

• Before initiating transactions, fill one or more `spi_slave_transaction_t` structs with the transaction parameters required. Either queue all transactions by calling the function `spi_slave_queue_trans()` and, at a later time, query the result by using the function `spi_slave_get_trans_result()`, or handle all requests individually by feeding them into `spi_slave_transmit()`. The latter two functions will be blocked until the Host has initiated and finished a transaction, causing the queued data to be sent and received.

• (Optional) To unload the SPI slave driver, call `spi_slave_free()`.

Transaction Data and Master/Slave Length Mismatches

Normally, the data that needs to be transferred to or from a Device is read or written to a chunk of memory indicated by the `spi_slave_transaction_t::rx_buffer` and `spi_slave_transaction_t::tx_buffer`. The SPI driver can be configured to use DMA for transfers, in which case these buffers must be allocated in DMA-capable memory using `pvPortMallocCaps(size, MALLOC_CAP_DMA).

The amount of data that the driver can read or write to the buffers is limited by `spi_slave_transaction_t::length`. However, this member does not define the actual length of an SPI transaction. A transaction’s length is determined by the clock and CS lines driven by the Host. The actual length of the transmission can be read only after a transaction is finished from the member `spi_slave_transaction_t::trans_len`.

If the length of the transmission is greater than the buffer length, only the initial number of bits specified in the `spi_slave_transaction_t::length` member will be sent and received. In this case, `spi_slave_transaction_t::trans_len` is set to `spi_slave_transaction_t::length` instead of the actual transaction length. To meet the actual transaction length requirements, set `spi_slave_transaction_t::trans_len` to a value greater than the maximum `spi_slave_transaction_t::trans_len` expected. If the transmission length is shorter than the buffer length, only the data equal to the length of the buffer will be transmitted.

GPIO Matrix and IO_MUX

Most of ESP32’s peripheral signals have direct connection to their dedicated IO_MUX pins. However, the signals can also be routed to any other available pins using the less direct GPIO matrix.

If at least one signal is routed through the GPIO matrix, then all signals will be routed through it. If the driver is configured so that all SPI signals are either routed to their dedicated IO_MUX pins or are not connected at all, the GPIO matrix will be bypassed.

The GPIO matrix introduces flexibility of routing but also increases the input delay of the MISO signal, which makes MISO setup time violations more likely. If SPI needs to operate at high speeds, use dedicated IO_MUX pins.

**Note:** For more details about the influence of the MISO input delay on the maximum clock frequency, see *Timing Considerations*.

The IO_MUX pins for SPI buses are given below.
Pin Name | GPIO Number (SPI2) | GPIO Number (SPI3)
--- | --- | ---
CS0 | 15 | 5
SCLK | 14 | 18
MISO | 12 | 19
MOSI | 13 | 23
QUADWP | 2 | 22
QUADHD | 4 | 21

**Speed and Timing Considerations**

**Transaction Interval**  The ESP32 SPI slave peripherals are designed as general purpose Devices controlled by a CPU. As opposed to dedicated slaves, CPU-based SPI Devices have a limited number of pre-defined registers. All transactions must be handled by the CPU, which means that the transfers and responses are not real-time, and there might be noticeable latency.

As a solution, a Device’s response rate can be doubled by using the functions `spi_slave_queue_trans()` and then `spi_slave_get_trans_result()` instead of using `spi_slave_transmit()`.

You can also configure a GPIO pin through which the Device will signal to the Host when it is ready for a new transaction. A code example of this can be found in `peripherals/spi_slave`.

**SCLK Frequency Requirements**  The SPI slaves are designed to operate at up to 10 MHz. The data cannot be recognized or received correctly if the clock is too fast or does not have a 50% duty cycle.

On top of that, there are additional requirements for the data to meet the timing constraints:

- **Read (MOSI):** The Device can read data correctly only if the data is already set at the launch edge. Although it is usually the case for most masters.
- **Write (MISO):** The output delay of the MISO signal needs to be shorter than half of a clock cycle period so that the MISO line is stable before the next latch edge. Given that the clock is balanced, the output delay and frequency limitations in different cases are given below.

<table>
<thead>
<tr>
<th>/</th>
<th>Output delay of MISO (ns)</th>
<th>Freq. limit (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IO_MUX</td>
<td>43.75</td>
<td>&lt;11.4</td>
</tr>
<tr>
<td>GPIO matrix</td>
<td>68.75</td>
<td>&lt;7.2</td>
</tr>
</tbody>
</table>

Note: 1. If the frequency reaches the maximum limitation, random errors may occur. 2. The clock uncertainty between the Host and the Device (12.5 ns) is included. 3. The output delay is measured under ideal circumstances (no load). If the MISO pin is heavily loaded, the output delay will be longer, and the maximum allowed frequency will be lower.

Exception: The frequency is allowed to be higher if the master has more tolerance for the MISO setup time, e.g., latch data at the next edge, or configurable latching time.

**Restrictions and Known Issues**

1. If DMA is enabled, the rx buffer should be word-aligned (starting from a 32-bit boundary and having a length of multiples of 4 bytes). Otherwise, DMA may write incorrectly or not in a boundary aligned manner. The driver reports an error if this condition is not satisfied. Also, a Host should write lengths that are multiples of 4 bytes. The data with inappropriate lengths will be discarded.

2. Furthermore, DMA requires SPI modes 1 and 3. For SPI modes 0 and 2, the MISO signal has to be launched half a clock cycle earlier to meet the timing. The new timing is as follows:
If DMA is enabled, a Device’s launch edge is half of an SPI clock cycle ahead of the normal time, shifting to the Master’s actual latch edge. In this case, if the GPIO matrix is bypassed, the hold time for data sampling is 68.75 ns and no longer a half of an SPI clock cycle. If the GPIO matrix is used, the hold time will increase to 93.75 ns. The Host should sample the data immediately at the latch edge or communicate in SPI modes 1 or 3. If your Host cannot meet these timing requirements, initialize your Device without DMA.

**Application Example**

The code example for Device/Host communication can be found in the peripherals/spi_slave directory of ESP-IDF examples.

**API Reference**

**Header File**

- components/driver/spi/include/driver/spi_slave.h

**Functions**

```c
esp_err_t spi_slave_initialize (spi_host_device_t host, const spi_bus_config_t *bus_config, const spi_slave_interface_config_t *slave_config, spi_dma_chan_t dma_chan)
```

Initialize a SPI bus as a slave interface.

**Warning:** SPI0/1 is not supported

**Warning:** If a DMA channel is selected, any transmit and receive buffer used should be allocated in DMA-capable memory.

**Warning:** The ISR of SPI is always executed on the core which calls this function. Never starve the ISR on this core or the SPI transactions will not be handled.

**Parameters**

- `host` - SPI peripheral to use as a SPI slave interface
- `bus_config` - Pointer to a `spi_bus_config_t` struct specifying how the host should be initialized
- `slave_config` - Pointer to a `spi_slave_interface_config_t` struct specifying the details for the slave interface
- `dma_chan` - Selecting a DMA channel for an SPI bus allows transactions on the bus with size only limited by the amount of internal memory.
  - Selecting SPI_DMA_DISABLED limits the size of transactions.
  - Set to SPI_DMA_DISABLED if only the SPI flash uses this bus.
  - Set to SPI_DMA_CH_AUTO to let the driver to allocate the DMA channel.

**Returns**

- ESP_ERR_INVALID_ARG if configuration is invalid
- ESP_ERR_INVALID_STATE if host already is in use
### espruino

- **ESP_ERR_NOT_FOUND** if there is no available DMA channel
- **ESP_ERR_NO_MEM** if out of memory
- **ESP_OK** on success

**esp_err_t spi_slave_free(spi_host_device_t host)**

Free a SPI bus claimed as a SPI slave interface.

**Parameters**
- **host** – SPI peripheral to free

**Returns**
- **ESP_ERR_INVALID_ARG** if parameter is invalid
- **ESP_ERR_INVALID_STATE** if not all devices on the bus are freed
- **ESP_OK** on success

**esp_err_t spi_slave_queue_trans(spi_host_device_t host, const spi_slave_transaction_t *trans_desc, TickType_t ticks_to_wait)**

Queue a SPI transaction for execution.

Queues a SPI transaction to be executed by this slave device. (The transaction queue size was specified when the slave device was initialised via spi_slave_initialize.) This function may block if the queue is full (depending on the ticks_to_wait parameter). No SPI operation is directly initiated by this function, the next queued transaction will happen when the master initiates a SPI transaction by pulling down CS and sending out clock signals.

This function hands over ownership of the buffers in trans_desc to the SPI slave driver; the application is not to access this memory until spi_slave_queue_trans is called to hand ownership back to the application.

**Parameters**
- **host** – SPI peripheral that is acting as a slave
- **trans_desc** – Description of transaction to execute. Not const because we may want to write status back into the transaction description.
- **ticks_to_wait** – Ticks to wait until there’s room in the queue; use portMAX_DELAY to never time out.

**Returns**
- **ESP_ERR_INVALID_ARG** if parameter is invalid
- **ESP_OK** on success

**esp_err_t spi_slave_get_trans_result(spi_host_device_t host, spi_slave_transaction_t **trans_desc, TickType_t ticks_to_wait)**

Get the result of a SPI transaction queued earlier.

This routine will wait until a transaction to the given device (queued earlier with spi_slave_queue_trans) has successfully completed. It will then return the description of the completed transaction so software can inspect the result and e.g. free the memory or re-use the buffers.

It is mandatory to eventually use this function for any transaction queued by spi_slave_queue_trans.

**Parameters**
- **host** – SPI peripheral to that is acting as a slave
- **trans_desc** – [out] Pointer to variable able to contain a pointer to the description of the transaction that is executed
- **ticks_to_wait** – Ticks to wait until there’s a returned item; use portMAX_DELAY to never time out.

**Returns**
- **ESP_ERR_INVALID_ARG** if parameter is invalid
- **ESP_ERR_NOT_SUPPORTED** if flag SPI_SLAVE_NO_RETURN_RESULT is set
- **ESP_OK** on success

**esp_err_t spi_slave_transmit(spi_host_device_t host, spi_slave_transaction_t *trans_desc, TickType_t ticks_to_wait)**

Do a SPI transaction.

Essentially does the same as spi_slave_queue_trans followed by spi_slave_get_trans_result. Do not use this when there is still a transaction queued that hasn’t been finalized using spi_slave_get_trans_result.
Parameters

- **host** - SPI peripheral to that is acting as a slave
- **trans_desc** - Pointer to variable able to contain a pointer to the description of the transaction that is executed. Not const because we may want to write status back into the transaction description.
- **ticks_to_wait** - Ticks to wait until there’s a returned item; use portMAX_DELAY to never time out.

Returns

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

Structures

```c
struct spi_slave_interface_config_t
```

This is a configuration for a SPI host acting as a slave device.

Public Members

```c
int spics_io_num
```

CS GPIO pin for this device.

```c
uint32_t flags
```

Bitwise OR of SPI_SLAVE_* flags.

```c
int queue_size
```

Transaction queue size. This sets how many transactions can be ‘in the air’ (queued using spi_slave_queue_trans but not yet finished using spi_slave_get_trans_result) at the same time.

```c
uint8_t mode
```

SPI mode, representing a pair of (CPOL, CPHA) configuration:

- 0: (0, 0)
- 1: (0, 1)
- 2: (1, 0)
- 3: (1, 1)

```c
slave_transaction_cb_t post_setup_cb
```

Callback called after the SPI registers are loaded with new data.

This callback is called within interrupt context should be in IRAM for best performance, see “Transferring Speed” section in the SPI Master documentation for full details. If not, the callback may crash during flash operation when the driver is initialized with ESP_INTR_FLAG_IRAM.

```c
slave_transaction_cb_t post_trans_cb
```

Callback called after a transaction is done.

This callback is called within interrupt context should be in IRAM for best performance, see “Transferring Speed” section in the SPI Master documentation for full details. If not, the callback may crash during flash operation when the driver is initialized with ESP_INTR_FLAG_IRAM.

```c
struct spi_slave_transaction_t
```

This structure describes one SPI transaction
Chapter 2. API Reference

Public Members

size_t length
Total data length, in bits.

size_t trans_len
Transaction data length, in bits.

const void *tx_buffer
Pointer to transmit buffer, or NULL for no MOSI phase.

void *rx_buffer
Pointer to receive buffer, or NULL for no MISO phase. When the DMA is enabled, must start at WORD boundary (rx_buffer%4==0), and has length of a multiple of 4 bytes.

void *user
User-defined variable. Can be used to store eg transaction ID.

Macros

SPI_SLAVE_TXBIT_LSBFIRST
Transmit command/address/data LSB first instead of the default MSB first.

SPI_SLAVE_RXBIT_LSBFIRST
Receive data LSB first instead of the default MSB first.

SPI_SLAVE_BIT_LSBFIRST
Transmit and receive LSB first.

SPI_SLAVE_NO_RETURN_RESULT
Don’t return the descriptor to the host on completion (use post_trans_cb to notify instead)

Type Definitions

typedef void (slave_transaction_cb_t)(spi_slave_transaction_t *trans)

2.6.23 ESP32-WROOM-32SE (Secure Element)

Overview

The ESP32-WROOM-32SE has integrated Microchip’s ATECC608A cryptoauth chip in the module. ATECC608A is secure element which would generate and store ECC private key in the hardware. The ECC private key can be used to enhance security to connect to IoT cloud services with use of X.509 based mutual authentication. The application example demonstrates ECDSA sign and verify functions using ECC private key stored in ATECC608A

Application Example

Secure Element ECDSA Sign/Verify example: peripherals/secure_element/atecc608_ecdsa.
How to configure and provision ESP32-WROOM-32SE for TLS

To configure and provision ATECC608A chip on ESP32-WROOM-32SE please visit esp_cryptoauth_utility

How to use ATECC608A of ESP32-WROOM-32SE for TLS

ATECC608A can be used for TLS connections using ESP-TLS. To configure ESP-TLS for using secure element please refer ATECC608A with ESP-TLS in ESP-TLS documentation.

2.6.24 Touch Sensor

Introduction

A touch sensor system is built on a substrate which carries electrodes and relevant connections under a protective flat surface. When a user touches the surface, the capacitance variation is used to evaluate if the touch was valid.

The sensing pads can be arranged in different combinations (e.g., matrix, slider), so that a larger area or more points can be detected. The touch pad sensing process is under the control of a hardware-implemented finite-state machine (FSM) which is initiated by software or a dedicated hardware timer.

For design, operation, and control registers of a touch sensor, see ESP32 Technical Reference Manual > On-Chip Sensors and Analog Signal Processing [PDF].

In-depth design details of touch sensors and firmware development guidelines for ESP32 are available in Touch Sensor Application Note.

For more information about testing touch sensors in various configurations, please check the Guide for ESP32-Sense-Kit.

Functionality Overview

Description of API is broken down into groups of functions to provide a quick overview of the following features:

- Initialization of touch pad driver
- Configuration of touch pad GPIO pins
- Taking measurements
- Adjusting parameters of measurements
- Filtering measurements
- Touch detection methods
- Setting up interrupts to report touch detection
- Waking up from Sleep mode on interrupt

For detailed description of a particular function, please go to Section API Reference. Practical implementation of this API is covered in Section Application Examples.

Initialization  Before using a touch pad, you need to initialize the touch pad driver by calling the function touch_pad_init(). This function sets several ...DEFAULT driver parameters listed in API Reference under Macros. It also removes the information about which pads have been touched before, if any, and disables interrupts.

If the driver is not required anymore, deinitialize it by calling touch_pad_deinit().
Configuration  Enabling the touch sensor functionality for a particular GPIO is done with `touch_pad_config()`. The following 10 capacitive touch pads are supported for ESP32.

<table>
<thead>
<tr>
<th>Touch Pad</th>
<th>GPIO Pin</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>GPIO4</td>
</tr>
<tr>
<td>T1</td>
<td>GPIO0</td>
</tr>
<tr>
<td>T2</td>
<td>GPIO2</td>
</tr>
<tr>
<td>T3</td>
<td>MTDO</td>
</tr>
<tr>
<td>T4</td>
<td>MTCK</td>
</tr>
<tr>
<td>T5</td>
<td>MTDI</td>
</tr>
<tr>
<td>T6</td>
<td>MTMS</td>
</tr>
<tr>
<td>T7</td>
<td>GPIO27</td>
</tr>
<tr>
<td>T8</td>
<td>32K_XN</td>
</tr>
<tr>
<td>T9</td>
<td>32K_XP</td>
</tr>
</tbody>
</table>

Use the function `touch_pad_set_fsm_mode()` to select if touch pad measurement (operated by FSM) should be started automatically by a hardware timer, or by software. If software mode is selected, use `touch_pad_sw_start()` to start the FSM.

Touch State Measurements  The following two functions come in handy to read raw or filtered measurements from the sensor:

- `touch_pad_read_raw_data()`
- `touch_pad_read_filtered()`

They can also be used, for example, to evaluate a particular touch pad design by checking the range of sensor readings when a pad is touched or released. This information can be then used to establish a touch threshold.

**Note:** Before using `touch_pad_read_filtered()`, you need to initialize and configure the filter by calling specific filter functions described in Section Filtering of Measurements.

For the demonstration of how to read the touch pad data, check the application example `peripherals/touch_sensor/touch_sensor_v1/touch_pad_read`.

Method of Measurements  The touch sensor will count the number of charge/discharge cycles over a fixed period of time (specified by `touch_pad_set_measurement_clock_cycles()`). The count result is the raw data that read from `touch_pad_read_raw_data()`. After finishing one measurement, the touch sensor will sleep until the next measurement start, this interval between two measurements can be set by `touch_pad_set_measurement_interval()`.

**Note:** If the specified clock cycles for measurement is too small, the result may be inaccurate, but increasing clock cycles will increase the power consumption as well. Additionally, the response of the touch sensor will slow down if the total time of the interval and measurement is too long.

Optimization of Measurements  A touch sensor has several configurable parameters to match the characteristics of a particular touch pad design. For instance, to sense smaller capacity changes, it is possible to narrow down the reference voltage range within which the touch pads are charged / discharged. The high and low reference voltages are set using the function `touch_pad_set_voltage()`.

Besides the ability to discern smaller capacity changes, a positive side effect is reduction of power consumption for low power applications. A likely negative effect is an increase in measurement noise. If the dynamic range of obtained readings is still satisfactory, then further reduction of power consumption might be done by reducing the measurement time with `touch_pad_set_measurement_clock_cycles()`.

The following list summarizes available measurement parameters and corresponding ‘set’ functions:
• Touch pad charge / discharge parameters:
  – voltage range: `touch_pad_set_voltage()`
  – speed (slope): `touch_pad_set_cnt_mode()`

• Clock cycles of one measurement: `touch_pad_set_measurement_clock_cycles()`

Relationship between the voltage range (high/low reference voltages), speed (slope), and measurement time is shown in the figure below.

![Diagram of touch pad relationship between measurement parameters](image)

Fig. 23: Touch pad - relationship between measurement parameters

The last chart Output represents the touch sensor reading, i.e., the count of pulses collected within the measurement time.

All functions are provided in pairs to set a specific parameter and to get the current parameter’s value, e.g., `touch_pad_set_voltage()` and `touch_pad_get_voltage()`.

**Filtering of Measurements** If measurements are noisy, you can filter them with provided API functions. Before using the filter, please start it by calling `touch_pad_filter_start()`.

The filter type is IIR (infinite impulse response), and it has a configurable period that can be set with the function `touch_pad_set_filter_period()`.

You can stop the filter with `touch_pad_filter_stop()`. If not required anymore, the filter can be deleted by invoking `touch_pad_filter_delete()`.

**Touch Detection** Touch detection is implemented in ESP32’s hardware based on the user-configured threshold and raw measurements executed by FSM. Use the functions `touch_pad_get_status()` to check which pads have been touched and `touch_pad_clear_status()` to clear the touch status information.

Hardware touch detection can also be wired to interrupts. This is described in the next section.

If measurements are noisy and capacity changes are small, hardware touch detection might be unreliable. To resolve this issue, instead of using hardware detection / provided interrupts, implement measurement filtering and perform touch detection in your own application. For sample implementation of both methods of touch detection, see peripherals/touch_sensor/touch_sensor_v1/touch_pad_interrupt.

**Touch Triggered Interrupts** Before enabling an interrupt on a touch detection, you should establish a touch detection threshold. Use the functions described in Touch State Measurements to read and display sensor measurements when a pad is touched and released. Apply a filter if measurements are noisy and relative capacity changes are small.
Chapter 2. API Reference

Depending on your application and environment conditions, test the influence of temperature and power supply voltage changes on measured values.

Once a detection threshold is established, it can be set during initialization with `touch_pad_config()` or at the runtime with `touch_pad_set_thresh()`.

In the next step, configure how interrupts are triggered. They can be triggered below or above the threshold, which is set with the function `touch_pad_set_trigger_mode()`.

Finally, configure and manage interrupt calls using the following functions:

- `touch_pad_isr_register()` / `touch_pad_isr_deregister()`
- `touch_pad_intr_enable()` / `touch_pad_intr_disable()`

When interrupts are operational, you can obtain the information from which particular pad an interrupt came by invoking `touch_pad_get_status()` and clear the pad status with `touch_pad_clear_status()`.

**Note:** Interrupts on touch detection operate on raw / unfiltered measurements checked against user established threshold and are implemented in hardware. Enabling the software filtering API (see Filtering of Measurements) does not affect this process.

**Wakeup from Sleep Mode** If touch pad interrupts are used to wake up the chip from a sleep mode, you can select a certain configuration of pads (SET1 or both SET1 and SET2) that should be touched to trigger the interrupt and cause the subsequent wakeup. To do so, use the function `touch_pad_set_trigger_source()`.

Configuration of required bit patterns of pads may be managed for each ‘SET’ with:

- `touch_pad_set_group_mask()` / `touch_pad_get_group_mask()`
- `touch_pad_clear_group_mask()`

**Application Examples**

- Touch sensor read example: `peripherals/touch_sensor/touch_sensor_v1/touch_pad_read`.
- Touch sensor interrupt example: `peripherals/touch_sensor/touch_sensor_v1/touch_pad_interrupt`.

**API Reference**

**Header File**

- `components/driver/touch_sensor/esp32/include/driver/touch_sensor.h`

**Functions**

```c
esp_err_t touch_pad_config(touch_pad_t touch_num, uint16_t threshold)
```

Configure touch pad interrupt threshold.

**Note:** If FSM mode is set to TOUCH_FSM_MODE_TIMER, this function will be blocked for one measurement cycle and wait for data to be valid.

**Parameters**

- `touch_num` – touch pad index
- `threshold` – interrupt threshold,

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_ARG if argument wrong
- ESP_FAIL if touch pad not initialized
**esp_err_t touch_pad_read** *(touch_pad_t touch_num, uint16_t *touch_value)*

get touch sensor counter value. Each touch sensor has a counter to count the number of charge/discharge cycles. When the pad is not ‘touched’, we can get a number of the counter. When the pad is ‘touched’, the value in counter will get smaller because of the larger equivalent capacitance.

**Note:** This API requests hardware measurement once. If IIR filter mode is enabled, please use ‘touch_pad_read_raw_data’ interface instead.

**Parameters**
- **touch_num** – touch pad index
- **touch_value** – pointer to accept touch sensor value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of ‘touch_value’ is 0.
- ESP_FAIL Touch pad not initialized

**esp_err_t touch_pad_read_filtered** *(touch_pad_t touch_num, uint16_t *touch_value)*

get filtered touch sensor counter value by IIR filter.

**Note:** touch_pad_filter_start has to be called before calling touch_pad_read_filtered. This function can be called from ISR

**Parameters**
- **touch_num** – touch pad index
- **touch_value** – pointer to accept touch sensor value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of ‘touch_value’ is 0.
- ESP_FAIL Touch pad not initialized

**esp_err_t touch_pad_read_raw_data** *(touch_pad_t touch_num, uint16_t *touch_value)*

get raw data (touch sensor counter value) from IIR filter process. Need not request hardware measurements.

**Note:** touch_pad_filter_start has to be called before calling touch_pad_read_raw_data. This function can be called from ISR

**Parameters**
- **touch_num** – touch pad index
- **touch_value** – pointer to accept touch sensor value

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch pad parameter error
- ESP_ERR_INVALID_STATE This touch pad hardware connection is error, the value of ‘touch_value’ is 0.
- ESP_FAIL Touch pad not initialized

**esp_err_t touch_pad_set_filter_read_cb** *(filter_cb_t read_cb)*

Register the callback function that is called after each IIR filter calculation.
Note: The ‘read_cb’ callback is called in timer task in each filtering cycle.

**Parameters read_cb** - Pointer to filtered callback function. If the argument passed in is NULL, the callback will stop.

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG set error

**esp_err_t touch_pad_isr_register** (intr_handler_t fn, void *arg)
Register touch-pad ISR. The handler will be attached to the same CPU core that this function is running on.

**Parameters**
- fn - Pointer to ISR handler
- arg - Parameter for ISR

**Returns**
- ESP_OK Success;
- ESP_ERR_INVALID_ARG GPIO error
- ESP_ERR_NO_MEM No memory

**esp_err_t touch_pad_set_measurement_clock_cycles** (uint16_t clock_cycle)
Set the clock cycles of each measurement.

Note: This function will specify the clock cycles of each measurement and the clock is sourced from SOC_MOD_CLK_RTC_FAST, its default frequency is SOC_CLK_RC_FAST_FREQ_APPROX The touch sensor will record the charge and discharge times during these clock cycles as the final result (raw value)

Note: If clock cycles is too small, it may lead to inaccurate results.

**Parameters**
- clock_cycle - The clock cycles of each measurement measure_time = clock_cycle / SOC_CLK_RC_FAST_FREQ_APPROX, the maximum measure time is 0xffff / SOC_CLK_RC_FAST_FREQ_APPROX

**Returns**
- ESP_OK Set the clock cycle success

**esp_err_t touch_pad_get_measurement_clock_cycles** (uint16_t *clock_cycle)
Get the clock cycles of each measurement.

**Parameters**
- clock_cycle - The clock cycles of each measurement

**Returns**
- ESP_OK Get the clock cycle success
- ESP_ERR_INVALID_ARG The input parameter is NULL

**esp_err_t touch_pad_set_measurement_interval** (uint16_t interval_cycle)
Set the interval between two measurements.

Note: The touch sensor will sleep between two measurements This function is to set the interval cycle And the interval is clocked from SOC_MOD_CLK_RTC_SLOW, its default frequency is SOC_CLK_RC_SLOW_FREQ_APPROX

**Parameters**
- interval_cycle - The interval between two measurements sleep_time = interval_cycle / SOC_CLK_RC_SLOW_FREQ_APPROX. The approximate frequency value of RTC_SLOW_CLK can be obtained using rtc_clk_slow_freq_get_hz function.

**Returns**
**Chapter 2. API Reference**

- ESP_OK Set interval cycle success

**esp_err_t touch_pad_get_measurement_interval** (uint16_t *interval_cycle)

Get the interval between two measurements.

**Parameters**

- *interval_cycle* - The interval between two measurements

**Returns**

- ESP_OK Get interval cycle success
- ESP_ERR_INVALID_ARG The input parameter is NULL

**esp_err_t touch_pad_set_meas_time** (uint16_t sleep_cycle, uint16_t meas_cycle)

Set touch sensor measurement and sleep time. Excessive total time will slow down the touch response. Too small measurement time will not be sampled enough, resulting in inaccurate measurements.

**Note:** The touch sensor will count the number of charge/discharge cycles over a fixed period of time (specified as the second parameter). That means the number of cycles (raw value) will decrease as the capacity of the touch pad is increasing.

**Note:** The greater the duty cycle of the measurement time, the more system power is consumed.

**Parameters**

- *sleep_cycle* - The touch sensor will sleep after each measurement. sleep_cycle decide the interval between each measurement. t_sleep = sleep_cycle / SOC_CLK_RC_SLOW_FREQ_APPROX. The approximate frequency value of RTC_SLOW_CLK can be obtained using rtc_clk_slow_freq_get_hz function.
- *meas_cycle* - The duration of the touch sensor measurement. t_meas = meas_cycle / SOC_CLK_RC_FAST_FREQ_APPROX, the maximum measure time is 0xffff / SOC_CLK_RC_FAST_FREQ_APPROX

**Returns**

- ESP_OK on success

**esp_err_t touch_pad_get_meas_time** (uint16_t *sleep_cycle, uint16_t *meas_cycle)

Get touch sensor measurement and sleep time.

**Parameters**

- *sleep_cycle* - Pointer to accept sleep cycle number
- *meas_cycle* - Pointer to accept measurement cycle count.

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG The input parameter is NULL

**esp_err_t touch_pad_sw_start** (void)

Trigger a touch sensor measurement, only support in SW mode of FSM.

**Returns**

- ESP_OK on success

**esp_err_t touch_pad_set_thresh** (touch_pad_t touch_num, uint16_t threshold)

Set touch sensor interrupt threshold.

**Parameters**

- *touch_num* - touch pad index
- *threshold* - threshold of touchpad count, refer to touch_pad_set_trigger_mode to see how to set trigger mode.

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong
**esp_err_t** **touch_pad_get_thresh**(touch_pad_t touch_num, uint16_t *threshold)

Get touch sensor interrupt threshold.

**Parameters**

- **touch_num** — touch pad index
- **threshold** — pointer to accept threshold

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t** **touch_pad_set_trigger_mode**(touch_trigger_mode_t mode)

Set touch sensor interrupt trigger mode. Interrupt can be triggered either when counter result is less than threshold or when counter result is more than threshold.

**Parameters**

- **mode** — touch sensor interrupt trigger mode

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t** **touch_pad_get_trigger_mode**(touch_trigger_mode_t *mode)

Get touch sensor interrupt trigger mode.

**Parameters**

- **mode** — pointer to accept touch sensor interrupt trigger mode

**Returns**

- ESP_OK on success

**esp_err_t** **touch_pad_set_trigger_source**(touch_trigger_src_t src)

Set touch sensor interrupt trigger source. There are two sets of touch signals. Set1 and set2 can be mapped to several touch signals. Either set will be triggered if at least one of its touch signal is ‘touched’. The interrupt can be configured to be generated if set1 is triggered, or only if both sets are triggered.

**Parameters**

- **src** — touch sensor interrupt trigger source

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t** **touch_pad_get_trigger_source**(touch_trigger_src_t *src)

Get touch sensor interrupt trigger source.

**Parameters**

- **src** — pointer to accept touch sensor interrupt trigger source

**Returns**

- ESP_OK on success

**esp_err_t** **touch_pad_set_group_mask**(uint16_t set1_mask, uint16_t set2_mask, uint16_t en_mask)

Set touch sensor group mask. Touch pad module has two sets of signals, ‘Touched’ signal is triggered only if at least one of touch pad in this group is “touched”. This function will set the register bits according to the given bitmask.

**Parameters**

- **set1_mask** — bitmask of touch sensor signal group1, it’s a 10-bit value
- **set2_mask** — bitmask of touch sensor signal group2, it’s a 10-bit value
- **en_mask** — bitmask of touch sensor work enable, it’s a 10-bit value

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t** **touch_pad_get_group_mask**(uint16_t *set1_mask, uint16_t *set2_mask, uint16_t *en_mask)

Get touch sensor group mask.

**Parameters**

- **set1_mask** — pointer to accept bitmask of touch sensor signal group1, it’s a 10-bit value
- **set2_mask** — pointer to accept bitmask of touch sensor signal group2, it’s a 10-bit value
- **en_mask** — pointer to accept bitmask of touch sensor work enable, it’s a 10-bit value
Returns

• ESP_OK on success

`esp_err_t touch_pad_clear_group_mask(uint16_t set1_mask, uint16_t set2_mask, uint16_t en_mask)`

Clear touch sensor group mask. Touch pad module has two sets of signals, Interrupt is triggered only if at least one of touch pad in this group is “touched”. This function will clear the register bits according to the given bitmask.

Parameters

• `set1_mask` – bitmask touch sensor signal group1, it’s a 10-bit value
• `set2_mask` – bitmask touch sensor signal group2, it’s a 10-bit value
• `en_mask` – bitmask of touch sensor work enable, it’s a 10-bit value

Returns

• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

`esp_err_t touch_pad_intr_enable(void)`

To enable touch pad interrupt.

Returns

• ESP_OK on success

`esp_err_t touch_pad_intr_disable(void)`

To disable touch pad interrupt.

Returns

• ESP_OK on success

`esp_err_t touch_pad_intr_clear(void)`

To clear touch pad interrupt.

Returns

• ESP_OK on success

`esp_err_t touch_pad_set_filter_period(uint32_t new_period_ms)`

Set touch pad filter calibration period, in ms. Need to call `touch_pad_filter_start` before all touch filter APIs

Parameters `new_period_ms` – filter period, in ms

Returns

• ESP_OK Success
• ESP_ERR_INVALID_STATE driver state error
• ESP_ERR_INVALID_ARG parameter error

`esp_err_t touch_pad_get_filter_period(uint32_t *p_period_ms)`

Get touch pad filter calibration period, in ms. Need to call `touch_pad_filter_start` before all touch filter APIs

Parameters `p_period_ms` – pointer to accept period

Returns

• ESP_OK Success
• ESP_ERR_INVALID_STATE driver state error
• ESP_ERR_INVALID_ARG parameter error

`esp_err_t touch_pad_filter_start(uint32_t filter_period_ms)`

Start touch pad filter function. This API will start a filter to process the noise in order to prevent false triggering when detecting slight change of capacitance. Need to call `touch_pad_filter_start` before all touch filter APIs

Note: This filter uses FreeRTOS timer, which is dispatched from a task with priority 1 by default on CPU 0. So if some application task with higher priority takes a lot of CPU0 time, then the quality of data obtained from this filter will be affected. You can adjust FreeRTOS timer task priority in menuconfig.

Parameters `filter_period_ms` – filter calibration period, in ms
Chapter 2. API Reference

Returns
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter error
- ESP_ERR_NO_MEM No memory for driver
- ESP_ERR_INVALID_STATE driver state error

`esp_err_t touch_pad_filter_stop (void)`
stop touch pad filter function Need to call `touch_pad_filter_start` before all touch filter APIs

Returns
- ESP_OK Success
- ESP_ERR_INVALID_STATE driver state error

`esp_err_t touch_pad_filter_delete (void)`
delete touch pad filter driver and release the memory Need to call `touch_pad_filter_start` before all touch filter APIs

Returns
- ESP_OK Success
- ESP_ERR_INVALID_STATE driver state error

Type Definitions

typedef void (*filter_cb_t)(uint16_t *raw_value, uint16_t *filtered_value)

Callback function that is called after each IIR filter calculation.

**Note:** This callback is called in timer task in each filtering cycle.

**Note:** This callback should not be blocked.

**Param raw_value** The latest raw data(touch sensor counter value) that points to all channels(`raw_value[0..TOUCH_PAD_MAX-1]`).

**Param filtered_value** The latest IIR filtered data(calculated from raw data) that points to all channels(`filtered_value[0..TOUCH_PAD_MAX-1]`).

Header File

- components/driver/touch_sensor/include/driver/touch_sensor_common.h

Functions

`esp_err_t touch_pad_init (void)`
Initialize touch module.

**Note:** If default parameter don’t match the usage scenario, it can be changed after this function.

Returns
- ESP_OK Success
- ESP_ERR_NO_MEM Touch pad init error
- ESP_ERR_NOT_SUPPORTED Touch pad is providing current to external XTAL
**esp_err_t touch_pad_deinit (void)**

Un-install touch pad driver.

**Note:** After this function is called, other touch functions are prohibited from being called.

**Returns**
- ESP_OK Success
- ESP_FAIL Touch pad driver not initialized

**esp_err_t touch_pad_io_init (touch_pad_t touch_num)**

Initialize touch pad GPIO.

**Parameters** touch_num – touch pad index

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t touch_pad_set_voltage (touch_high_volt_t refh, touch_low_volt_t refl, touch_volt_atten_t atten)**

Set touch sensor high voltage threshold of chanrge. The touch sensor measures the channel capacitance value by charging and discharging the channel. So the high threshold should be less than the supply voltage.

**Parameters**
- refh – the value of DREFH
- refl – the value of DREFL
- atten – the attenuation on DREFH

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t touch_pad_get_voltage (touch_high_volt_t *refh, touch_low_volt_t *refl, touch_volt_atten_t *atten)**

Get touch sensor reference voltage.

**Parameters**
- refh – pointer to accept DREFH value
- refl – pointer to accept DREFL value
- atten – pointer to accept the attenuation on DREFH

**Returns**
- ESP_OK on success

**esp_err_t touch_pad_set_cnt_mode (touch_pad_t touch_num, touch_cnt_slope_t slope, touch_tie_opt_t opt)**

Set touch sensor charge/discharge speed for each pad. If the slope is 0, the counter would always be zero. If the slope is 1, the charging and discharging would be slow, accordingly. If the slope is set 7, which is the maximum value, the charging and discharging would be fast.

**Note:** The higher the charge and discharge current, the greater the immunity of the touch channel, but it will increase the system power consumption.

**Parameters**
- touch_num – touch pad index
- slope – touch pad charge/discharge speed
- opt – the initial voltage

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong
**esp_err_t** `touch_pad_get_cnt_mode` *(touch_pad_t touch_num, touch_cnt_slope_t *slope, touch_tie_opt_t *opt)*

Get touch sensor charge/discharge speed for each pad.

**Parameters**
- `touch_num` – touch pad index
- `slope` – pointer to accept touch pad charge/discharge slope
- `opt` – pointer to accept the initial voltage

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t** `touch_pad_isr_deregister` *(void (*fn)(void*), void *arg)*

Deregister the handler previously registered using `touch_pad_isr_handler_register`.

**Parameters**
- `fn` – handler function to call (as passed to `touch_pad_isr_handler_register`)
- `arg` – argument of the handler (as passed to `touch_pad_isr_handler_register`)

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if a handler matching both `fn` and `arg` isn’t registered

**esp_err_t** `touch_pad_get_wakeup_status` *(touch_pad_t *pad_num)*

Get the touch pad which caused wakeup from deep sleep.

**Parameters** `pad_num` – pointer to touch pad which caused wakeup

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter is NULL

**esp_err_t** `touch_pad_get_fsm_mode` *(touch_fsm_mode_t *mode)*

Set touch sensor FSM mode, the test action can be triggered by the timer, as well as by the software.

**Parameters** `mode` – FSM mode

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if argument is wrong

**esp_err_t** `touch_pad_set_fsm_mode` *(touch_fsm_mode_t mode)*

Get touch sensor FSM mode.

**Parameters** `mode` – pointer to accept FSM mode

**Returns**
- ESP_OK on success

**esp_err_t** `touch_pad_clear_status` *(void)*

To clear the touch sensor channel active status.

**Note:** The FSM automatically updates the touch sensor status. It is generally not necessary to call this API to clear the status.

**Returns**
- ESP_OK on success

**uint32_t** `touch_pad_get_status` *(void)*

Get the touch sensor channel active status mask. The bit position represents the channel number. The 0/1 status of the bit represents the trigger status.

**Returns**
- The touch sensor status. e.g. Touch1 trigger status is `status_mask & (BIT1)`. 

---

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**Release v5.1.2**
bool touch_pad_meas_is_done(void)
Check touch sensor measurement status.

Returns
- True measurement is under way
- False measurement done

GPIO Lookup Macros Some useful macros can be used to specified the GPIO number of a touch pad channel, or vice versa. e.g.
1. TOUCH_PAD_NUM5_GPIO_NUM is the GPIO number of channel 5 (12);
2. TOUCH_PAD_GPIO4_CHANNEL is the channel number of GPIO 4 (channel 0).

Header File
- components/soc/esp32/include/soc/touch_sensor_channel.h

Macros
TOUCH_PAD_GPIO4_CHANNEL
TOUCH_PAD_NUM0_GPIO_NUM
TOUCH_PAD_GPIO0_CHANNEL
TOUCH_PAD_NUM1_GPIO_NUM
TOUCH_PAD_GPIO2_CHANNEL
TOUCH_PAD_NUM2_GPIO_NUM
TOUCH_PAD_GPIO15_CHANNEL
TOUCH_PAD_NUM3_GPIO_NUM
TOUCH_PAD_GPIO13_CHANNEL
TOUCH_PAD_NUM4_GPIO_NUM
TOUCH_PAD_GPIO12_CHANNEL
TOUCH_PAD_NUM5_GPIO_NUM
TOUCH_PAD_GPIO14_CHANNEL
TOUCH_PAD_NUM6_GPIO_NUM
TOUCH_PAD_GPIO27_CHANNEL
Chapter 2. API Reference

TOUCH_PAD_NUM7_GPIO_NUM

TOUCH_PAD_GPIO33_CHANNEL

TOUCH_PAD_NUM8_GPIO_NUM

TOUCH_PAD_GPIO32_CHANNEL

TOUCH_PAD_NUM9_GPIO_NUM

Header File

- components/hal/include/hal/touch_sensor_types.h

Macros

TOUCH_PAD_BIT_MASK_ALL

TOUCH_PAD_SLOPE_DEFAULT

TOUCH_PAD_TIE_OPT_DEFAULT

TOUCH_PAD_BIT_MASK_MAX

TOUCH_PAD_HIGH_VOLTAGE_THRESHOLD

TOUCH_PAD_LOW_VOLTAGE_THRESHOLD

TOUCH_PAD_ATTEN_VOLTAGE_THRESHOLD

TOUCH_PAD_IDLE_CH_CONNECT_DEFAULT

TOUCH_PAD_THRESHOLD_MAX

If set touch threshold max value, The touch sensor can’t be in touched status

TOUCH_PAD_SLEEP_CYCLE_DEFAULT

The timer frequency is RTC_SLOW_CLK (can be 150k or 32k depending on the options), max value is 0xffff

TOUCH_PAD_MEASURE_CYCLE_DEFAULT

The timer frequency is 8Mhz, the max value is 0x7fff

TOUCH_FSM_MODE_DEFAULT

The touch FSM my best be started by the software or timer

TOUCH_TRIGGER_MODE_DEFAULT

Interrupts can be triggered if sensor value gets below or above threshold

TOUCH_TRIGGER_SOURCE_DEFAULT

The wakeup trigger source can be SET1 or both SET1 and SET2
Enumerations

enum touch_pad_t
    Touch pad channel

    Values:

    enumerator TOUCH_PAD_NUM0
        Touch pad channel 0 is GPIO4(ESP32)

    enumerator TOUCH_PAD_NUM1
        Touch pad channel 1 is GPIO0(ESP32) / GPIO1(ESP32-S2)

    enumerator TOUCH_PAD_NUM2
        Touch pad channel 2 is GPIO2(ESP32) / GPIO2(ESP32-S2)

    enumerator TOUCH_PAD_NUM3
        Touch pad channel 3 is GPIO15(ESP32) / GPIO3(ESP32-S2)

    enumerator TOUCH_PAD_NUM4
        Touch pad channel 4 is GPIO13(ESP32) / GPIO4(ESP32-S2)

    enumerator TOUCH_PAD_NUM5
        Touch pad channel 5 is GPIO12(ESP32) / GPIO5(ESP32-S2)

    enumerator TOUCH_PAD_NUM6
        Touch pad channel 6 is GPIO14(ESP32) / GPIO6(ESP32-S2)

    enumerator TOUCH_PAD_NUM7
        Touch pad channel 7 is GPIO27(ESP32) / GPIO7(ESP32-S2)

    enumerator TOUCH_PAD_NUM8
        Touch pad channel 8 is GPIO33(ESP32) / GPIO8(ESP32-S2)

    enumerator TOUCH_PAD_NUM9
        Touch pad channel 9 is GPIO32(ESP32) / GPIO9(ESP32-S2)

    enumerator TOUCH_PAD_MAX

enum touch_high_volt_t
    Touch sensor high reference voltage

    Values:

    enumerator TOUCH_HVOLT_KEEP
        Touch sensor high reference voltage, no change

    enumerator TOUCH_HVOLT_2V4
        Touch sensor high reference voltage, 2.4V

    enumerator TOUCH_HVOLT_2V5
        Touch sensor high reference voltage, 2.5V
enumerator TOUCH_HVOLT_2V6
    Touch sensor high reference voltage, 2.6V

touch_low_volt_t
    Touch sensor low reference voltage

    Values:

enumerator TOUCH_LVOLT_KEEP
    Touch sensor low reference voltage, no change

touch_volt_atten_t
    Touch sensor high reference voltage attenuation

    Values:

enumerator TOUCH_HVOLT_ATTEN_KEEP
    Touch sensor high reference voltage attenuation, no change

touch_volt_atten_t
    Touch sensor high reference voltage attenuation

    Values:

enumerator TOUCH_HVOLT_ATTEN_1V5
    Touch sensor high reference voltage attenuation, 1.5V attenuation
enumerator TOUCH_HVOLT_ATTEN_MAX

definition touch_cnt_slope_t

    Touch sensor charge/discharge speed

Values:

enumerator TOUCH_PAD_SLOPE_0

    Touch sensor charge / discharge speed, always zero

enumerator TOUCH_PAD_SLOPE_1

    Touch sensor charge / discharge speed, slowest

enumerator TOUCH_PAD_SLOPE_2

    Touch sensor charge / discharge speed

enumerator TOUCH_PAD_SLOPE_3

    Touch sensor charge / discharge speed

enumerator TOUCH_PAD_SLOPE_4

    Touch sensor charge / discharge speed

enumerator TOUCH_PAD_SLOPE_5

    Touch sensor charge / discharge speed

enumerator TOUCH_PAD_SLOPE_6

    Touch sensor charge / discharge speed

enumerator TOUCH_PAD_SLOPE_7

    Touch sensor charge / discharge speed, fast

enumerator TOUCH_PAD_SLOPE_MAX


definition touch_tie_opt_t

    Touch sensor initial charge level

Values:

enumerator TOUCH_PAD_TIE_OPT_LOW

    Initial level of charging voltage, low level

enumerator TOUCH_PAD_TIE_OPT_HIGH

    Initial level of charging voltage, high level

enumerator TOUCH_PAD_TIE_OPT_MAX


definition touch_fsm_mode_t

    Touch sensor FSM mode

Values:
enumerator **TOUCH_FSM_MODE_TIMER**
   To start touch FSM by timer

enumerator **TOUCH_FSM_MODE_SW**
   To start touch FSM by software trigger

enumerator **TOUCH_FSM_MODE_MAX**

enum **touch_trigger_mode_t**
   
   *Values:*

   enumerator **TOUCH_TRIGGER_BELOW**
      Touch interrupt will happen if counter value is less than threshold.

   enumerator **TOUCH_TRIGGER_ABOVE**
      Touch interrupt will happen if counter value is larger than threshold.

   enumerator **TOUCH_TRIGGER_MAX**

enum **touch_trigger_src_t**
   
   *Values:*

   enumerator **TOUCH_TRIGGER_SOURCE_BOTH**
      wakeup interrupt is generated if both SET1 and SET2 are “touched”

   enumerator **TOUCH_TRIGGER_SOURCE_SET1**
      wakeup interrupt is generated if SET1 is “touched”

   enumerator **TOUCH_TRIGGER_SOURCE_MAX**

### 2.6.25 Two-Wire Automotive Interface (TWAI)

**Overview**

The Two-Wire Automotive Interface (TWAI) is a real-time serial communication protocol suited for automotive and industrial applications. It is compatible with ISO11898-1 Classical frames, thus can support Standard Frame Format (11-bit ID) and Extended Frame Format (29-bit ID). The ESP32 contains 1 TWAI controller(s) that can be configured to communicate on a TWAI bus via an external transceiver.

**Warning:** The TWAI controller is not compatible with ISO11898-1 FD Format frames, and will interpret such frames as errors.

This programming guide is split into the following sections:

**Sections**

- **Two-Wire Automotive Interface (TWAI)**
  - **Overview**
**TWAI Protocol Summary**

The TWAI is a multi-master, multi-cast, asynchronous, serial communication protocol. TWAI also supports error detection and signalling, and inbuilt message prioritization.

**Multi-master:** Any node on the bus can initiate the transfer of a message.

**Multi-cast:** When a node transmits a message, all nodes on the bus will receive the message (i.e., broadcast) thus ensuring data consistency across all nodes. However, some nodes can selectively choose which messages to accept via the use of acceptance filtering (multi-cast).

**Asynchronous:** The bus does not contain a clock signal. All nodes on the bus operate at the same bit rate and synchronize using the edges of the bits transmitted on the bus.

**Error Detection and Signalling:** Every node will constantly monitor the bus. When any node detects an error, it will signal the detection by transmitting an error frame. Other nodes will receive the error frame and transmit their own error frames in response. This will result in an error detection being propagated to all nodes on the bus.

**Message Priorities:** Messages contain an ID field. If two or more nodes attempt to transmit simultaneously, the node transmitting the message with the lower ID value will win arbitration of the bus. All other nodes will become receivers ensuring that there is at most one transmitter at any time.

**TWAI Messages**  
TWAI Messages are split into Data Frames and Remote Frames. Data Frames are used to deliver a data payload to other nodes, whereas a Remote Frame is used to request a Data Frame from other nodes (other nodes can optionally respond with a Data Frame). Data and Remote Frames have two frame formats known as **Extended Frame** and **Standard Frame** which contain a 29-bit ID and an 11-bit ID respectively. A TWAI message consists of the following fields:

- 29-bit or 11-bit ID: Determines the priority of the message (lower value has higher priority).
- Data Length Code (DLC) between 0 to 8: Indicates the size (in bytes) of the data payload for a Data Frame, or the amount of data to request for a Remote Frame.
- Up to 8 bytes of data for a Data Frame (should match DLC).

**Error States and Counters**  
The TWAI protocol implements a feature known as “fault confinement” where a persistently erroneous node will eventually eliminate itself form the bus. This is implemented by requiring every node to maintain two internal error counters known as the **Transmit Error Counter (TEC)** and the **Receive Error Counter (REC)**. The two error counters are incremented and decremented according to a set of rules (where the counters increase on an error, and decrease on a successful message transmission/reception). The values of the counters are used to determine a node’s **error state**, namely **Error Active**, **Error Passive**, and **Bus-Off**.

**Error Active:** A node is Error Active when both TEC and REC are less than 128 and indicates that the node is operating normally. Error Active nodes are allowed to participate in bus communications, and will actively signal the detection of any errors by automatically transmitting an **Active Error Flag** over the bus.

**Error Passive:** A node is Error Passive when either the TEC or REC becomes greater than or equal to 128. Error Passive nodes are still able to take part in bus communications, but will instead transmit a **Passive Error Flag** upon detection of an error.

**Bus-Off:** A node becomes Bus-Off when the TEC becomes greater than or equal to 256. A Bus-Off node is unable influence the bus in any manner (essentially disconnected from the bus) thus eliminating itself from the bus. A node will remain in the Bus-Off state until it undergoes bus-off recovery.
Signals Lines and Transceiver

The TWAI controller does not contain an integrated transceiver. Therefore, to connect the TWAI controller to a TWAI bus, an external transceiver is required. The type of external transceiver used should depend on the application’s physical layer specification (e.g., using SN65HVD23x transceivers for ISO 11898-2 compatibility).

The TWAI controller’s interface consists of 4 signal lines known as TX, RX, BUS-OFF, and CLKOUT. These four signal lines can be routed through the GPIO Matrix to the ESP32’s GPIO pads.

![Fig. 24: Signal lines of the TWAI controller](image)

**TX and RX:** The TX and RX signal lines are required to interface with an external transceiver. Both signal lines represent/interpret a dominant bit as a low logic level (0V), and a recessive bit as a high logic level (3.3V).

**BUS-OFF:** The BUS-OFF signal line is optional and is set to a low logic level (0V) whenever the TWAI controller reaches a bus-off state. The BUS-OFF signal line is set to a high logic level (3.3V) otherwise.

**CLKOUT:** The CLKOUT signal line is optional and outputs a prescaled version of the controller’s source clock.

**Note:** An external transceiver must internally loopback the TX to RX such that a change in logic level to the TX signal line can be observed on the RX line. Failing to do so will cause the TWAI controller to interpret differences in logic levels between the two signal lines as a loss in arbitration or a bit error.

Driver Configuration

This section covers how to configure the TWAI driver.

**Operating Modes** The TWAI driver supports the following modes of operations:

**Normal Mode:** The normal operating mode allows the TWAI controller to take part in bus activities such as transmitting and receiving messages/error frames. Acknowledgement from another node is required when transmitting a message.

**No Ack Mode:** The No Acknowledgement mode is similar to normal mode, however acknowledgements are not required for a message transmission to be considered successful. This mode is useful when self testing the TWAI controller (loopback of transmissions).
Listen Only Mode: This mode will prevent the TWAI controller from influencing the bus. Therefore, transmission of messages/acknowledgement/error frames will be disabled. However, the TWAI controller will still be able to receive messages but will not acknowledge the message. This mode is suited for bus monitor applications.

Alerts The TWAI driver contains an alert feature that is used to notify the application layer of certain TWAI controller or TWAI bus events. Alerts are selectively enabled when the TWAI driver is installed, but can be reconfigured during runtime by calling `twai_reconfigure_alerts()`. The application can then wait for any enabled alerts to occur by calling `twai_read_alerts()`. The TWAI driver supports the following alerts:

<table>
<thead>
<tr>
<th>Alert Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWAI_ALERT_TX_IDLE</td>
<td>No more messages queued for transmission</td>
</tr>
<tr>
<td>TWAI_ALERT_TX_SUCCESS</td>
<td>The previous transmission was successful</td>
</tr>
<tr>
<td>TWAI_ALERT_RX_DATA</td>
<td>A frame has been received and added to the RX queue</td>
</tr>
<tr>
<td>TWAI_ALERT_BELOW_ERR_WARN</td>
<td>Both error counters have dropped below error warning limit</td>
</tr>
<tr>
<td>TWAI_ALERT_ERR_ACTIVE</td>
<td>TWAI controller has become error active</td>
</tr>
<tr>
<td>TWAI_ALERT_RECOVERY_IN_PROGRESS</td>
<td>TWAI controller is undergoing bus recovery</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_RECOVERED</td>
<td>TWAI controller has successfully completed bus recovery</td>
</tr>
<tr>
<td>TWAI_ALERT_ARB_LOST</td>
<td>The previous transmission lost arbitration</td>
</tr>
<tr>
<td>TWAI_ALERT_ABOVE_ERR_WARN</td>
<td>One of the error counters have exceeded the error warning limit</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_ERROR</td>
<td>A (Bit, Stuff, CRC, Form, ACK) error has occurred on the bus</td>
</tr>
<tr>
<td>TWAI_ALERT_TX_FAILED</td>
<td>The previous transmission has failed</td>
</tr>
<tr>
<td>TWAI_ALERT_RX_QUEUE_FULL</td>
<td>The RX queue is full causing a received frame to be lost</td>
</tr>
<tr>
<td>TWAI_ALERT_ERR_PASS</td>
<td>TWAI controller has become error passive</td>
</tr>
<tr>
<td>TWAI_ALERT_BUS_OFF</td>
<td>Bus-off condition occurred. TWAI controller can no longer influence bus</td>
</tr>
</tbody>
</table>

Note: The TWAI controller’s error warning limit is used to preemptively warn the application of bus errors before the error passive state is reached. By default, the TWAI driver sets the error warning limit to 96. The TWAI_ALERT_ABOVE_ERR_WARN is raised when the TEC or REC becomes larger then or equal to the error warning limit. The TWAI_ALERT_BELOW_ERR_WARN is raised when both TEC and REC return back to values below 96.

Note: When enabling alerts, the TWAI_ALERT_AND_LOG flag can be used to cause the TWAI driver to log any raised alerts to UART. However, alert logging is disabled and TWAI_ALERT_AND_LOG if the CONFIG_TWAI_ISR_IN_IRAM option is enabled (see Placing ISR into IRAM).

Note: The TWAI_ALERT_ALL and TWAI_ALERT_NONE macros can also be used to enable/disable all alerts during configuration/reconfiguration.

Bit Timing The operating bit rate of the TWAI driver is configured using the `twai_timing_config_t` structure. The period of each bit is made up of multiple time quanta, and the period of a time quantum is determined by a prescaled version of the TWAI controller’s source clock. A single bit contains the following segments in the following order:

1. The Synchronization Segment consists of a single time quantum
2. Timing Segment 1 consists of 1 to 16 time quanta before sample point
3. Timing Segment 2 consists of 1 to 8 time quanta after sample point

The Baudrate Prescaler is used to determine the period of each time quantum by dividing the TWAI controller’s source clock. On the ESP32, the `brp` can be any even number from 2 to 128. Alternatively, you can decide the resolution of each quantum, by setting `twai_timing_config_t::quanta_resolution_hz` to a non-zero
value. In this way, the driver can calculate the underlying \texttt{brp} value for you. It’s useful when you set different clock sources but want the bitrate to keep the same.

Supported clock source for a TWAI controller is listed in the \texttt{twai_clock_source_t} and can be specified in \texttt{twai_timing_config_t::clk_src}.

If the ESP32 is a revision 2 or later chip, the \texttt{brp} will also support any multiple of 4 from 132 to 256, and can be enabled by setting the \texttt{CONFIG_ESP32_REV_MIN} to revision 2 or higher.

![Diagram](image)

Fig. 25: Bit timing configuration for 500kbit/s given BRP = 8, clock source frequency is 80MHz

The sample point of a bit is located on the intersection of Timing Segment 1 and 2. Enabling \textbf{Triple Sampling} will cause 3 time quanta to be sampled per bit instead of 1 (extra samples are located at the tail end of Timing Segment 1).

The \textbf{Synchronization Jump Width} is used to determine the maximum number of time quanta a single bit time can be lengthened/shortened for synchronization purposes. \texttt{sjw} can range from \textbf{1} to \textbf{4}.

\textbf{Note}: Multiple combinations of \texttt{brp}, \texttt{tseg_1}, \texttt{tseg_2}, and \texttt{sjw} can achieve the same bit rate. Users should tune these values to the physical characteristics of their bus by taking into account factors such as \textbf{propagation delay}, \textbf{node information processing time}, and \textbf{phase errors}.

Bit timing \textbf{macro initializers} are also available for commonly used bit rates. The following macro initializers are provided by the TWAI driver.

- \texttt{TWAI\_TIMING\_CONFIG\_1MBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_800KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_500KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_250KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_125KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_100KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_50KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_25KBITS}

Revision 2 or later of the ESP32 also supports the following bit rates:

- \texttt{TWAI\_TIMING\_CONFIG\_20KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_16KBITS}
- \texttt{TWAI\_TIMING\_CONFIG\_12\_5KBITS}

\textbf{Acceptance Filter} The TWAI controller contains a hardware acceptance filter which can be used to filter messages of a particular ID. A node that filters out a message will not receive the message, but will still acknowledge it. Acceptance filters can make a node more efficient by filtering out messages sent over the bus that are irrelevant to the node. The acceptance filter is configured using two 32-bit values within \texttt{twai_filter_config_t} known as the \textbf{acceptance code} and the \textbf{acceptance mask}.

The \textbf{acceptance code} specifies the bit sequence which a message’s ID, RTR, and data bytes must match in order for the message to be received by the TWAI controller. The \textbf{acceptance mask} is a bit sequence specifying which bits of the acceptance code can be ignored. This allows for a messages of different IDs to be accepted by a single acceptance code.
Chapter 2. API Reference

The acceptance filter can be used under **Single or Dual Filter Mode**. Single Filter Mode will use the acceptance code and mask to define a single filter. This allows for the first two data bytes of a standard frame to be filtered, or the entirety of an extended frame’s 29-bit ID. The following diagram illustrates how the 32-bit acceptance code and mask will be interpreted under Single Filter Mode (Note: The yellow and blue fields represent standard and extended frame formats respectively).

![Fig. 26: Bit layout of single filter mode (Right side MSBit)](image)

**Dual Filter Mode** will use the acceptance code and mask to define two separate filters allowing for increased flexibility of ID’s to accept, but does not allow for all 29-bits of an extended ID to be filtered. The following diagram illustrates how the 32-bit acceptance code and mask will be interpreted under **Dual Filter Mode** (Note: The yellow and blue fields represent standard and extended frame formats respectively).

![Fig. 27: Bit layout of dual filter mode (Right side MSBit)](image)

**Disabling TX Queue** The TX queue can be disabled during configuration by setting the `tx_queue_len` member of `twai_general_config_t` to 0. This will allow applications that do not require message transmission to save a small amount of memory when using the TWAI driver.

**Placing ISR into IRAM** The TWAI driver’s ISR (Interrupt Service Routine) can be placed into IRAM so that the ISR can still run whilst the cache is disabled. Placing the ISR into IRAM may be necessary to maintain the TWAI driver’s functionality during lengthy cache disabling operations (such as SPI Flash writes, OTA updates etc). Whilst the cache is disabled, the ISR will continue to:

- Read received messages from the RX buffer and place them into the driver’s RX queue.
- Load messages pending transmission from the driver’s TX queue and write them into the TX buffer.

To place the TWAI driver’s ISR, users must do the following:

- Enable the `CONFIG_TWAI_ISR_IN_IRAM` option using `idf.py menuconfig`.
- When calling `twai_driver_install()`, the `intr_flags` member of `twai_general_config_t` should set the `ESP_INTR_FLAG_IRAM` set.

**Note:** When the `CONFIG_TWAI_ISR_IN_IRAM` option is enabled, the TWAI driver will no longer log any alerts (i.e., the TWAI_ALERT_AND_LOG flag will not have any effect).

**ESP32 Errata Workarounds** The ESP32’s TWAI controller contains multiple hardware errata (more details about the errata can be found in the ESP32’s ECO document). Some of these errata are critical, and under specific circumstances, can place the TWAI controller into an unrecoverable state (i.e., the controller gets stuck until it is reset by the CPU).
The TWAI driver contains software workarounds for these critical errata. With these workarounds, the ESP32 TWAI driver can operate normally, albeit with degraded performance. The degraded performance will affect users in the following ways depending on what particular errata conditions are encountered:

- The TWAI driver can occasionally drop some received messages.
- The TWAI driver can be unresponsive for a short period of time (i.e., will not transmit or ACK for 11 bit times or longer).
- If `CONFIG_TWAI_ISR_IN_IRAM` is enabled, the workarounds will increase IRAM usage by approximately 1KB.

The software workarounds are enabled by default and it is recommended that users keep this workarounds enabled.

**Driver Operation**

The TWAI driver is designed with distinct states and strict rules regarding the functions or conditions that trigger a state transition. The following diagram illustrates the various states and their transitions.

![State transition diagram](image)

<table>
<thead>
<tr>
<th>Label</th>
<th>Transition</th>
<th>Action/Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Uninstalled -&gt; Stopped</td>
<td><code>twai_driver_install()</code></td>
</tr>
<tr>
<td>B</td>
<td>Stopped -&gt; Uninstalled</td>
<td><code>twai_driver_uninstall()</code></td>
</tr>
<tr>
<td>C</td>
<td>Stopped -&gt; Running</td>
<td><code>twai_start()</code></td>
</tr>
<tr>
<td>D</td>
<td>Running -&gt; Stopped</td>
<td><code>twai_stop()</code></td>
</tr>
<tr>
<td>E</td>
<td>Running -&gt; Bus-Off</td>
<td>Transmit Error Counter &gt;= 256</td>
</tr>
<tr>
<td>F</td>
<td>Bus-Off -&gt; Uninstalled</td>
<td><code>twai_driver_uninstall()</code></td>
</tr>
<tr>
<td>G</td>
<td>Bus-Off -&gt; Recovering</td>
<td><code>twai_initiate_recovery()</code></td>
</tr>
<tr>
<td>H</td>
<td>Recovering -&gt; Stopped</td>
<td>128 occurrences of 11 consecutive recessive bits.</td>
</tr>
</tbody>
</table>

**Driver States**

Uninstalled: In the uninstalled state, no memory is allocated for the driver and the TWAI controller is powered OFF.

Stopped: In this state, the TWAI controller is powered ON and the TWAI driver has been installed. However the TWAI controller will be unable to take part in any bus activities such as transmitting, receiving, or acknowledging messages.

Running: In the running state, the TWAI controller is able to take part in bus activities. Therefore messages can be transmitted/received/acknowledged. Furthermore the TWAI controller will be able to transmit error frames upon detection of errors on the bus.

Bus-Off: The bus-off state is automatically entered when the TWAI controller’s Transmit Error Counter becomes greater than or equal to 256. The bus-off state indicates the occurrence of severe errors on the bus or in the TWAI controller. Whilst in the bus-off state, the TWAI controller will be unable to take part in any bus activities. To exit the bus-off state, the TWAI controller must undergo the bus recovery process.
Chapter 2. API Reference

Recovering: The recovering state is entered when the TWAI controller undergoes bus recovery. The TWAI controller/TWAI driver will remain in the recovering state until the 128 occurrences of 11 consecutive recessive bits is observed on the bus.

Message Fields and Flags: The TWAI driver distinguishes different types of messages by using the various bit field members of the `twai_message_t` structure. These bit field members determine whether a message is in standard or extended format, a remote frame, and the type of transmission to use when transmitting such a message.

These bit field members can also be toggled using the `flags` member of `twai_message_t` and the following message flags:

<table>
<thead>
<tr>
<th>Message Flag</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWAI_MSG_FLAG_EXTD</td>
<td>Message is in Extended Frame Format (29bit ID)</td>
</tr>
<tr>
<td>TWAI_MSG_FLAG_RTR</td>
<td>Message is a Remote Frame (Remote Transmission Request)</td>
</tr>
<tr>
<td>TWAI_MSG_FLAG_SS</td>
<td>Transmit message using Single Shot Transmission (Message will not be re-transmitted upon error or loss of arbitration). Unused for received message.</td>
</tr>
<tr>
<td>TWAI_MSG_FLAG_SELF</td>
<td>Transmit message using Self Reception Request (Transmitted message will also received by the same node). Unused for received message.</td>
</tr>
<tr>
<td>TWAI_MSG_FLAG_DLC_NON_COMP</td>
<td>Message’s Data length code is larger than 8. This will break compliance with TWAI</td>
</tr>
<tr>
<td>TWAI_MSG_FLAG_NONE</td>
<td>Clears all bit fields. Equivalent to a Standard Frame Format (11bit ID) Data Frame.</td>
</tr>
</tbody>
</table>

Examples

Configuration & Installation: The following code snippet demonstrates how to configure, install, and start the TWAI driver via the use of the various configuration structures, macro initializers, the `twai_driver_install()` function, and the `twai_start()` function.

```c
#include "driver/gpio.h"
#include "driver/twai.h"

void app_main()
{
    //Initialize configuration structures using macro initializers
    twai_general_config_t g_config = TWAI_GENERAL_CONFIG_DEFAULT(GPIO_NUM_21, GPIO_MODE_INPUT, GPIO_NUM_22, TWAI_MODE_NORMAL);
    twai_timing_config_t t_config = TWAI_TIMING_CONFIG_500KBITS();
    twai_filter_config_t f_config = TWAI_FILTER_CONFIG_ACCEPT_ALL();

    //Install TWAI driver
    if (twai_driver_install(&g_config, &t_config, &f_config) == ESP_OK) {
        printf("Driver installed\n");
    }
    else {
        printf("Failed to install driver\n");
        return;
    }

    //Start TWAI driver
    if (twai_start() == ESP_OK) {
        printf("Driver started\n");
    }
    else {
        printf("Failed to start driver\n");
        return;
    }
    ...
}
```
The usage of macro initializers is not mandatory and each of the configuration structures can be manually.

**Message Transmission**  The following code snippet demonstrates how to transmit a message via the usage of the `twai_message_t` type and `twai_transmit()` function.

```c
#include "driver/twai.h"

//Configure message to transmit
twai_message_t message;
message.identifier = 0xAAAA;
message.extd = 1;
message.data_length_code = 4;
for (int i = 0; i < 4; i++) {
    message.data[i] = 0;
}

//Queue message for transmission
if (twai_transmit(&message, pdMS_TO_TICKS(1000)) == ESP_OK) {
    printf("Message queued for transmission\n");
} else {
    printf("Failed to queue message for transmission\n");
}
```

**Message Reception**  The following code snippet demonstrates how to receive a message via the usage of the `twai_message_t` type and `twai_receive()` function.

```c
#include "driver/twai.h"

//Wait for message to be received
twai_message_t message;
if (twai_receive(&message, pdMS_TO_TICKS(10000)) == ESP_OK) {
    printf("Message received\n");
} else {
    printf("Failed to receive message\n");
    return;
}

//Process received message
if (message.extd) {
    printf("Message is in Extended Format\n");
} else {
    printf("Message is in Standard Format\n");
}
printf("ID is \d\n", message.identifier);
if (!message.rtr) {
    for (int i = 0; i < message.data_length_code; i++) {
        printf("Data byte \d = \d\n", i, message.data[i]);
    }
}
```

**Reconfiguring and Reading Alerts**  The following code snippet demonstrates how to reconfigure and read TWAI driver alerts via the use of the `twai_reconfigure_alerts()` and `twai_read_alerts()` functions.

```c
#include "driver/twai.h"
(continues on next page)
```
//Reconfigure alerts to detect Error Passive and Bus-Off error states
uint32_t alerts_to_enable = TWAI_ALERT_ERR_PASS | TWAI_ALERT_BUS_OFF;
if (twai_reconfigure_alerts(alerts_to_enable, NULL) == ESP_OK) {
    printf("Alerts reconfigured\n");
} else {
    printf("Failed to reconfigure alerts\n");
}

//Block indefinitely until an alert occurs
uint32_t alerts_triggered;
twai_read_alerts(&alerts_triggered, portMAX_DELAY);

Stop and Uninstall The following code demonstrates how to stop and uninstall the TWAI driver via the use of the
\texttt{twai\_stop()} and \texttt{twai\_driver\_uninstall()} functions.

```
#include "driver/twai.h"

//Stop the TWAI driver
if (twai_stop() == ESP_OK) {
    printf("Driver stopped\n");
} else {
    printf("Failed to stop driver\n");
    return;
}

//Uninstall the TWAI driver
if (twai_driver_uninstall() == ESP_OK) {
    printf("Driver uninstalled\n");
} else {
    printf("Failed to uninstall driver\n");
    return;
}
```

Multiple ID Filter Configuration The acceptance mask in \texttt{twai\_filter\_config\_t} can be configured such that two or more IDs will be accepted for a single filter. For a particular filter to accept multiple IDs, the conflicting bit positions amongst the IDs must be set in the acceptance mask. The acceptance code can be set to any one of the IDs.

The following example shows how the calculate the acceptance mask given multiple IDs:

```
ID1 = 11'b101 1010 0000
ID2 = 11'b101 1010 0001
ID3 = 11'b101 1010 0100
ID4 = 11'b101 1010 1000
//Acceptance Mask
MASK = 11'b000 0000 1101
```

Application Examples Network Example: The TWAI Network example demonstrates communication between two ESP32s using the TWAI driver API. One TWAI node acts as a network master that initiates and ceases the transfer of a data from another node acting as a network slave. The example can be found via \texttt{peripherals/twai/twai\_network}.

Alert and Recovery Example: This example demonstrates how to use the TWAI driver’s alert and bus-off recovery API. The example purposely introduces errors on the bus to put the TWAI controller into the Bus-Off state.
An alert is used to detect the Bus-Off state and trigger the bus recovery process. The example can be found via peripherals/twai/twai_alert_and_recovery.

**Self Test Example:** This example uses the No Acknowledge Mode and Self Reception Request to cause the TWAI controller to send and simultaneously receive a series of messages. This example can be used to verify if the connections between the TWAI controller and the external transceiver are working correctly. The example can be found via peripherals/twai/twai_self_test.

## API Reference

### Header File

- components/hal/include/hal/twai_types.h

### Structures

```c
struct twai_message_t
```

Structure to store a TWAI message.

---

**Note:** The flags member is deprecated

### Public Members

- `uint32_t extd`
  - Extended Frame Format (29bit ID)

- `uint32_t rtr`
  - Message is a Remote Frame

- `uint32_t ss`
  - Transmit as a Single Shot Transmission. Unused for received.

- `uint32_t self`
  - Transmit as a Self Reception Request. Unused for received.

- `uint32_t dlc_non_comp`
  - Message’s Data length code is larger than 8. This will break compliance with ISO 11898-1

- `uint32_t reserved`
  - Reserved bits

- `uint32_t flags`
  - Deprecated: Alternate way to set bits using message flags

- `uint32_t identifier`
  - 11 or 29 bit identifier

- `uint8_t data_length_code`
  - Data length code
Chapter 2. API Reference

```c
uint8_t data[TWAI_FRAME_MAX_DLC]
Data bytes (not relevant in RTR frame)
```

```c
struct twai_timing_config_t
Structure for bit timing configuration of the TWAI driver.
```

**Note:** Macro initializers are available for this structure

### Public Members

#### twai_clock_source_t clk_src
Clock source, set to 0 or TWAI_CLK_SRC_DEFAULT if you want a default clock source

```c
uint32_t quanta_resolution_hz
The resolution of one timing quanta, in Hz. Note: the value of brp will be reflected by this field if it’s non-zero, otherwise, brp needs to be set manually
```

```c
uint32_t brp
Baudrate prescale (i.e., clock divider). Any even number from 2 to 128 for ESP32, 2 to 32768 for non-ESP32 chip. Note: For ESP32 ECO 2 or later, multiples of 4 from 132 to 256 are also supported
```

```c
uint8_t tseg_1
Timing segment 1 (Number of time quanta, between 1 to 16)
```

```c
uint8_t tseg_2
Timing segment 2 (Number of time quanta, 1 to 8)
```

```c
uint8_t sjw
Synchronization Jump Width (Max time quanta jump for synchronize from 1 to 4)
```

```c
bool triple_sampling
Enables triple sampling when the TWAI controller samples a bit
```

```c
struct twai_filter_config_t
Structure for acceptance filter configuration of the TWAI driver (see documentation)
```

**Note:** Macro initializers are available for this structure

### Public Members

```c
uint32_t acceptance_code
32-bit acceptance code
```

```c
uint32_t acceptance_mask
32-bit acceptance mask
```

Submit Document Feedback
bool single_filter
Use Single Filter Mode (see documentation)

Macros

TWAI_EXTD_ID_MASK
TWAI Constants.
Bit mask for 29 bit Extended Frame Format ID

TWAI_STD_ID_MASK
Bit mask for 11 bit Standard Frame Format ID

TWAI_FRAME_MAX_DLC
Max data bytes allowed in TWAI

TWAI_FRAME_EXTD_ID_LEN_BYTES
EFF ID requires 4 bytes (29bit)

TWAI_FRAME_STD_ID_LEN_BYTES
SFF ID requires 2 bytes (11bit)

TWAI_ERR_PASS_THRESH
Error counter threshold for error passive

Type Definitions
typedef soc_periph_twai_clk_src_t twai_clock_source_t
RMT group clock source.

Note: User should select the clock source based on the power and resolution requirement

Enumerations
enum twai_mode_t
TWAI Controller operating modes.
Values:

enumerator TWAI_MODE_NORMAL
Normal operating mode where TWAI controller can send/receive/acknowledge messages

enumerator TWAI_MODE_NO_ACK
Transmission does not require acknowledgment. Use this mode for self testing

enumerator TWAI_MODE_LISTEN_ONLY
The TWAI controller will not influence the bus (No transmissions or acknowledgments) but can receive messages
Header File

- components/driver/twai/include/driver/twai.h

Functions

**esp_err_t** **twai_driver_install** (const **twai_general_config_t** *g_config, const **twai_timing_config_t** *t_config, const **twai_filter_config_t** *f_config)

Install TWAI driver.

This function installs the TWAI driver using three configuration structures. The required memory is allocated and the TWAI driver is placed in the stopped state after running this function.

**Note:** Macro initializers are available for the configuration structures (see documentation)

**Note:** To reinstall the TWAI driver, call **twai_driver_uninstall()** first

**Parameters**

- **g_config** [in] General configuration structure
- **t_config** [in] Timing configuration structure
- **f_config** [in] Filter configuration structure

**Returns**

- ESP_OK: Successfully installed TWAI driver
- ESP_ERR_INVALID_ARG: Arguments are invalid, e.g. invalid clock source, invalid quanta resolution
- ESP_ERR_NO_MEM: Insufficient memory
- ESP_ERR_INVALID_STATE: Driver is already installed

**esp_err_t** **twai_driver_uninstall** (void)

Uninstall the TWAI driver.

This function uninstalls the TWAI driver, freeing the memory utilized by the driver. This function can only be called when the driver is in the stopped state or the bus-off state.

**Warning:** The application must ensure that no tasks are blocked on TX/RX queues or alerts when this function is called.

**Returns**

- ESP_OK: Successfully uninstalled TWAI driver
- ESP_ERR_INVALID_STATE: Driver is not in stopped/bus-off state, or is not installed

**esp_err_t** **twai_start** (void)

Start the TWAI driver.

This function starts the TWAI driver, putting the TWAI driver into the running state. This allows the TWAI driver to participate in TWAI bus activities such as transmitting/receiving messages. The TX and RX queue are reset in this function, clearing any messages that are unread or pending transmission. This function can only be called when the TWAI driver is in the stopped state.

**Returns**

- ESP_OK: TWAI driver is now running
- ESP_ERR_INVALID_STATE: Driver is not in stopped state, or is not installed

**esp_err_t** **twai_stop** (void)

Stop the TWAI driver.
This function stops the TWAI driver, preventing any further message from being transmitted or received until `twai_start()` is called. Any messages in the TX queue are cleared. Any messages in the RX queue should be read by the application after this function is called. This function can only be called when the TWAI driver is in the running state.

**Warning:** A message currently being transmitted/received on the TWAI bus will be ceased immediately. This may lead to other TWAI nodes interpreting the unfinished message as an error.

### Returns
- ESP_OK: TWAI driver is now Stopped
- ESP_ERR_INVALID_STATE: Driver is not in running state, or is not installed

```c
esp_err_t twai_transmit (const twai_message_t *message, TickType_t ticks_to_wait)
```

Transmit a TWAI message.

This function queues a TWAI message for transmission. Transmission will start immediately if no other messages are queued for transmission. If the TX queue is full, this function will block until more space becomes available or until it times out. If the TX queue is disabled (TX queue length = 0 in configuration), this function will return immediately if another message is undergoing transmission. This function can only be called when the TWAI driver is in the running state and cannot be called under Listen Only Mode.

**Note:** This function does not guarantee that the transmission is successful. The TX_SUCCESS/TX_FAILED alert can be enabled to alert the application upon the success/failure of a transmission.

```c
Parameters
- message – [in] Message to transmit
- ticks_to_wait – [in] Number of FreeRTOS ticks to block on the TX queue
```

### Returns
- ESP_OK: Transmission successfully queued/initiated
- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_TIMEOUT: Timed out waiting for space on TX queue
- ESP_FAIL: TX queue is disabled and another message is currently transmitting
- ESP_ERR_INVALID_STATE: TWAI driver is not in running state, or is not installed
- ESP_ERR_NOT_SUPPORTED: Listen Only Mode does not support transmissions

```c
esp_err_t twai_receive (twai_message_t *message, TickType_t ticks_to_wait)
```

Receive a TWAI message.

This function receives a message from the RX queue. The flags field of the message structure will indicate the type of message received. This function will block if there are no messages in the RX queue.

**Warning:** The flags field of the received message should be checked to determine if the received message contains any data bytes.

```c
Parameters
- message – [out] Received message
- ticks_to_wait – [in] Number of FreeRTOS ticks to block on RX queue
```

### Returns
- ESP_OK: Message successfully received from RX queue
- ESP_ERR_TIMEOUT: Timed out waiting for message

```c
Espressif Systems 1418 Release v5.1.2
Submit Document Feedback
```
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

`esp_err_t twai_read_alerts(uint32_t*alerts, TickType_t ticks_to_wait)`

Read TWAI driver alerts.

This function will read the alerts raised by the TWAI driver. If no alert has been issued when this function is called, this function will block until an alert occurs or until it timeouts.

**Note:** Multiple alerts can be raised simultaneously. The application should check for all alerts that have been enabled.

**Parameters**
- `alerts` - [out] Bit field of raised alerts (see documentation for alert flags)
- `ticks_to_wait` - [in] Number of FreeRTOS ticks to block for alert

**Returns**
- ESP_OK: Alerts read
- ESP_ERR_TIMEOUT: Timed out waiting for alerts
- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

`esp_err_t twai_reconfigure_alerts(uint32_t alerts_enabled, uint32_t*current_alerts)`

Reconfigure which alerts are enabled.

This function reconfigures which alerts are enabled. If there are alerts which have not been read whilst reconfiguring, this function can read those alerts.

**Parameters**
- `alerts_enabled` - [in] Bit field of alerts to enable (see documentation for alert flags)
- `current_alerts` - [out] Bit field of currently raised alerts. Set to NULL if unused

**Returns**
- ESP_OK: Alerts reconfigured
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

`esp_err_t twai_initiate_recovery(void)`

Start the bus recovery process.

This function initiates the bus recovery process when the TWAI driver is in the bus-off state. Once initiated, the TWAI driver will enter the recovering state and wait for 128 occurrences of the bus-free signal on the TWAI bus before returning to the stopped state. This function will reset the TX queue, clearing any messages pending transmission.

**Note:** The BUS_RECOVERED alert can be enabled to alert the application when the bus recovery process completes.

**Returns**
- ESP_OK: Bus recovery started
- ESP_ERR_INVALID_STATE: TWAI driver is not in the bus-off state, or is not installed

`esp_err_t twai_get_status_info(twai_status_info_t*status_info)`

Get current status information of the TWAI driver.

**Parameters**
- `status_info` - [out] Status information

**Returns**
- ESP_OK: Status information retrieved
- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_INVALID_STATE: TWAI driver is not installed
Chapter 2. API Reference

`esp_err_t twai_clear_transmit_queue(void)`
Clear the transmit queue.
This function will clear the transmit queue of all messages.

**Note:** The transmit queue is automatically cleared when `twai_stop()` or `twai_initiate_recovery()` is called.

**Returns**
- ESP_OK: Transmit queue cleared
- ESP_ERR_INVALID_STATE: TWAI driver is not installed or TX queue is disabled

`esp_err_t twai_clear_receive_queue(void)`
Clear the receive queue.
This function will clear the receive queue of all messages.

**Note:** The receive queue is automatically cleared when `twai_start()` is called.

**Returns**
- ESP_OK: Transmit queue cleared
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

**Structures**

`struct twai_general_config_t`
Structure for general configuration of the TWAI driver.

**Note:** Macro initializers are available for this structure

**Public Members**

`twai_mode_t mode`
Mode of TWAI controller

`gpio_num_t tx_io`
Transmit GPIO number

`gpio_num_t rx_io`
Receive GPIO number

`gpio_num_t clkout_io`
CLKOUT GPIO number (optional, set to -1 if unused)

`gpio_num_t bus_off_io`
Bus off indicator GPIO number (optional, set to -1 if unused)

`uint32_t tx_queue_len`
Number of messages TX queue can hold (set to 0 to disable TX Queue)
uint32_t *rx_queue_len
    Number of messages RX queue can hold

uint32_t alerts_enabled
    Bit field of alerts to enable (see documentation)

uint32_t clkout_divider
    CLKOUT divider. Can be 1 or any even number from 2 to 14 (optional, set to 0 if unused)

int intr_flags
    Interrupt flags to set the priority of the driver’s ISR. Note that to use the ESP_INTR_FLAG_IRAM, the CONFIG_TWAI_ISR_IN_IRAM option should be enabled first.

struct twai_status_info_t
    Structure to store status information of TWAI driver.

Public Members

twai_state_t state
    Current state of TWAI controller (Stopped/Running/Bus-Off/Recovery)

uint32_t *msgs_to_tx
    Number of messages queued for transmission or awaiting transmission completion

uint32_t *msgs_to_rx
    Number of messages in RX queue waiting to be read

uint32_t tx_error_counter
    Current value of Transmit Error Counter

uint32_t rx_error_counter
    Current value of Receive Error Counter

uint32_t *tx_failed_count
    Number of messages that failed transmissions

uint32_t *rx_missed_count
    Number of messages that were lost due to a full RX queue (or errata workaround if enabled)

uint32_t *rx_overrun_count
    Number of messages that were lost due to a RX FIFO overrun

uint32_t *arb_lost_count
    Number of instances arbitration was lost

uint32_t *bus_error_count
    Number of instances a bus error has occurred
Macros

**TWAI_IO_UNUSED**
Marks GPIO as unused in TWAI configuration

Enumerations

```c
enum twai_state_t
TWAI driver states.

Values:

enumerator TWAI_STATE_STOPPED
Stopped state. The TWAI controller will not participate in any TWAI bus activities

enumerator TWAI_STATE_RUNNING
Running state. The TWAI controller can transmit and receive messages

enumerator TWAI_STATE_BUS_OFF
Bus-off state. The TWAI controller cannot participate in bus activities until it has recovered

enumerator TWAI_STATE_RECOVERING
Recovering state. The TWAI controller is undergoing bus recovery
```

2.6.26 Universal Asynchronous Receiver/Transmitter (UART)

Introduction

A Universal Asynchronous Receiver/Transmitter (UART) is a hardware feature that handles communication (i.e.,
timing requirements and data framing) using widely-adopted asynchronous serial communication interfaces, such
as RS232, RS422, and RS485. A UART provides a widely adopted and cheap method to realize full-duplex or
half-duplex data exchange among different devices.

The ESP32 chip has 3 UART controllers (also referred to as port), each featuring an identical set of registers to
simplify programming and for more flexibility.

Each UART controller is independently configurable with parameters such as baud rate, data bit length, bit ordering,
number of stop bits, parity bit, etc. All the controllers are compatible with UART-enabled devices from various
manufacturers and can also support Infrared Data Association (IrDA) protocols.

Functional Overview

The overview describes how to establish communication between an ESP32 and other UART devices using the
functions and data types of the UART driver. A typical programming workflow is broken down into the sections
provided below:

1. **Set Communication Parameters** - Setting baud rate, data bits, stop bits, etc.
2. **Set Communication Pins** - Assigning pins for connection to a device
3. **Install Drivers** - Allocating ESP32’s resources for the UART driver
4. **Run UART Communication** - Sending/receiving data
5. **Use Interrupts** - Triggering interrupts on specific communication events
6. **Deleting a Driver** - Freeing allocated resources if a UART communication is no longer required

Steps 1 to 3 comprise the configuration stage. Step 4 is where the UART starts operating. Steps 5 and 6 are optional.

The UART driver’s functions identify each of the UART controllers using `uart_port_t`. This identification is
needed for all the following function calls.
Set Communication Parameters  UART communication parameters can be configured all in a single step or individually in multiple steps.

Single Step  Call the function `uart_param_config()` and pass to it a `uart_config_t` structure. The `uart_config_t` structure should contain all the required parameters. See the example below.

```c
const uart_port_t uart_num = UART_NUM_2;
uart_config_t uart_config = {
    .baud_rate = 115200,
    .data_bits = UART_DATA_8_BITS,
    .parity = UART_PARITY_DISABLE,
    .stop_bits = UART_STOP_BITS_1,
    .flow_ctrl = UART_HW_FLOWCTRL_CTS_RTS,
    .rx_flow_ctrl_thresh = 122,
};
// Configure UART parameters
ESP_ERROR_CHECK(uart_param_config(uart_num, &uart_config));
```

For more information on how to configure the hardware flow control options, please refer to peripherals/uart/uart_echo.

Multiple Steps  Configure specific parameters individually by calling a dedicated function from the table given below. These functions are also useful if re-configuring a single parameter.

<table>
<thead>
<tr>
<th>Parameter to Configure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baudrate</td>
<td><code>uart_set_baudrate()</code></td>
</tr>
<tr>
<td>Number of transmitted bits</td>
<td><code>uart_set_word_length()</code> selected out of <code>uart_word_length_t</code></td>
</tr>
<tr>
<td>Parity control</td>
<td><code>uart_set_parity()</code> selected out of <code>uart_parity_t</code></td>
</tr>
<tr>
<td>Number of stop bits</td>
<td><code>uart_set_stop_bits()</code> selected out of <code>uart_stop_bits_t</code></td>
</tr>
<tr>
<td>Hardware flow control mode</td>
<td><code>uart_set_hw_flow_ctrl()</code> selected out of <code>uart_hw_flowcontrol_t</code></td>
</tr>
<tr>
<td>Communication mode</td>
<td><code>uart_set_mode()</code> selected out of <code>uart_mode_t</code></td>
</tr>
</tbody>
</table>

Each of the above functions has a `get` counterpart to check the currently set value. For example, to check the current baud rate value, call `uart_get_baudrate()`.

Set Communication Pins  After setting communication parameters, configure the physical GPIO pins to which the other UART device will be connected. For this, call the function `uart_set_pin()` and specify the GPIO pin numbers to which the driver should route the Tx, Rx, RTS, and CTS signals. If you want to keep a currently allocated pin number for a specific signal, pass the macro `UART_PIN_NO_CHANGE`.

The same macro `UART_PIN_NO_CHANGE` should be specified for pins that will not be used.

```c
// Set UART pins (TX: IO4, RX: IO5, RTS: IO18, CTS: IO19)
ESP_ERROR_CHECK(uart_set_pin(UART_NUM_2, 4, 5, 18, 19));
```

Install Drivers  Once the communication pins are set, install the driver by calling `uart_driver_install()` and specify the following parameters:

- Size of Tx ring buffer
- Size of Rx ring buffer
- Event queue handle and size
- Flags to allocate an interrupt

The function will allocate the required internal resources for the UART driver.
// Setup UART buffered IO with event queue
const int uart_buffer_size = (1024 * 2);
QueueHandle_t uart_queue;
// Install UART driver using an event queue here
ESP_ERROR_CHECK(uart_driver_install(UART_NUM_2, uart_buffer_size, uart_buffer_size, 10, &uart_queue, 0));

Once this step is complete, you can connect the external UART device and check the communication.

**Run UART Communication**  Serial communication is controlled by each UART controller’s finite state machine (FSM).

The process of sending data involves the following steps:

1. Write data into Tx FIFO buffer
2. FSM serializes the data
3. FSM sends the data out

The process of receiving data is similar, but the steps are reversed:

1. FSM processes an incoming serial stream and parallelizes it
2. FSM writes the data into Rx FIFO buffer
3. Read the data from Rx FIFO buffer

Therefore, an application will only write and read data from a specific buffer using `uart_write_bytes()` and `uart_read_bytes()` respectively, and the FSM will do the rest.

**Transmit Data**  After preparing the data for transmission, call the function `uart_write_bytes()` and pass the data buffer’s address and data length to it. The function will copy the data to the Tx ring buffer (either immediately or after enough space is available), and then exit. When there is free space in the Tx FIFO buffer, an interrupt service routine (ISR) moves the data from the Tx ring buffer to the Tx FIFO buffer in the background. The code below demonstrates the use of this function.

```c
// Write data to UART.
char* test_str = "This is a test string.
uart_write_bytes(uart_num, (const char*)test_str, strlen(test_str));
```

The function `uart_write_bytes_with_break()` is similar to `uart_write_bytes()` but adds a serial break signal at the end of the transmission. A ‘serial break signal’ means holding the Tx line low for a period longer than one data frame.

```c
// Write data to UART, end with a break signal.
uart_write_bytes_with_break(uart_num, "test break\n", strlen("test break\n"), 100);
```

Another function for writing data to the Tx FIFO buffer is `uart_tx_chars()`. Unlike `uart_write_bytes()`, this function will not block until space is available. Instead, it will write all data which can immediately fit into the hardware Tx FIFO, and then return the number of bytes that were written.

There is a ‘companion’ function `uart_wait_tx_done()` that monitors the status of the Tx FIFO buffer and returns once it is empty.

```c
// Wait for packet to be sent
const uart_port_t uart_num = UART_NUM_2;
ESP_ERROR_CHECK(uart_wait_tx_done(uart_num, 100)); // wait timeout is 100 RTOS_ticks (TickType_t)
```

**Receive Data**  Once the data is received by the UART and saved in the Rx FIFO buffer, it needs to be retrieved using the function `uart_read_bytes()`. Before reading data, you can check the number of bytes available in the Rx FIFO buffer by calling `uart_get_buffered_data_len()`. An example of using these functions is given below.
// Read data from UART.
const uart_port_t uart_num = UART_NUM_2;
uint8_t data[128];
int length = 0;
ESP_ERROR_CHECK(uart_get_buffered_data_len(uart_num, (size_t *)&length));
length = uart_read_bytes(uart_num, data, length, 100);

If the data in the Rx FIFO buffer is no longer needed, you can clear the buffer by calling `uart_flush()`.

**Software Flow Control**  If the hardware flow control is disabled, you can manually set the RTS and DTR signal levels by using the functions `uart_set_rts()` and `uart_set_dtr()` respectively.

**Communication Mode Selection**  The UART controller supports a number of communication modes. A mode can be selected using the function `uart_set_mode()`. Once a specific mode is selected, the UART driver will handle the behavior of a connected UART device accordingly. As an example, it can control the RS485 driver chip using the RTS line to allow half-duplex RS485 communication.

// Setup UART in rs485 half duplex mode
ESP_ERROR_CHECK(uart_set_mode(uart_num, UART_MODE_RS485_HALF_DUPLEX));

**Use Interrupts**  There are many interrupts that can be generated depending on specific UART states or detected errors. The full list of available interrupts is provided in ESP32 Technical Reference Manual > UART Controller (UART) > UART Interrupts and UHCI Interrupts [PDF]. You can enable or disable specific interrupts by calling `uart_enable_intr_mask()` or `uart_disable_intr_mask()` respectively.

The `uart_driver_install()` function installs the driver’s internal interrupt handler to manage the Tx and Rx ring buffers and provides high-level API functions like events (see below).

The API provides a convenient way to handle specific interrupts discussed in this document by wrapping them into dedicated functions:

- **Event detection**: There are several events defined in `uart_event_type_t` that may be reported to a user application using the FreeRTOS queue functionality. You can enable this functionality when calling `uart_driver_install()` described in Install Drivers. An example of using Event detection can be found in peripherals/uart/uart_events.

- **FIFO space threshold or transmission timeout reached**: The Tx and Rx FIFO buffers can trigger an interrupt when they are filled with a specific number of characters, or on a timeout of sending or receiving data. To use these interrupts, do the following:
  - Configure respective threshold values of the buffer length and timeout by entering them in the structure `uart_intr_config_t` and calling `uart_intr_config()`.
  - Enable the interrupts using the functions `uart_enable_tx_intr()` and `uart_enable_rx_intr()`.
  - Disable these interrupts using the corresponding functions `uart_disable_tx_intr()` or `uart_disable_rx_intr()`.

- **Pattern detection**: An interrupt triggered on detecting a ‘pattern’ of the same character being received/sent repeatedly. This functionality is demonstrated in the example peripherals/uart/uart_events. It can be used, e.g., to detect a command string with a specific number of identical characters (the ‘pattern’) at the end. The following functions are available:
  - Configure and enable this interrupt using `uart_enable_pattern_det_baud_intr()`.
  - Disable the interrupt using `uart_disable_pattern_det_baud_intr()`.

**Macros**  The API also defines several macros. For example, `UART_FIFO_LEN` defines the length of hardware FIFO buffers; `UART_BITRATE_MAX` gives the maximum baud rate supported by the UART controllers, etc.

**Deleting a Driver**  If the communication established with `uart_driver_install()` is no longer required, the driver can be removed to free allocated resources by calling `uart_driver_delete()`.
Overview of RS485 Specific Communication Options

**Note:** The following section will use `[UART_REGISTER_NAME].[UART_FIELD_BIT]` to refer to UART register fields/bits. For more information on a specific option bit, see ESP32 Technical Reference Manual > UART Controller (UART) > Register Summary [PDF]. Use the register name to navigate to the register description and then find the field/bit.

- `UART_RS485_CONF_REG.UART_RS485_EN`: setting this bit enables RS485 communication mode support.
- `UART_RS485_CONF_REG.UART_RS485TX_RX_EN`: if this bit is set, the transmitter’s output signal loops back to the receiver’s input signal.
- `UART_RS485_CONF_REG.UART_RS485RXBY_TX_EN`: if this bit is set, the transmitter will still be sending data if the receiver is busy (remove collisions automatically by hardware).

The ESP32’s RS485 UART hardware can detect signal collisions during transmission of a datagram and generate the interrupt `UART_RS485_CLASH_INT` if this interrupt is enabled. The term collision means that a transmitted datagram is not equal to the one received on the other end. Data collisions are usually associated with the presence of other active devices on the bus or might occur due to bus errors.

The collision detection feature allows handling collisions when their interrupts are activated and triggered. The interrupts `UART_RS485_FRM_ERR_INT` and `UART_RS485_PARITY_ERR_INT` can be used with the collision detection feature to control frame errors and parity bit errors accordingly in RS485 mode. This functionality is supported in the UART driver and can be used by selecting the `UART_MODE_RS485_APP_CTRL` mode (see the function `uart_set_mode()`).

The collision detection feature can work with circuit A and circuit C (see Section Interface Connection Options). In the case of using circuit A or B, the RTS pin connected to the DE pin of the bus driver should be controlled by the user application. Use the function `uart_get_collision_flag()` to check if the collision detection flag has been raised.

The ESP32 UART controllers themselves do not support half-duplex communication as they cannot provide automatic control of the RTS pin connected to the RE/DE input of RS485 bus driver. However, half-duplex communication can be achieved via software control of the RTS pin by the UART driver. This can be enabled by selecting the `UART_MODE_RS485_HALF_DUPLEX` mode when calling `uart_set_mode()`.

Once the host starts writing data to the Tx FIFO buffer, the UART driver automatically asserts the RTS pin (logic 1); once the last bit of the data has been transmitted, the driver de-asserts the RTS pin (logic 0). To use this mode, the software would have to disable the hardware flow control function. This mode works with all the used circuits shown below.

**Interface Connection Options** This section provides example schematics to demonstrate the basic aspects of ESP32’s RS485 interface connection.

**Note:**
- The schematics below do **not** necessarily contain all required elements.
- The analog devices ADM483 & ADM2483 are examples of common RS485 transceivers and **can be replaced** with other similar transceivers.

**Circuit A: Collision Detection Circuit**

```plaintext
VCC -------------------+
|                      |
|    +-------------x--+
| RXD <-----| R | B|--------<> < B
|          | D | ADM483 |
| TXD ------<> B
```

(continues on next page)
This circuit is preferable because it allows for collision detection and is quite simple at the same time. The receiver in the line driver is constantly enabled, which allows the UART to monitor the RS485 bus. Echo suppression is performed by the UART peripheral when the bit UART_RS485_CONF_REG.UART_RS485TX_RX_EN is enabled.

Circuit B: Manual Switching Transmitter/Receiver Without Collision Detection

This circuit does not allow for collision detection. It suppresses the null bytes that the hardware receives when the bit UART_RS485_CONF_REG.UART_RS485TX_RX_EN is set. The bit UART_RS485_CONF_REG.UART_RS485RXBY_TX_EN is not applicable in this case.

Circuit C: Auto Switching Transmitter/Receiver

This galvanically isolated circuit does not require RTS pin control by a software application or driver because it controls the transceiver direction automatically. However, it requires suppressing null bytes during transmission by setting UART_RS485_CONF_REG.UART_RS485RXBY_TX_EN to 1 and UART_RS485_CONF_REG.UART_RS485TX_RX_EN to 0. This setup can work in any RS485 UART mode or even in UART_MODE_UART.
Application Examples

The table below describes the code examples available in the directory `peripherals/uart/`.

<table>
<thead>
<tr>
<th>Code Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>peripherals/uart/uart_echo</td>
<td>Configuring UART settings, installing the UART driver, and reading/writing over the UART1 interface.</td>
</tr>
<tr>
<td>peripherals/uart/uart_events</td>
<td>Reporting various communication events, using pattern detection interrupts.</td>
</tr>
<tr>
<td>peripherals/uart/uart_async_rxtxtasks</td>
<td>Transmitting and receiving data in two separate FreeRTOS tasks over the same UART.</td>
</tr>
<tr>
<td>peripherals/uart/uart_select</td>
<td>Using synchronous I/O multiplexing for UART file descriptors.</td>
</tr>
<tr>
<td>peripherals/uart/uart_echo_rs485</td>
<td>Setting up UART driver to communicate over RS485 interface in half-duplex mode. This example is similar to <code>peripherals/uart/uart_echo</code> but allows communication through an RS485 interface chip connected to ESP32 pins.</td>
</tr>
<tr>
<td>peripherals/uart/nmea0183_parser</td>
<td>Obtaining GPS information by parsing NMEA0183 statements received from GPS via the UART peripheral.</td>
</tr>
</tbody>
</table>

API Reference

Header File

- components/driver/uart/include/driver/uart.h

Functions

```c
esp_err_t uart_driver_install (uart_port_t uart_num, int rx_buffer_size, int tx_buffer_size, int queue_size, QueueHandle_t *uart_queue, int intr_alloc_flags)
```

Install UART driver and set the UART to the default configuration. UART ISR handler will be attached to the same CPU core that this function is running on.

**Note:** Rx_buffer_size should be greater than UART_FIFO_LEN. Tx_buffer_size should be either zero or greater than UART_FIFO_LEN.

**Parameters**

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).
- **rx_buffer_size** - UART RX ring buffer size.
- **tx_buffer_size** - UART TX ring buffer size. If set to zero, driver will not use TX buffer, TX function will block task until all data have been sent out.
- **queue_size** - UART event queue size/depth.
- **uart_queue** - UART event queue handle (out param). On success, a new queue handle is written here to provide access to UART events. If set to NULL, driver will not use an event queue.
- **intr_alloc_flags** - Flags used to allocate the interrupt. One or multiple (ORred) ESP_INTR_FLAG_* values. See esp_intr_alloc.h for more info. Do not set ESP_INTR_FLAG_IRAM here (the driver’s ISR handler is not located in IRAM)

**Returns**

- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_driver_delete (uart_port_t uart_num)
```

Uninstall UART driver.

**Parameters**

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).

**Returns**

- ESP_OK Success
- ESP_FAIL Parameter error
Chapter 2. API Reference

• ESP_OK Success
• ESP_FAIL Parameter error

bool uart_is_driver_installed(uart_port_t uart_num)
Checks whether the driver is installed or not.

Parameters uart_num – UART port number, the max port number is (UART_NUM_MAX -1).

Returns
• true driver is installed
• false driver is not installed

esp_err_t uart_set_word_length(uart_port_t uart_num, uart_word_length_t data_bit)
Set UART data bits.

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• data_bit – UART data bits

Returns
• ESP_OK Success
• ESP_FAIL Parameter error

esp_err_t uart_get_word_length(uart_port_t uart_num, uart_word_length_t *data_bit)
Get the UART data bit configuration.

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• data_bit – Pointer to accept value of UART data bits.

Returns
• ESP_FAIL Parameter error
• ESP_OK Success, result will be put in (*data_bit)

esp_err_t uart_set_stop_bits(uart_port_t uart_num, uart_stop_bits_t stop_bits)
Set UART stop bits.

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• stop_bits – UART stop bits

Returns
• ESP_OK Success
• ESP_FAIL Fail

esp_err_t uart_get_stop_bits(uart_port_t uart_num, uart_stop_bits_t *stop_bits)
Get the UART stop bit configuration.

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• stop_bits – Pointer to accept value of UART stop bits.

Returns
• ESP_FAIL Parameter error
• ESP_OK Success, result will be put in (*stop_bit)

esp_err_t uart_set_parity(uart_port_t uart_num, uart_parity_t parity_mode)
Set UART parity mode.

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• parity_mode – the enum of uart parity configuration

Returns
• ESP_FAIL Parameter error
• ESP_OK Success

esp_err_t uart_get_parity(uart_port_t uart_num, uart_parity_t *parity_mode)
Get the UART parity mode configuration.
### Parameters
- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).
- **parity_mode** - Pointer to accept value of UART parity mode.

### Returns
- ESP_FAIL Parameter error
- ESP_OK Success, result will be put in (*parity_mode)

```c
esp_err_t uart_get_sclk_freq(uart_sclk_t sclk, uint32_t*out_freq_hz)
```

Get the frequency of a clock source for the UART.

### Parameters
- **sclk** - Clock source
- **out_freq_hz** - [out] Output of frequency, in Hz

### Returns
- ESP.ERR_INVALID_ARG: if the clock source is not supported
- otherwise ESP_OK

```c
esp_err_t uart_set_baudrate(uart_port_t uart_num, uint32_t baudrate)
```

Set UART baud rate.

### Parameters
- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).
- **baudrate** - UART baud rate.

### Returns
- ESP_FAIL Parameter error
- ESP_OK Success

```c
esp_err_t uart_get_baudrate(uart_port_t uart_num, uint32_t*baudrate)
```

Get the UART baud rate configuration.

### Parameters
- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).
- **baudrate** - Pointer to accept value of UART baud rate

### Returns
- ESP_FAIL Parameter error
- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_set_line_inverse(uart_port_t uart_num, uint32_t inverse_mask)
```

Set UART line inverse mode.

### Parameters
- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).
- **inverse_mask** - Choose the wires that need to be inverted. Using the ORred mask of uart_signal_inv_t

### Returns
- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_set_hw_flow_ctrl(uart_port_t uart_num, uart_hw_flowcontrol_t flow_ctrl, uint8_t rx_thresh)
```

Set hardware flow control.

### Parameters
- **uart_num** - UART port number, the max port number is (UART_NUM_MAX -1).
- **flow_ctrl** - Hardware flow control mode
- **rx_thresh** - Threshold of Hardware RX flow control (0 ~ UART_FIFO_LEN). Only when UART_HW_FLOWCTRL_RTS is set, will the rx_thresh value be set.

### Returns
- ESP_OK Success
- ESP_FAIL Parameter error
\textbf{esp_err_t} \textit{uart_set_sw_flow_ctrl} (\textit{uart_port_t} uart_num, \textit{bool} enable, \textit{uint8_t} rx_thresh_xon, \textit{uint8_t} rx_thresh_xoff)

Set software flow control.

\textbf{Parameters}

\begin{itemize}
  \item \textit{uart_num} – UART_NUM_0, UART_NUM_1 or UART_NUM_2
  \item \textit{enable} – switch on or off
  \item \textit{rx_thresh_xon} – low water mark
  \item \textit{rx_thresh_xoff} – high water mark
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

\textbf{esp_err_t} \textit{uart_get_hw_flow_ctrl} (\textit{uart_port_t} uart_num, \textit{uart_hw_flowcontrol_t} *flow_ctrl)

Get the UART hardware flow control configuration.

\textbf{Parameters}

\begin{itemize}
  \item \textit{uart_num} – UART port number, the max port number is (UART_NUM_MAX -1).
  \item \textit{flow_ctrl} – Option for different flow control mode.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item ESP_FAIL Parameter error
  \item ESP_OK Success, result will be put in (*flow_ctrl)
\end{itemize}

\textbf{esp_err_t} \textit{uart_clear_intr_status} (\textit{uart_port_t} uart_num, \textit{uint32_t} clr_mask)

Clear UART interrupt status.

\textbf{Parameters}

\begin{itemize}
  \item \textit{uart_num} – UART port number, the max port number is (UART_NUM_MAX -1).
  \item \textit{clr_mask} – Bit mask of the interrupt status to be cleared.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

\textbf{esp_err_t} \textit{uart_enable_intr_mask} (\textit{uart_port_t} uart_num, \textit{uint32_t} enable_mask)

Set UART interrupt enable.

\textbf{Parameters}

\begin{itemize}
  \item \textit{uart_num} – UART port number, the max port number is (UART_NUM_MAX -1).
  \item \textit{enable_mask} – Bit mask of the enable bits.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

\textbf{esp_err_t} \textit{uart_disable_intr_mask} (\textit{uart_port_t} uart_num, \textit{uint32_t} disable_mask)

Clear UART interrupt enable bits.

\textbf{Parameters}

\begin{itemize}
  \item \textit{uart_num} – UART port number, the max port number is (UART_NUM_MAX -1).
  \item \textit{disable_mask} – Bit mask of the disable bits.
\end{itemize}

\textbf{Returns}

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}

\textbf{esp_err_t} \textit{uart_enable_rx_intr} (\textit{uart_port_t} uart_num)

Enable UART RX interrupt (RX_FULL & RX_TIMEOUT INTERRUPT)

\textbf{Parameters} \textit{uart_num} – UART port number, the max port number is (UART_NUM_MAX -1).

\textbf{Returns}

\begin{itemize}
  \item ESP_OK Success
  \item ESP_FAIL Parameter error
\end{itemize}
esp_err_t uart_disable_rx_intr (uart_port_t uart_num)
Disable UART RX interrupt (RX_FULL & RX_TIMEOUT INTERRUPT)

Parameters uart_num – UART port number, the max port number is (UART_NUM_MAX -1).

Returns
• ESP_OK Success
• ESP_FAIL Parameter error

esp_err_t uart_disable_tx_intr (uart_port_t uart_num)
Disable UART TX interrupt (TX_FULL & TX_TIMEOUT INTERRUPT)

Parameters uart_num – UART port number

Returns
• ESP_OK Success
• ESP_FAIL Parameter error

esp_err_t uart_enable_tx_intr (uart_port_t uart_num, int enable, int thresh)
Enable UART TX interrupt (TX_FULL & TX_TIMEOUT INTERRUPT)

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• enable – 1: enable; 0: disable
• thresh – Threshold of TX interrupt, 0 ~ UART_FIFO_LEN

Returns
• ESP_OK Success
• ESP_FAIL Parameter error

esp_err_t uart_set_pin (uart_port_t uart_num, int tx_io_num, int rx_io_num, int rts_io_num, int cts_io_num)
Assign signals of a UART peripheral to GPIO pins.

Note: If the GPIO number configured for a UART signal matches one of the IOMUX signals for that GPIO, the signal will be connected directly via the IOMUX. Otherwise the GPIO and signal will be connected via the GPIO Matrix. For example, if on an ESP32 the call `uart_set_pin(0, 1, 3, -1, -1)` is performed, as GPIO1 is UART0’s default TX pin and GPIO3 is UART0’s default RX pin, both will be connected to respectively U0TXD and U0RXD through the IOMUX, totally bypassing the GPIO matrix. The check is performed on a per-pin basis. Thus, it is possible to have RX pin binded to a GPIO through the GPIO matrix, whereas TX is binded to its GPIO through the IOMUX.

Note: Internal signal can be output to multiple GPIO pads. Only one GPIO pad can connect with input signal.

Parameters
• uart_num – UART port number, the max port number is (UART_NUM_MAX -1).
• tx_io_num – UART TX pin GPIO number.
• rx_io_num – UART RX pin GPIO number.
• rts_io_num – UART RTS pin GPIO number.
• cts_io_num – UART CTS pin GPIO number.

Returns
• ESP_OK Success
• ESP_FAIL Parameter error

esp_err_t uart_set_rts (uart_port_t uart_num, int level)
Manually set the UART RTS pin level.

Note: UART must be configured with hardware flow control disabled.
Chapter 2. API Reference

Parameters

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX-1).
- **level** - 1: RTS output low (active); 0: RTS output high (block)

Returns

- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_set_dtr(uart_port_t uart_num, int level)
```
Manually set the UART DTR pin level.

Parameters

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX-1).
- **level** - 1: DTR output low; 0: DTR output high

Returns

- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_set_tx_idle_num(uart_port_t uart_num, uint16_t idle_num)
```
Set UART idle interval after tx FIFO is empty.

Parameters

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX-1).
- **idle_num** - idle interval after tx FIFO is empty (unit: the time it takes to send one bit under current baudrate)

Returns

- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_param_config(uart_port_t uart_num, const uart_config_t *uart_config)
```
Set UART configuration parameters.

Parameters

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX-1).
- **uart_config** - UART parameter settings

Returns

- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_intr_config(uart_port_t uart_num, const uart_intr_config_t *intr_conf)
```
Configure UART interrupts.

Parameters

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX-1).
- **intr_conf** - UART interrupt settings

Returns

- ESP_OK Success
- ESP_FAIL Parameter error

```c
esp_err_t uart_wait_tx_done(uart_port_t uart_num, TickType_t ticks_to_wait)
```
Wait until UART TX FIFO is empty.

Parameters

- **uart_num** - UART port number, the max port number is (UART_NUM_MAX-1).
- **ticks_to_wait** - Timeout, count in RTOS ticks

Returns

- ESP_OK Success
- ESP_FAIL Parameter error
- ESP_ERR_TIMEOUT Timeout

```c
int uart_tx_chars(uart_port_t uart_num, const char *buffer, uint32_t len)
```
Send data to the UART port from a given buffer and length.
This function will not wait for enough space in TX FIFO. It will just fill the available TX FIFO and return when the FIFO is full.

**Note:** This function should only be used when UART TX buffer is not enabled.

### Parameters
- `uart_num` - UART port number, the max port number is (UART_NUM_MAX -1).
- `buffer` - data buffer address
- `len` - data length to send

### Returns
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

```c
int uart_write_bytes (uart_port_t uart_num, const void *src, size_t size)
```

Send data to the UART port from a given buffer and length.

If the UART driver’s parameter ‘tx_buffer_size’ is set to zero: This function will not return until all the data have been sent out, or at least pushed into TX FIFO.

Otherwise, if the ‘tx_buffer_size’ > 0, this function will return after copying all the data to tx ring buffer, UART ISR will then move data from the ring buffer to TX FIFO gradually.

### Parameters
- `uart_num` - UART port number, the max port number is (UART_NUM_MAX -1).
- `src` - data buffer address
- `size` - data length to send

### Returns
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

```c
int uart_write_bytes_with_break (uart_port_t uart_num, const void *src, size_t size, int brk_len)
```

Send data to the UART port from a given buffer and length.

If the UART driver’s parameter ‘tx_buffer_size’ is set to zero: This function will not return until all the data and the break signal have been sent out. After all data is sent out, send a break signal.

Otherwise, if the ‘tx_buffer_size’ > 0, this function will return after copying all the data to tx ring buffer, UART ISR will then move data from the ring buffer to TX FIFO gradually. After all data sent out, send a break signal.

### Parameters
- `uart_num` - UART port number, the max port number is (UART_NUM_MAX -1).
- `src` - data buffer address
- `size` - data length to send
- `brk_len` - break signal duration(unit: the time it takes to send one bit at current baudrate)

### Returns
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

```c
int uart_read_bytes (uart_port_t uart_num, void *buf, uint32_t length, TickType_t ticks_to_wait)
```

UART read bytes from UART buffer.

### Parameters
- `uart_num` - UART port number, the max port number is (UART_NUM_MAX -1).
- `buf` - pointer to the buffer.
- `length` - data length
- `ticks_to_wait` - sTimeout, count in RTOS ticks

### Returns
- (-1) Error
- OTHERS (>=0) The number of bytes read from UART buffer
**esp_err_t uart_flush (uart_port_t uart_num)**

Alias of uart_flush_input. UART ring buffer flush. This will discard all data in the UART RX buffer.

**Note:** Instead of waiting the data sent out, this function will clear UART rx buffer. In order to send all the data in tx FIFO, we can use uart_wait_tx_done function.

**Parameters**
- **uart_num** – UART port number, the max port number is (UART_NUM_MAX -1).

**Returns**
- ESP_OK Success
- ESP_FAIL Parameter error

**esp_err_t uart_flush_input (uart_port_t uart_num)**

Clear input buffer, discard all the data is in the ring-buffer.

**Note:** In order to send all the data in tx FIFO, we can use uart_wait_tx_done function.

**Parameters**
- **uart_num** – UART port number, the max port number is (UART_NUM_MAX -1).

**Returns**
- ESP_OK Success
- ESP_FAIL Parameter error

**esp_err_t uart_get_buffered_data_len (uart_port_t uart_num, size_t *size)**

UART get RX ring buffer cached data length.

**Parameters**
- **uart_num** – UART port number, the max port number is (UART_NUM_MAX -1).
- **size** – Pointer of size_t to accept cached data length

**Returns**
- ESP_OK Success
- ESP_FAIL Parameter error

**esp_err_t uart_get_tx_buffer_free_size (uart_port_t uart_num, size_t *size)**

UART get TX ring buffer free space size.

**Parameters**
- **uart_num** – UART port number, the max port number is (UART_NUM_MAX -1).
- **size** – Pointer of size_t to accept the free space size

**Returns**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**esp_err_t uart_disable_pattern_det_intr (uart_port_t uart_num)**

UART disable pattern detect function. Designed for applications like ‘AT commands’. When the hardware detects a series of one same character, the interrupt will be triggered.

**Parameters**
- **uart_num** – UART port number, the max port number is (UART_NUM_MAX -1).

**Returns**
- ESP_OK Success
- ESP_FAIL Parameter error

**esp_err_t uart_enable_pattern_det_baud_intr (uart_port_t uart_num, char pattern_chr, uint8_t chr_num, int chr_tout, int post_idle, int pre_idle)**

UART enable pattern detect function. Designed for applications like ‘AT commands’. When the hardware detect a series of one same character, the interrupt will be triggered.

**Parameters**
- **uart_num** – UART port number.
• **pattern_chr** – character of the pattern.
• **chr_num** – number of the character, 8bit value.
• **chr_tout** – timeout of the interval between each pattern characters, 16bit value, unit is the baud-rate cycle you configured. When the duration is more than this value, it will not take this data as at_cmd char.
• **post_idle** – idle time after the last pattern character, 16bit value, unit is the baud-rate cycle you configured. When the duration is less than this value, it will not take the previous data as the last at_cmd char
• **pre_idle** – idle time before the first pattern character, 16bit value, unit is the baud-rate cycle you configured. When the duration is less than this value, it will not take this data as the first at_cmd char.

**Returns**
- ESP_OK Success
- ESP_FAIL Parameter error

```c
int uart_pattern_pop_pos(uart_port_t uart_num)
```

Return the nearest detected pattern position in buffer. The positions of the detected pattern are saved in a queue, this function will dequeue the first pattern position and move the pointer to next pattern position.

The following APIs will modify the pattern position info: uart_flush_input, uart_read_bytes, uart_driver_delete, uart_pop_pattern_pos It is the application’s responsibility to ensure atomic access to the pattern queue and the rx data buffer when using pattern detect feature.

**Note:** If the RX buffer is full and flow control is not enabled, the detected pattern may not be found in the rx buffer due to overflow.

**Parameters**
- `uart_num` – UART port number, the max port number is (UART_NUM_MAX -1).

**Returns**
- (-1) No pattern found for current index or parameter error
- others the pattern position in rx buffer.

```c
int uart_pattern_get_pos(uart_port_t uart_num)
```

Return the nearest detected pattern position in buffer. The positions of the detected pattern are saved in a queue. This function do nothing to the queue.

The following APIs will modify the pattern position info: uart_flush_input, uart_read_bytes, uart_driver_delete, uart_pop_pattern_pos It is the application’s responsibility to ensure atomic access to the pattern queue and the rx data buffer when using pattern detect feature.

**Note:** If the RX buffer is full and flow control is not enabled, the detected pattern may not be found in the rx buffer due to overflow.

**Parameters**
- `uart_num` – UART port number, the max port number is (UART_NUM_MAX -1).

**Returns**
- (-1) No pattern found for current index or parameter error
- others the pattern position in rx buffer.

```c
esp_err_t uart_pattern_queue_reset(uart_port_t uart_num, int queue_length)
```

Allocate a new memory with the given length to save record the detected pattern position in rx buffer.

**Parameters**
- `uart_num` – UART port number, the max port number is (UART_NUM_MAX -1).
• queue_length – Max queue length for the detected pattern. If the queue length is not large enough, some pattern positions might be lost. Set this value to the maximum number of patterns that could be saved in data buffer at the same time.

Returns
• ESP_ERR_NO_MEM No enough memory
• ESP_ERR_INVALID_STATE Driver not installed
• ESP_FAIL Parameter error
• ESP_OK Success

esp_err_t uart_set_mode (uart_port_t uart_num, uart_mode_t mode)
UART set communication mode.

Note: This function must be executed after uart_driver_install(), when the driver object is initialized.

Parameters
• uart_num – Uart number to configure, the max port number is (UART_NUM_MAX -1).
• mode – UART UART mode to set

Returns
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

esp_err_t uart_set_rx_full_threshold (uart_port_t uart_num, int threshold)
Set uart threshold value for RX fifo full.

Note: If application is using higher baudrate and it is observed that bytes in hardware RX fifo are overwritten then this threshold can be reduced

Parameters
• uart_num – UART_NUM_0, UART_NUM_1 or UART_NUM_2
• threshold – Threshold value above which RX fifo full interrupt is generated

Returns
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_ERR_INVALID_STATE Driver is not installed

esp_err_t uart_set_tx_empty_threshold (uart_port_t uart_num, int threshold)
Set uart threshold values for TX fifo empty.

Parameters
• uart_num – UART_NUM_0, UART_NUM_1 or UART_NUM_2
• threshold – Threshold value below which TX fifo empty interrupt is generated

Returns
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_ERR_INVALID_STATE Driver is not installed

esp_err_t uart_set_rx_timeout (uart_port_t uart_num, const uint8_t tout_thresh)
UART set threshold timeout for TOUT feature.

Parameters
• uart_num – Uart number to configure, the max port number is (UART_NUM_MAX -1).
• tout_thresh – This parameter defines timeout threshold in uart symbol periods. The maximum value of threshold is 126. tout_thresh = 1, defines TOUT interrupt timeout equal to transmission time of one symbol (~11 bit) on current baudrate. If the time is
Chapter 2. API Reference

expired the UART_RXFIFO_TOUT_INT interrupt is triggered. If tout_thresh == 0, the TOUT feature is disabled.

Returns
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_ERR_INVALID_STATE Driver is not installed

esp_err_t uart_get_collision_flag(uart_port_t uart_num, bool *collision_flag)
Returns collision detection flag for RS485 mode Function returns the collision detection flag into variable pointed by collision_flag. *collision_flag = true, if collision detected else it is equal to false. This function should be executed when actual transmission is completed (after uart_write_bytes()).

Parameters
• uart_num – UART number, the max port number is (UART_NUM_MAX - 1).
• collision_flag – Pointer to variable of type bool to return collision flag.

Returns
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

esp_err_t uart_set_wakeup_threshold(uart_port_t uart_num, int wakeup_threshold)
Set the number of RX pin signal edges for light sleep wakeup.
UART can be used to wake up the system from light sleep. This feature works by counting the number of positive edges on RX pin and comparing the count to the threshold. When the count exceeds the threshold, system is woken up from light sleep. This function allows setting the threshold value.

Stop bit and parity bits (if enabled) also contribute to the number of edges. For example, letter ‘a’ with ASCII code 97 is encoded as 0100001101 on the wire (with 8n1 configuration), start and stop bits included. This sequence has 3 positive edges (transitions from 0 to 1). Therefore, to wake up the system when ‘a’ is sent, set wakeup_threshold=3.
The character that triggers wakeup is not received by UART (i.e. it can not be obtained from UART FIFO). Depending on the baud rate, a few characters after that will also not be received. Note that when the chip enters and exits light sleep mode, APB frequency will be changing. To ensure that UART has correct Baud rate all the time, it is necessary to select a source clock which has a fixed frequency and remains active during sleep. For the supported clock sources of the chips, please refer to uart_sclk_t or soc_periph_uart_clk_src_legacy_t

Note: in ESP32, the wakeup signal can only be input via IO_MUX (i.e. GPIO3 should be configured as function_1 to wake up UART0, GPIO9 should be configured as function_5 to wake up UART1), UART2 does not support light sleep wakeup feature.

Parameters
• uart_num – UART number, the max port number is (UART_NUM_MAX - 1).
• wakeup_threshold – number of RX edges for light sleep wakeup, value is 3 .. 0x3ff.

Returns
• ESP_OK on success
• ESP_ERR_INVALID_ARG if uart_num is incorrect or wakeup_threshold is outside of [3, 0x3ff] range.

esp_err_t uart_get_wakeup_threshold(uart_port_t uart_num, int *out_wakeup_threshold)
Get the number of RX pin signal edges for light sleep wakeup.
See description of uart_set_wakeup_threshold for the explanation of UART wakeup feature.

Parameters
• uart_num – UART number, the max port number is (UART_NUM_MAX - 1).
• out_wakeup_threshold – [out] output, set to the current value of wakeup threshold for the given UART.

Returns
• ESP_OK on success
• ESP_ERR_INVALID_ARG if out_wakeup_threshold is NULL

`esp_err_t uart_wait_tx_idle_polling(uart_port_t uart_num)`
Wait until UART tx memory empty and the last char send ok (polling mode).

* 

Returns
• ESP_OK on success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_FAIL Driver not installed

Parameters `uart_num` – UART number

`esp_err_t uart_set_loop_back(uart_port_t uart_num, bool loop_back_en)`
Configure TX signal loop back to RX module, just for the test usage.

* 

Returns
• ESP_OK on success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_FAIL Driver not installed

Parameters
• `uart_num` – UART number
• `loop_back_en` – Set true to enable the loop back function, else set it false.

`void uart_set_always_rx_timeout(uart_port_t uart_num, bool always_rx_timeout_en)`
Configure behavior of UART RX timeout interrupt.
When always_rx_timeout is true, timeout interrupt is triggered even if FIFO is full. This function can cause extra timeout interrupts triggered only to send the timeout event. Call this function only if you want to ensure timeout interrupt will always happen after a byte stream.

Parameters
• `uart_num` – UART number
• `always_rx_timeout_en` – Set to false enable the default behavior of timeout interrupt, set it to true to always trigger timeout interrupt.

Structures

`struct uart_intr_config_t`  
UART interrupt configuration parameters for uart_intr_config function.

Public Members

`uint32_t intr_enable_mask`  
UART interrupt enable mask, choose from UART_XXXX_INT_ENA_M under UART_INT_ENA_REG(i), connect with bit-or operator

`uint8_t rx_timeout_thresh`  
UART timeout interrupt threshold (unit: time of sending one byte)
uint8_t txfifo_empty_intr_thresh
    UART TX empty interrupt threshold.

uint8_t rxfifo_full_thresh
    UART RX full interrupt threshold.

struct uart_event_t
    Event structure used in UART event queue.

Public Members

uart_event_type_t type
    UART event type

size_t size
    UART data size for UART_DATA event

bool timeout_flag
    UART data read timeout flag for UART_DATA event (no new data received during configured RX TOUT) If the event is caused by FIFO-full interrupt, then there will be no event with the timeout flag before the next byte coming.

Macros

UART_NUM_0
    UART port 0

UART_NUM_1
    UART port 1

UART_NUM_2
    UART port 2

UART_NUM_MAX
    UART port max

UART_PIN_NO_CHANGE

UART_FIFO_LEN
    Length of the UART HW FIFO.

UART_BITRATE_MAX
    Maximum configurable bitrate.

Type Definitions

typedef intr_handle_t uart_isr_handle_t
Enumerations

class **uart_event_type_t**

UART event types used in the ring buffer.

*Values:*

- Enumerator **UART_DATA**
  UART data event
- Enumerator **UART_BREAK**
  UART break event
- Enumerator **UART_BUFFER_FULL**
  UART RX buffer full event
- Enumerator **UART_FIFO_OVF**
  UART FIFO overflow event
- Enumerator **UART_FRAME_ERR**
  UART RX frame error event
- Enumerator **UART_PARITY_ERR**
  UART RX parity event
- Enumerator **UART_DATA_BREAK**
  UART TX data and break event
- Enumerator **UART_PATTERN_DET**
  UART pattern detected
- Enumerator **UART_EVENT_MAX**
  UART event max index

**Header File**

- components/hal/include/hal/uart_types.h

**Structures**

```c
struct **uart_at_cmd_t**

UART AT cmd char configuration parameters. Note that this function may differ on different chip. Please refer to the TRM at configuration.
```

**Public Members**

```c
uint8_t **cmd_char**

UART AT cmd char
```
Chapter 2. API Reference

uint8_t char_num
   AT cmd char repeat number

uint32_t gap_tout
   gap time (in baud-rate) between AT cmd char

uint32_t pre_idle
   the idle time (in baud-rate) between the non AT char and first AT char

uint32_t post_idle
   the idle time (in baud-rate) between the last AT char and the none AT char

struct uart_sw_flowctrl_t
   UART software flow control configuration parameters.

Public Members

uint8_t xon_char
   Xon flow control char

uint8_t xoff_char
   Xoff flow control char

uint8_t xon_thrd
   If the software flow control is enabled and the data amount in rxfifo is less than xon_thrd, an xon_char will be sent

uint8_t xoff_thrd
   If the software flow control is enabled and the data amount in rxfifo is more than xoff_thrd, an xoff_char will be sent

struct uart_config_t
   UART configuration parameters for uart_param_config function.

Public Members

int baud_rate
   UART baud rate

uart_word_length_t data_bits
   UART byte size

uart_parity_t parity
   UART parity mode

uart_stop_bits_t stop_bits
   UART stop bits
Chapter 2. API Reference

\texttt{uart_hw_flowcontrol_t flow_ctrl}

UART HW flow control mode (cts/rts)

\texttt{uint8_t rx_flow_ctrl_thresh}

UART HW RTS threshold

\texttt{uart_sclk_t source_clk}

UART source clock selection

**Type Definitions**

typedef int \texttt{uart_port_t}

UART port number, can be UART_NUM_0 \sim (UART_NUM_MAX - 1).

typedef \texttt{soc_periph_uart_clk_src_legacy_t uart_sclk_t}

UART source clock.

**Enumerations**

enum \texttt{uart_mode_t}

UART mode selection.

\textit{Values}:

enumerator \texttt{UART_MODE_UART}

mode: regular UART mode

enumerator \texttt{UART_MODE_RS485_HALF_DUPLEX}

mode: half duplex RS485 UART mode control by RTS pin

enumerator \texttt{UART_MODE_IRDA}

mode: IRDA UART mode

enumerator \texttt{UART_MODE_RS485_COLLISION_DETECT}

mode: RS485 collision detection UART mode (used for test purposes)

enumerator \texttt{UART_MODE_RS485_APP_CTRL}

mode: application control RS485 UART mode (used for test purposes)

enum \texttt{uart_word_length_t}

UART word length constants.

\textit{Values}:

enumerator \texttt{UART_DATA_5_BITS}

word length: 5 bits

enumerator \texttt{UART_DATA_6_BITS}

word length: 6 bits
enumerator UART_DATA_7_BITS
    word length: 7bits

enumerator UART_DATA_8_BITS
    word length: 8bits

enumerator UART_DATA_BITS_MAX

definition uart_stop_bits_t
    UART stop bits number.
    Values:

enumerator UART_STOP_BITS_1
    stop bit: 1bit

enumerator UART_STOP_BITS_1_5
    stop bit: 1.5bits

enumerator UART_STOP_BITS_2
    stop bit: 2bits

enumerator UART_STOP_BITS_MAX

definition uart_parity_t
    UART parity constants.
    Values:

enumerator UART_PARITY_DISABLE
    Disable UART parity

enumerator UART_PARITY_EVEN
    Enable UART even parity

enumerator UART_PARITY_ODD
    Enable UART odd parity

definition uart_hw_flowcontrol_t
    UART hardware flow control modes.
    Values:

enumerator UART_HW_FLOWCTRL_DISABLE
    disable hardware flow control

enumerator UART_HW_FLOWCTRL_RTS
    enable RX hardware flow control (rts)

enumerator UART_HW_FLOWCTRL_CTS
    enable TX hardware flow control (cts)
enumerator UART_HW_FLOWCTRL_CTS_RTS
disable hardware flow control

enumerator UART_HW_FLOWCTRL_MAX

enum uart_signal_inv_t
UART signal bit map.
Values:

enumerator UART_SIGNAL_INV_DISABLE
Disable UART signal inverse

enumerator UART_SIGNAL_IRDA_TX_INV
inversethe UART irda_tx signal

enumerator UART_SIGNAL_IRDA_RX_INV
inversethe UART irda_rx signal

enumerator UART_SIGNAL_RXD_INV
inversethe UART rxd signal

enumerator UART_SIGNAL_CTS_INV
inversethe UART cts signal

enumerator UART_SIGNAL_DSR_INV
inversethe UART dsr signal

enumerator UART_SIGNAL_TXD_INV
inversethe UART txd signal

enumerator UART_SIGNAL_RTS_INV
inversethe UART rts signal

enumerator UART_SIGNAL_DTR_INV
inversethe UART dtr signal

**GPIO Lookup Macros** The UART peripherals have dedicated IO_MUX pins to which they are connected directly. However, signals can also be routed to other pins using the less direct GPIO matrix. To use direct routes, you need to know which pin is a dedicated IO_MUX pin for a UART channel. GPIO Lookup Macros simplify the process of finding and assigning IO_MUX pins. You choose a macro based on either the IO_MUX pin number, or a required UART channel name, and the macro will return the matching counterpart for you. See some examples below.

**Note:** These macros are useful if you need very high UART baud rates (over 40 MHz), which means you will have to use IO_MUX pins only. In other cases, these macros can be ignored, and you can use the GPIO Matrix as it allows you to configure any GPIO pin for any UART function.

1. **UART_NUM_2_TXD_DIRECT_GPIO_NUM** returns the IO_MUX pin number of UART channel 2 TXD pin (pin 17)
2. **UART_GPIO19_DIRECT_CHANNEL** returns the UART number of GPIO 19 when connected to the UART peripheral via IO_MUX (this is UART_NUM_0).

3. **UART_CTS_GPIO19_DIRECT_CHANNEL** returns the UART number of GPIO 19 when used as the UART CTS pin via IO_MUX (this is UART_NUM_0). It is similar to the above macro but specifies the pin function which is also part of the IO_MUX assignment.

### Header File

- components/soc/esp32/include/soc/uart_channel.h

### Macros

- UART_GPIO1_DIRECT_CHANNEL
- UART_NUM_0_TXD_DIRECT_GPIO_NUM
- UART_GPIO3_DIRECT_CHANNEL
- UART_NUM_0_RXD_DIRECT_GPIO_NUM
- UART_GPIO19_DIRECT_CHANNEL
- UART_NUM_0_CTS_DIRECT_GPIO_NUM
- UART_GPIO22_DIRECT_CHANNEL
- UART_NUM_0_RTS_DIRECT_GPIO_NUM
- UART_TXD_GPIO1_DIRECT_CHANNEL
- UART_RXD_GPIO3_DIRECT_CHANNEL
- UART_CTS_GPIO19_DIRECT_CHANNEL
- UART_RTS_GPIO22_DIRECT_CHANNEL
- UART_GPIO10_DIRECT_CHANNEL
- UART_NUM_1_TXD_DIRECT_GPIO_NUM
- UART_GPIO9_DIRECT_CHANNEL
- UART_NUM_1_RXD_DIRECT_GPIO_NUM
- UART_GPIO6_DIRECT_CHANNEL
- UART_NUM_1_CTS_DIRECT_GPIO_NUM
- UART_GPIO10_DIRECT_CHANNEL
Chapter 2. API Reference

UART_GPIO11_DIRECT_CHANNEL
UART_NUM_1_RTS_DIRECT_GPIO_NUM
UART_TXD_GPIO10_DIRECT_CHANNEL
UART_RXD_GPIO9_DIRECT_CHANNEL
UART_CTS_GPIO6_DIRECT_CHANNEL
UART_RTS_GPIO11_DIRECT_CHANNEL
UART_GPIO17_DIRECT_CHANNEL
UART_NUM_2_TXD_DIRECT_GPIO_NUM
UART_GPIO16_DIRECT_CHANNEL
UART_NUM_2_RXD_DIRECT_GPIO_NUM
UART_GPIO8_DIRECT_CHANNEL
UART_NUM_2_CTS_DIRECT_GPIO_NUM
UART_GPIO7_DIRECT_CHANNEL
UART_NUM_2_RTS_DIRECT_GPIO_NUM
UART_TXD_GPIO17_DIRECT_CHANNEL
UART_RXD_GPIO16_DIRECT_CHANNEL
UART_CTS_GPIO8_DIRECT_CHANNEL
UART_RTS_GPIO7_DIRECT_CHANNEL

Code examples for this API section are provided in the peripherals directory of ESP-IDF examples.

2.7 Project Configuration
Chapter 2. API Reference

2.7.1 Introduction

The esp-idf-kconfig package that ESP-IDF uses is based on kconfiglib, which is a Python extension to the Kconfig system. Kconfig provides a compile-time project configuration mechanism and offers configuration options of several types (e.g., integers, strings, and booleans). Kconfig files specify dependencies between options, default values of options, the way options are grouped together, etc.

For the full list of available features, please see Kconfig and kconfiglib extensions.

2.7.2 Project Configuration Menu

Application developers can open a terminal-based project configuration menu with the idf.py menuconfig build target.

After being updated, this configuration is saved in the sdkconfig file under the project root directory. Based on sdkconfig, application build targets will generate the sdkconfig.h file under the build directory, and will make the sdkconfig options available to the project build system and source files.

2.7.3 Using sdkconfig.defaults

In some cases, for example, when the sdkconfig file is under revision control, it may be inconvenient for the build system to change the sdkconfig file. The build system offers a solution to prevent it from happening, which is to create the sdkconfig.defaults file. This file is never touched by the build system, and can be created manually or automatically. It contains all the options which matter to the given application and are different from the default ones. The format is the same as that of the sdkconfig file. sdkconfig.defaults can be created manually when one remembers all the changed configuration, or it can be generated automatically by running the idf.py save-defconfig command.

Once sdkconfig.defaults is created, sdkconfig can be deleted or added to the ignore list of the revision control system (e.g., the .gitignore file for git). Project build targets will automatically create the sdkconfig file, populate it with the settings from the sdkconfig.defaults file, and configure the rest of the settings to their default values. Note that during the build process, settings from sdkconfig.defaults will not override those already in sdkconfig. For more information, see Custom Sdkconfig Defaults.

2.7.4 Kconfig Format Rules

Format rules for Kconfig files are as follows:

- Option names in any menus should have consistent prefixes. The prefix currently should have at least 3 characters.
- The unit of indentation should be 4 spaces. All sub-items belonging to a parent item are indented by one level deeper. For example, menu is indented by 0 spaces, config menu by 4 spaces, help in config by 8 spaces, and the text under help by 12 spaces.
- No trailing spaces are allowed at the end of the lines.
- The maximum length of options is 40 characters.
- The maximum length of lines is 120 characters.

Note: The help section of each config in the menu is treated as reStructuredText to generate the reference documentation for each option.

Format Checker

tools/ci/check_kconfigs.py is provided for checking Kconfig files against the above format rules. The checker checks all Kconfig and Kconfig.projbuild files in the ESP-IDF directory, and generates a new file with suffix .new with some suggestions about how to fix issues (if there are any). Please note that the checker cannot
correct all format issues and the responsibility of the developer is to final check and make corrections in order to pass the tests. For example, indentations will be corrected if there isn’t any misleading formatting, but it cannot come up with a common prefix for options inside a menu.

2.7.5 Backward Compatibility of Kconfig Options

The standard Kconfig tools ignore unknown options in sdkconfig. So if a developer has custom settings for options which are renamed in newer ESP-IDF releases, then the given setting for the option would be silently ignored. Therefore, several features have been adopted to avoid this:

1. kconfig is used by the tool chain to pre-process sdkconfig files before anything else. For example, menuconfig would read them, so the settings for old options will be kept and not ignored.
2. kconfig recursively finds all sdkconfig.rename files in ESP-IDF directory which contain old and new Kconfig option names. Old options are replaced by new ones in the sdkconfig file. Renames that should only appear for a single target can be placed in a target-specific rename file sdkconfig.rename.TARGET, where TARGET is the target name, e.g. sdkconfig.rename.esp32s2.
3. kconfig post-processes sdkconfig files and generates all build outputs (sdkconfig.h, sdkconfig.cmake, and auto.conf) by adding a list of compatibility statements, i.e., the values of old options are set for new options after modification. If users still use old options in their code, this will prevent it from breaking.
4. Deprecated options and their replacements are automatically generated by kconfig.

2.7.6 Configuration Options Reference

Subsequent sections contain the list of available ESP-IDF options automatically generated from Kconfig files. Note that due to dependencies between options, some options listed here may not be visible by default in menuconfig.

By convention, all option names are upper-case letters with underscores. When Kconfig generates sdkconfig and sdkconfig.h files, option names are prefixed with CONFIG_. So if an option ENABLE_FOO is defined in a Kconfig file and selected in menuconfig, then the sdkconfig and sdkconfig.h files will have CONFIG_ENABLE_FOO defined. In the following sections, option names are also prefixed with CONFIG_, same as in the source code.

Build type

Contains:

- CONFIG_APP_COMPATIBLE_PRE_V3_1_BOOTLOADERS
- CONFIG_APP_COMPATIBLE_PRE_V2_1_BOOTLOADERS
- CONFIG_APP_BUILD_TYPE
- CONFIG_APP_BUILD_TYPEPURE_RAM_APP
- CONFIG_APP_REPRODUCIBLE_BUILD
- CONFIG_APP_NO_BLOBS

CONFIG_APP_BUILD_TYPE

Application build type

Found in: Build type

Select the way the application is built.

By default, the application is built as a binary file in a format compatible with the ESP-IDF bootloader. In addition to this application, 2nd stage bootloader is also built. Application and bootloader binaries can be written into flash and loaded/executed from there.

Another option, useful for only very small and limited applications, is to only link the .elf file of the application, such that it can be loaded directly into RAM over JTAG or UART. Note that since IRAM and DRAM sizes are very limited, it is not possible to build any complex application this way. However
Chapter 2. API Reference

for some kinds of testing and debugging, this option may provide faster iterations, since the application does not need to be written into flash.

Note: when APP_BUILD_TYPE_RAM is selected and loaded with JTAG, ESP-IDF does not contain all the startup code required to initialize the CPUs and ROM memory (data/bss). Therefore it is necessary to execute a bit of ROM code prior to executing the application. A gdbinit file may look as follows (for ESP32):

```
# Connect to a running instance of OpenOCD target remote :3333
# Reset and halt the target
mon reset halt
# Run to a specific point in ROM code, where most of initialization is complete.
thb *0x40007d54 c
# Load the application into RAM
load
# Run till app_main tb
app_main c
```

Execute this gdbinit file as follows:

```
xtensa-esp32-elf-gdb build/app-name.elf-x gdbinit
```

Example gdbinit files for other targets can be found in tools/test_apps/system/gdb_loadable_elf/

When loading the BIN with UART, the ROM will jump to ram and run the app after finishing the ROM startup code, so there’s no additional startup initialization required. You can use the `load_ram` in esptool.py to load the generated .bin file into ram and execute.

**Example:**

```
esptool.py -chip {chip} -p {port} -b {baud} -no-stub load_ram {app.bin}
```

Recommended `sdkconfig.defaults` for building loadable ELF files is as follows. `CONFIG_APP_BUILD_TYPE_RAM` is required, other options help reduce application memory footprint.

```
CONFIG_APP_BUILD_TYPE_RAM=y
CONFIG_VFS_SUPPORT_TERMIOS=
CONFIG_NEWLIB_NANO_FORMAT=y
CONFIG_ESP_SYSTEM_PANIC_PRINT_HALT=y
CONFIG_ESP_DEBUG_STUBS_ENABLE=
CONFIG_ESP_ERR_TO_NAME_LOOKUP=
```

Available options:

- Default (binary application + 2nd stage bootloader) (CONFIG_APP_BUILD_TYPE_APP_2NDBOOT)
- Build app runs entirely in RAM (EXPERIMENTAL) (CONFIG_APP_BUILD_TYPE_RAM)

**CONFIG_APP_BUILD_TYPEPURE_RAM_APP**

Build app without SPI_FLASH/PSRAM support (saves ram)

**Found in:** Build type

If this option is enabled, external memory and related peripherals, such as Cache, MMU, Flash and PSRAM, won’t be initialized. Corresponding drivers won’t be introduced either. Components that depend on the spi_flash component will also be unavailable, such as app_update, etc. When this option is enabled, about 26KB of RAM space can be saved.

**CONFIG_APP_REPRODUCIBLE_BUILD**

Enable reproducible build

**Found in:** Build type

If enabled, all date, time, and path information would be eliminated. A .gdbinit file would be create automatically. (or will be append if you have one already)

**Default value:**

- No (disabled)
CONFIG_APP_NO_BLOBS

No Binary Blobs

Found in: Build type

If enabled, this disables the linking of binary libraries in the application build. Note that after enabling this Wi-Fi/Bluetooth will not work.

Default value:
  • No (disabled)

CONFIG_APP_COMPATIBLE_PRE_V2_1_BOOTLOADERS

App compatible with bootloaders before ESP-IDF v2.1

Found in: Build type

Bootloaders before ESP-IDF v2.1 did less initialisation of the system clock. This setting needs to be enabled to build an app which can be booted by these older bootloaders.

If this setting is enabled, the app can be booted by any bootloader from IDF v1.0 up to the current version.

If this setting is disabled, the app can only be booted by bootloaders from IDF v2.1 or newer.

Enabling this setting adds approximately 1KB to the app’s IRAM usage.

Default value:
  • No (disabled)

CONFIG_APP_COMPATIBLE_PRE_V3_1_BOOTLOADERS

App compatible with bootloader and partition table before ESP-IDF v3.1

Found in: Build type

Partition tables before ESP-IDF V3.1 do not contain an MD5 checksum field, and the bootloader before ESP-IDF v3.1 cannot read a partition table that contains an MD5 checksum field.

Enable this option only if your app needs to boot on a bootloader and/or partition table that was generated from a version *before* ESP-IDF v3.1.

If this option and Flash Encryption are enabled at the same time, and any data partitions in the partition table are marked Encrypted, then the partition encrypted flag should be manually verified in the app before accessing the partition (see CVE-2021-27926).

Default value:
  • No (disabled)

Bootloader config

Contains:

• CONFIG_BOOTLOADER_LOG_LEVEL
• CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION
• CONFIG_BOOTLOADER_SPI_WP_PIN
• CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE
• CONFIG_BOOTLOADER_REGION_PROTECTION_ENABLE
• CONFIG_BOOTLOADER_FLASH_XMC_SUPPORT
• CONFIG_BOOTLOADER_APP_TEST
• CONFIG_BOOTLOADER_FACTORY_RESET
• CONFIG_BOOTLOADER_HOLD_TIME_GPIO
• CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC
• CONFIG_BOOTLOADER_SKIP_VALIDATE_ALWAYS
**CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION**

Bootloader optimization Level

*Found in: Bootloader config*

This option sets compiler optimization level (gcc -O argument) for the bootloader.

- The default “Size” setting will add the -Os flag to CFLAGS.
- The “Debug” setting will add the -Og flag to CFLAGS.
- The “Performance” setting will add the -O2 flag to CFLAGS.
- The “None” setting will add the -O0 flag to CFLAGS.

Note that custom optimization levels may be unsupported.

Available options:

- Size (-Os) (CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION_SIZE)
- Debug (-Og) (CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION_DEBUG)
- Optimize for performance (-O2) (CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION_PERF)
- Debug without optimization (-O0) (CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION_NONE)

**CONFIG_BOOTLOADER_LOG_LEVEL**

Bootloader log verbosity

*Found in: Bootloader config*

Specify how much output to see in bootloader logs.

Available options:

- No output (CONFIG_BOOTLOADER_LOG_LEVEL_NONE)
- Error (CONFIG_BOOTLOADER_LOG_LEVEL_ERROR)
- Warning (CONFIG_BOOTLOADER_LOG_LEVEL_WARN)
- Info (CONFIG_BOOTLOADER_LOG_LEVEL_INFO)
- Debug (CONFIG_BOOTLOADER_LOG_LEVEL_DEBUG)
- Verbose (CONFIG_BOOTLOADER_LOG_LEVEL_VERBOSE)

**CONFIG_BOOTLOADER_SPI_CUSTOM_WP_PIN**

Use custom SPI Flash WP Pin when flash pins set in eFuse (read help)

*Found in: Bootloader config*

This setting is only used if the SPI flash pins have been overridden by setting the eFuses SPI_PAD_CONFIG_XXX, and the SPI flash mode is QIO or QOUT.

When this is the case, the eFuse config only defines 3 of the 4 Quad I/O data pins. The WP pin (aka ESP32 pin “SD_DATA_3” or SPI flash pin “IO2”) is not specified in eFuse. The same pin is also used for external SPIRAM if it is enabled.

If this config item is set to N (default), the correct WP pin will be automatically used for any Espressif chip or module with integrated flash. If a custom setting is needed, set this config item to Y and specify the GPIO number connected to the WP.
Default value:
- No (disabled) if CONFIG_ESPTOOLPY_FLASHMODE_QIO || CONFIG_ESPTOOLPY_FLASHMODE_QOUT

CONFIG_BOOTLOADER_SPI_WP_PIN

Custom SPI Flash WP Pin

Found in: Bootloader config

The option “Use custom SPI Flash WP Pin” must be set or this value is ignored

If burning a customized set of SPI flash pins in eFuse and using QIO or QOUT mode for flash, set this value to the GPIO number of the SPI flash WP pin.

Range:
- from 0 to 33 if CONFIG_ESPTOOLPY_FLASHMODE_QIO || CONFIG_ESPTOOLPY_FLASHMODE_QOUT

Default value:
- 7 if CONFIG_ESPTOOLPY_FLASHMODE_QIO || CONFIG_ESPTOOLPY_FLASHMODE_QOUT

CONFIG_BOOTLOADER_VDDSDIO_BOOST

VDDSDIO LDO voltage

Found in: Bootloader config

If this option is enabled, and VDDSDIO LDO is set to 1.8V (using eFuse or MTDI bootstrapping pin), bootloader will change LDO settings to output 1.9V instead. This helps prevent flash chip from browning out during flash programming operations.

This option has no effect if VDDSDIO is set to 3.3V, or if the internal VDDSDIO regulator is disabled via eFuse.

Available options:

- 1.8V (CONFIG_BOOTLOADER_VDDSDIO_BOOST_1_8V)
- 1.9V (CONFIG_BOOTLOADER_VDDSDIO_BOOST_1_9V)

CONFIG_BOOTLOADER_FACTORY_RESET

GPIO triggers factory reset

Found in: Bootloader config

Allows to reset the device to factory settings: - clear one or more data partitions; - boot from “factory” partition. The factory reset will occur if there is a GPIO input held at the configured level while device starts up. See settings below.

Default value:
- No (disabled)

CONFIG_BOOTLOADER_NUM_PIN_FACTORY_RESET

Number of the GPIO input for factory reset

Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET

The selected GPIO will be configured as an input with internal pull-up enabled (note that on some SoCs, not all pins have an internal pull-up, consult the hardware datasheet for details.) To trigger a factory reset, this GPIO must be held high or low (as configured) on startup.
Range:
- from 0 to 39 if `CONFIG_BOOTLOADER_FACTORY_RESET`

**Default value:**
- 4 if `CONFIG_BOOTLOADER_FACTORY_RESET`

**CONFIG_BOOTLOADER_FACTORY_RESET_PIN_LEVEL**
Factory reset GPIO level

*Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET*

Pin level for factory reset, can be triggered on low or high.

Available options:

- Reset on GPIO low (CONFIG_BOOTLOADER_FACTORY_RESET_PIN_LOW)
- Reset on GPIO high (CONFIG_BOOTLOADER_FACTORY_RESET_PIN_HIGH)

**CONFIG_BOOTLOADER_OTA_DATA_ERASE**
Clear OTA data on factory reset (select factory partition)

*Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET*

The device will boot from “factory” partition (or OTA slot 0 if no factory partition is present) after a factory reset.

**CONFIG_BOOTLOADER_DATA_FACTORY_RESET**
Comma-separated names of partitions to clear on factory reset

*Found in: Bootloader config > CONFIG_BOOTLOADER_FACTORY_RESET*

Allows customers to select which data partitions will be erased while factory reset.

Specify the names of partitions as a comma-delimited with optional spaces for readability. (Like this: “nvs, phy_init, …”) Make sure that the name specified in the partition table and here are the same. Partitions of type “app” cannot be specified here.

**Default value:**
- “nvs” if `CONFIG_BOOTLOADER_FACTORY_RESET`

**CONFIG_BOOTLOADER_APP_TEST**
GPIO triggers boot from test app partition

*Found in: Bootloader config*

Allows to run the test app from “TEST” partition. A boot from “test” partition will occur if there is a GPIO input pulled low while device starts up. See settings below.

**Default value:**
- No (disabled) if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_NUM_PIN_APP_TEST**
Number of the GPIO input to boot TEST partition

*Found in: Bootloader config > CONFIG_BOOTLOADER_APP_TEST*

The selected GPIO will be configured as an input with internal pull-up enabled. To trigger a test app, this GPIO must be pulled low on reset. After the GPIO input is deactivated and the device reboots, the
old application will boot. (factory or OTA[x]). Note that GPIO34-39 do not have an internal pullup and an external one must be provided.

**Range:**
- from 0 to 39 if `CONFIG_BOOTLOADER_APP_TEST`

**Default value:**
- 18 if `CONFIG_BOOTLOADER_APP_TEST`

**CONFIG_BOOTLOADER_APP_TEST_PIN_LEVEL**

App test GPIO level

*Found in: Bootloader config > CONFIG_BOOTLOADER_APP_TEST*

Pin level for app test, can be triggered on low or high.

**Available options:**

- Enter test app on GPIO low (CONFIG_BOOTLOADER_APP_TEST_PIN_LOW)
- Enter test app on GPIO high (CONFIG_BOOTLOADER_APP_TEST_PIN_HIGH)

**CONFIG_BOOTLOADER_HOLD_TIME_GPIO**

Hold time of GPIO for reset/test mode (seconds)

*Found in: Bootloader config*

The GPIO must be held low continuously for this period of time after reset before a factory reset or test partition boot (as applicable) is performed.

**Default value:**
- 5 if `CONFIG_BOOTLOADER_FACTORY_RESET` || `CONFIG_BOOTLOADER_APP_TEST`

**CONFIG_BOOTLOADER_REGION_PROTECTION_ENABLE**

Enable protection for unmapped memory regions

*Found in: Bootloader config*

Protects the unmapped memory regions of the entire address space from unintended accesses. This will ensure that an exception will be triggered whenever the CPU performs a memory operation on unmapped regions of the address space.

**Default value:**
- Yes (enabled)

**CONFIG_BOOTLOADER_WDT_ENABLE**

Use RTC watchdog in start code

*Found in: Bootloader config*

Tracks the execution time of startup code. If the execution time is exceeded, the RTC_WDT will restart system. It is also useful to prevent a lock up in start code caused by an unstable power source. NOTE: Tracks the execution time starts from the bootloader code - re-set timeout, while selecting the source for slow_clk - and ends calling app_main. Re-set timeout is needed due to WDT uses a SLOW_CLK clock source. After changing a frequency slow_clk a time of WDT needs to re-set for new frequency. slow_clk depends on RTC_CLK_SRC (INTERNAL_RC or EXTERNALCRYSTAL).

**Default value:**
- Yes (enabled)
CONFIG_BOOTLOADER_WDT_DISABLE_IN_USER_CODE

Allows RTC watchdog disable in user code

*Found in:* Bootloader config > CONFIG_BOOTLOADER_WDT_ENABLE

If this option is set, the ESP-IDF app must explicitly reset, feed, or disable the rtc_wdt in the app’s own code. If this option is not set (default), then rtc_wdt will be disabled by ESP-IDF before calling the app_main() function.

Use function rtc_wdt_feed() for resetting counter of rtc_wdt. Use function rtc_wdt_disable() for disabling rtc_wdt.

**Default value:**
- No (disabled)

CONFIG_BOOTLOADER_WDT_TIME_MS

Timeout for RTC watchdog (ms)

*Found in:* Bootloader config > CONFIG_BOOTLOADER_WDT_ENABLE

Verify that this parameter is correct and more then the execution time. Pay attention to options such as reset to factory, trigger test partition and encryption on boot - these options can increase the execution time. Note: RTC_WDT will reset while encryption operations will be performed.

**Range:**
- from 0 to 120000

**Default value:**
- 9000

CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE

Enable app rollback support

*Found in:* Bootloader config

After updating the app, the bootloader runs a new app with the “ESP_OTA_IMG_PENDING_VERIFY” state set. This state prevents the re-run of this app. After the first boot of the new app in the user code, the function should be called to confirm the operability of the app or vice versa about its non-operability. If the app is working, then it is marked as valid. Otherwise, it is marked as not valid and rolls back to the previous working app. A reboot is performed, and the app is booted before the software update. Note: If during the first boot a new app the power goes out or the WDT works, then roll back will happen. Rollback is possible only between the apps with the same security versions.

**Default value:**
- No (disabled)

CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK

Enable app anti-rollback support

*Found in:* Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE

This option prevents rollback to previous firmware/application image with lower security version.

**Default value:**
- No (disabled) if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE

Espressif Systems 1456 Release v5.1.2
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**CONFIG_BOOTLOADER_APP_SECURE_VERSION**

eFuse secure version of app

*Found in:* Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE > CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK

The secure version is the sequence number stored in the header of each firmware. The security version is set in the bootloader, version is recorded in the eFuse field as the number of set ones. The allocated number of bits in the efuse field for storing the security version is limited (see BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD option).

Bootloader: When bootloader selects an app to boot, an app is selected that has a security version greater or equal that recorded in eFuse field. The app is booted with a higher (or equal) secure version.

The security version is worth increasing if in previous versions there is a significant vulnerability and their use is not acceptable.

Your partition table should has a scheme with ota_0 + ota_1 (without factory).

**Default value:**

- 0 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD**

Size of the efuse secure version field

*Found in:* Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE > CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK

The size of the efuse secure version field. Its length is limited to 32 bits for ESP32 and 16 bits for ESP32-S2. This determines how many times the security version can be increased.

**Range:**

- from 1 to 32 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`
- from 1 to 16 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**Default value:**

- 32 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`
- 16 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_EFUSE_SECURE_VERSION_EMULATE**

Emulate operations with efuse secure version (only test)

*Found in:* Bootloader config > CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE > CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK

This option allows to emulate read/write operations with all eFuses and efuse secure version. It allows to test anti-rollback implementation without permanent write eFuse bits. There should be an entry in partition table with following details: `emul_efuse, data, efuse, , 0x2000`.

This option enables: EFUSE_VIRTUAL and EFUSE_VIRTUAL_KEEP_IN_FLASH.

**Default value:**

- No (disabled) if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

**CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP**

Skip image validation when exiting deep sleep

*Found in:* Bootloader config

This option disables the normal validation of an image coming out of deep sleep (checksums, SHA256, and signature). This is a trade-off between wakeup performance from deep sleep, and image integrity checks.
Only enable this if you know what you are doing. It should not be used in conjunction with using deep_sleep() entry and changing the active OTA partition as this would skip the validation upon first load of the new OTA partition.

It is possible to enable this option with Secure Boot if “allow insecure options” is enabled, however it’s strongly recommended to NOT enable it as it may allow a Secure Boot bypass.

**Default value:**
- No (disabled) if (CONFIG_SECURE_BOOT && CONFIG_SECURE_BOOT_INSECURE) ||
  CONFIG_SECURE_BOOT

**CONFIG_BOOTLOADER_SKIP_VALIDATE_ON_POWER_ON**

Skip image validation from power on reset (READ HELP FIRST)

*Found in: Bootloader config*

Some applications need to boot very quickly from power on. By default, the entire app binary is read from flash and verified which takes up a significant portion of the boot time.

Enabling this option will skip validation of the app when the SoC boots from power on. Note that in this case it’s not possible for the bootloader to detect if an app image is corrupted in the flash, therefore it’s not possible to safely fall back to a different app partition. Flash corruption of this kind is unlikely but can happen if there is a serious firmware bug or physical damage.

Following other reset types, the bootloader will still validate the app image. This increases the chances that flash corruption resulting in a crash can be detected following soft reset, and the bootloader will fall back to a valid app image. To increase the chances of successfully recovering from a flash corruption event, keep the option BOOTLOADER_WDT_ENABLE enabled and consider also enabling BOOTLOADER_WDT_DISABLE_IN_USER_CODE - then manually disable the RTC Watchdog once the app is running. In addition, enable both the Task and Interrupt watchdog timers with reset options set.

**Default value:**
- No (disabled)

**CONFIG_BOOTLOADER_SKIP_VALIDATE_ALWAYS**

Skip image validation always (READ HELP FIRST)

*Found in: Bootloader config*

Selecting this option prevents the bootloader from ever validating the app image before booting it. Any flash corruption of the selected app partition will make the entire SoC unbootable.

Although flash corruption is a very rare case, it is not recommended to select this option. Consider selecting “Skip image validation from power on reset” instead. However, if boot time is the only important factor then it can be enabled.

**Default value:**
- No (disabled)

**CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC**

Reserve RTC FAST memory for custom purposes

*Found in: Bootloader config*

This option allows the customer to place data in the RTC FAST memory, this area remains valid when rebooted, except for power loss. This memory is located at a fixed address and is available for both the bootloader and the application. (The application and bootloader must be compiled with the same option). The RTC FAST memory has access only through PRO_CPU.

**Default value:**
- No (disabled)
CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC_SIZE

Size in bytes for custom purposes

*Found in: Bootloader config > CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC*

This option reserves in RTC FAST memory the area for custom purposes. If you want to create your own bootloader and save more information in this area of memory, you can increase it. It must be a multiple of 4 bytes. This area (rtc_retain_mem_t) is reserved and has access from the bootloader and an application.

**Default value:**
- 0 if CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC

CONFIG_BOOTLOADER_FLASH_XMC_SUPPORT

Enable the support for flash chips of XMC (READ HELP FIRST)

*Found in: Bootloader config*

Perform the startup flow recommended by XMC. Please consult XMC for the details of this flow. XMC chips will be forbidden to be used, when this option is disabled.

**Don’t disable this unless you know what you are doing.**

**Default value:**
- Yes (enabled)

**Security features**

Contains:

- CONFIG_SECURE_BOOT_INSECURE
- CONFIG_SECURE_SIGNED_APPS_SCHEME
- CONFIG_SECURE_SIGNED_ON_BOOT_NO_SECURE_BOOT
- CONFIG_SECURE_FLASH_CHECK_ENC_EN_IN_APP
- CONFIG_SECURE_BOOT_ECDSA_KEY_LEN_SIZE
- CONFIG_SECURE_BOOT_ENABLE_AGGRESSIVE_KEY_REVOKE
- CONFIG_SECURE_FLASH_ENC_ENABLED
- CONFIG_SECURE_BOOT
- CONFIG_SECURE_BOOTLOADER_KEY_ENCODING
- Potentially insecure options
- CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
- CONFIG_SECURE_BOOT_VERIFICATION_KEY
- CONFIG_SECURE_BOOTLOADER_MODE
- CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES
- CONFIG_SECURE_UART_ROM_DL_MODE
- CONFIG_SECURE_SIGNED_ON_UPDATE_NO_SECURE_BOOT

CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT

Require signed app images

*Found in: Security features*

Require apps to be signed to verify their integrity.

This option uses the same app signature scheme as hardware secure boot, but unlike hardware secure boot it does not prevent the bootloader from being physically updated. This means that the device can be secured against remote network access, but not physical access. Compared to using hardware Secure Boot this option is much simpler to implement.
**CONFIG_SECURE_SIGNED_APPS_SCHEME**

App Signing Scheme

*Found in: Security features*

Select the Secure App signing scheme. Depends on the Chip Revision. There are two secure boot versions:

1. **Secure boot V1**
   - Legacy custom secure boot scheme. Supported in ESP32 SoC.

2. **Secure boot V2**
   - RSA based secure boot scheme. Supported in ESP32-ECO3 (ESP32 Chip Revision 3 onwards), ESP32-S2, ESP32-C3, ESP32-S3 SoCs.
   - ECDSA based secure boot scheme. Supported in ESP32-C2 SoC.

Available options:

- **ECDSA (CONFIG_SECURE_SIGNED_APPS_ECDSA_SCHEME)**
  Embeds the ECDSA public key in the bootloader and signs the application with an ECDSA key. Refer to the documentation before enabling.

- **RSA (CONFIG_SECURE_SIGNED_APPS_RSA_SCHEME)**
  Appends the RSA-3072 based Signature block to the application. Refer to `<Secure Boot Version 2 documentation link>` before enabling.

- **ECDSA (V2) (CONFIG_SECURE_SIGNED_APPS_ECDSA_V2_SCHEME)**
  For Secure boot V2 (e.g., ESP32-C2 SoC), appends ECDSA based signature block to the application. Refer to documentation before enabling.

**CONFIG_SECURE_BOOT_ECDSA_KEY_LEN_SIZE**

ECDSA key size

*Found in: Security features*

Select the ECDSA key size. Two key sizes are supported

- 192 bit key using NISTP192 curve
- 256 bit key using NISTP256 curve (Recommended)

The advantage of using 256 bit key is the extra randomness which makes it difficult to be bruteforced compared to 192 bit key. At present, both key sizes are practically implausible to bruteforce.

Available options:

- **Using ECC curve NISTP192 (CONFIG_SECURE_BOOT_ECDSA_KEY_LEN_192_BITS)**
- **Using ECC curve NISTP256 (Recommended) (CONFIG_SECURE_BOOT_ECDSA_KEY_LEN_256_BITS)**

**CONFIG_SECURE_SIGNED_ON_BOOT_NO_SECURE_BOOT**

Bootloader verifies app signatures

*Found in: Security features*

If this option is set, the bootloader will be compiled with code to verify that an app is signed before booting it.

If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option doesn’t add significant security by itself so most users will want to leave it disabled.

*Default value:*
CONFIG_SECURE_SIGNED_ON_UPDATE_NO_SECURE_BOOT

Verify app signature on update

Found in: Security features

If this option is set, any OTA updated apps will have the signature verified before being considered valid. When enabled, the signature is automatically checked whenever the esp_ota_ops.h APIs are used for OTA updates, or esp_image_format.h APIs are used to verify apps. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option still adds significant security against network-based attackers by preventing spoofing of OTA updates.

Default value:
- Yes (enabled) if CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT

CONFIG_SECURE_BOOT

Enable hardware Secure Boot in bootloader (READ DOCS FIRST)

Found in: Security features

Build a bootloader which enables Secure Boot on first boot. Once enabled, Secure Boot will not boot a modified bootloader. The bootloader will only load a partition table or boot an app if the data has a verified digital signature. There are implications for reflashing updated apps once secure boot is enabled.

When enabling secure boot, JTAG and ROM BASIC Interpreter are permanently disabled by default.

Default value:
- No (disabled)

CONFIG_SECURE_BOOT_VERSION

Select secure boot version

Found in: Security features > CONFIG_SECURE_BOOT

Select the Secure Boot Version. Depends on the Chip Revision. Secure Boot V2 is the new RSA / ECDSA based secure boot scheme.

- RSA based scheme is supported in ESP32 (Revision 3 onwards), ESP32-S2, ESP32-C3 (ECO3), ESP32-S3.
- ECDSA based scheme is supported in ESP32-C2 SoC.

Please note that, RSA or ECDSA secure boot is property of specific SoC based on its HW design, supported crypto accelerators, die-size, cost and similar parameters. Please note that RSA scheme has requirement for bigger key sizes but at the same time it is comparatively faster than ECDSA verification.

Secure Boot V1 is the AES based (custom) secure boot scheme supported in ESP32 SoC.

Available options:

- Enable Secure Boot version 1 (CONFIG_SECURE_BOOT_V1_ENABLED)
  Build a bootloader which enables secure boot version 1 on first boot. Refer to the Secure Boot section of the ESP-IDF Programmer’s Guide for this version before enabling.
- Enable Secure Boot version 2 (CONFIG_SECURE_BOOT_V2_ENABLED)
  Build a bootloader which enables Secure Boot version 2 on first boot. Refer to Secure Boot V2 section of the ESP-IDF Programmer’s Guide for this version before enabling.
CONFIG_SECURE_BOOTLOADER_MODE

Secure bootloader mode

Found in: Security features

Available options:

- One-time flash (CONFIG_SECURE_BOOTLOADER_ONE_TIME_FLASH)
  On first boot, the bootloader will generate a key which is not readable externally or by software. A digest is generated from the bootloader image itself. This digest will be verified on each subsequent boot. Enabling this option means that the bootloader cannot be changed after the first time it is booted.

- Reflashable (CONFIG_SECURE_BOOTLOADER_REFLASHERABLE)
  Generate a reusable secure bootloader key, derived (via SHA-256) from the secure boot signing key. This allows the secure bootloader to be re-flashed by anyone with access to the secure boot signing key. This option is less secure than one-time flash, because a leak of the digest key from one device allows re-flashing of any device that uses it.

CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES

Sign binaries during build

Found in: Security features

Once secure boot or signed app requirement is enabled, app images are required to be signed.

If enabled (default), these binary files are signed as part of the build process. The file named in “Secure boot private signing key” will be used to sign the image.

If disabled, unsigned app/partition data will be built. They must be signed manually using espsecure.py. Version 1 to enable ECDSA Based Secure Boot and Version 2 to enable RSA based Secure Boot. (for example, on a remote signing server.)

CONFIG_SECURE_BOOT_SIGNING_KEY

Secure boot private signing key

Found in: Security features > CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES

Path to the key file used to sign app images.

Key file is an ECDSA private key (NIST256p curve) in PEM format for Secure Boot V1. Key file is an RSA private key in PEM format for Secure Boot V2.

Path is evaluated relative to the project directory.

You can generate a new signing key by running the following command: espsecure.py generate Signing key secure Boot Signing key.pem

See the Secure Boot section of the ESP-IDF Programmer’s Guide for this version for details.

Default value:

- “secure_boot_signing_key.pem” if CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES

CONFIG_SECURE_BOOT_VERIFICATION_KEY

Secure boot public signature verification key

Found in: Security features
Path to a public key file used to verify signed images. Secure Boot V1: This ECDSA public key is compiled into the bootloader and/or app, to verify app images.

Key file is in raw binary format, and can be extracted from a PEM formatted private key using the espsecure.py extract_public_key command.

Refer to the Secure Boot section of the ESP-IDF Programmer’s Guide for this version before enabling.

**CONFIG_SECURE_BOOT_ENABLE_AGGRESSIVE_KEY_REVOKE**

Enable Aggressive key revoke strategy

*Found in: Security features*

If this option is set, ROM bootloader will revoke the public key digest burned in eFuse block if it fails to verify the signature of software bootloader with it. Revocation of keys does not happen when enabling secure boot. Once secure boot is enabled, key revocation checks will be done on subsequent boot-up, while verifying the software bootloader

This feature provides a strong resistance against physical attacks on the device.

NOTE: Once a digest slot is revoked, it can never be used again to verify an image. This can lead to permanent bricking of the device, in case all keys are revoked because of signature verification failure.

*Default value:*
- No (disabled) if `CONFIG_SECURE_BOOT && SOC_SUPPORT_SECURE_BOOT_REVOKE_KEY`

**CONFIG_SECURE_BOOTLOADER_KEY_ENCODING**

Hardware Key Encoding

*Found in: Security features*

In reflashable secure bootloader mode, a hardware key is derived from the signing key (with SHA-256) and can be written to eFuse with espfuse.py.

Normally this is a 256-bit key, but if 3/4 Coding Scheme is used on the device then the eFuse key is truncated to 192 bits.

This configuration item doesn’t change any firmware code, it only changes the size of key binary which is generated at build time.

*Available options:*
- No encoding (256 bit key) (CONFIG_SECURE_BOOTLOADER_KEY_ENCODING_256BIT)
- 3/4 encoding (192 bit key) (CONFIG_SECURE_BOOTLOADER_KEY_ENCODING_192BIT)

**CONFIG_SECURE_BOOT_INSECURE**

Allow potentially insecure options

*Found in: Security features*

You can disable some of the default protections offered by secure boot, in order to enable testing or a custom combination of security features.

Only enable these options if you are very sure.

Refer to the Secure Boot section of the ESP-IDF Programmer’s Guide for this version before enabling.

*Default value:*
- No (disabled) if `CONFIG_SECURE_BOOT`
CONFIG_SECURE_FLASH_ENC_ENABLED

Enable flash encryption on boot (READ DOCS FIRST)

*Found in: Security features*

If this option is set, flash contents will be encrypted by the bootloader on first boot.

Note: After first boot, the system will be permanently encrypted. Re-flashing an encrypted system is complicated and not always possible.

Read *Flash Encryption* before enabling.

**Default value:**
- No (disabled)

CONFIG_SECURE_FLASH_ENCRYPTION_KEYSIZE

Size of generated AES-XTS key

*Found in: Security features > CONFIG_SECURE_FLASH_ENC_ENABLED*

Size of generated AES-XTS key.

- AES-128 uses a 256-bit key (32 bytes) derived from 128 bits (16 bytes) burned in half Efuse key block. Internally, it calculates SHA256(128 bits)
- AES-128 uses a 256-bit key (32 bytes) which occupies one Efuse key block.
- AES-256 uses a 512-bit key (64 bytes) which occupies two Efuse key blocks.

This setting is ignored if either type of key is already burned to Efuse before the first boot. In this case, the pre-burned key is used and no new key is generated.

Available options:

- AES-128 key derived from 128 bits (SHA256(128 bits)) (CONFIG_SECURE_FLASH_ENCRYPTION_AES128_DERIVED)
- AES-128 (256-bit key) (CONFIG_SECURE_FLASH_ENCRYPTION_AES128)
- AES-256 (512-bit key) (CONFIG_SECURE_FLASH_ENCRYPTION_AES256)

CONFIG_SECURE_FLASH_ENCRYPTION_MODE

Enable usage mode

*Found in: Security features > CONFIG_SECURE_FLASH_ENC_ENABLED*

By default Development mode is enabled which allows ROM download mode to perform flash encryption operations (plaintext is sent to the device, and it encrypts it internally and writes ciphertext to flash.) This mode is not secure, it’s possible for an attacker to write their own chosen plaintext to flash.

Release mode should always be selected for production or manufacturing. Once enabled it’s no longer possible for the device in ROM Download Mode to use the flash encryption hardware.

When EFUSE_VIRTUAL is enabled, SECURE_FLASH_ENCRYPTION_MODE_RELEASE is not available. For CI tests we use IDF_CI_BUILD to bypass it ( “export IDF_CI_BUILD=1” ). We do not recommend bypassing it for other purposes.

Refer to the Flash Encryption section of the ESP-IDF Programmer’s Guide for details.

Available options:

- Development (NOT SECURE) (CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT)
- Release (CONFIG_SECURE_FLASH_ENCRYPTION_MODE_RELEASE)
Potentially insecure options  Contains:

- `CONFIG_SECURE_BOOT_V2_ALLOW_EFUSE_RD_DIS`
- `CONFIG_SECURE_BOOT_ALLOW_SHORT_APP_PARTITION`
- `CONFIG_SECURE_BOOT_ALLOW_JTAG`
- `CONFIG_SECURE_BOOT_ALLOW_ROM_BASIC`
- `CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_DEC`
- `CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_ENC`
- `CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_CACHE`
- `CONFIG_SECURE_BOOT_ALLOW_UNUSED_DIGEST_SLOTS`
- `CONFIG_SECURE_FLASH_REQUIRE_ALREADY_ENABLED`
- `CONFIG_SECURE_FLASH_SKIP_WRITE_PROTECTION_CACHE`

**CONFIG_SECURE_BOOT_ALLOW_ROM_BASIC**

Leave ROM BASIC Interpreter available on reset

*Found in: Security features > Potentially insecure options*

By default, the BASIC ROM Console starts on reset if no valid bootloader is read from the flash.

When either flash encryption or secure boot are enabled, the default is to disable this BASIC fallback mode permanently via eFuse.

If this option is set, this eFuse is not burned and the BASIC ROM Console may remain accessible. Only set this option in testing environments.

**Default value:**

- No (disabled) if `CONFIG_SECURE_BOOT_INSECURE` || `CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT`

**CONFIG_SECURE_BOOT_ALLOW_JTAG**

Allow JTAG Debugging

*Found in: Security features > Potentially insecure options*

If not set (default), the bootloader will permanently disable JTAG (across entire chip) on first boot when either secure boot or flash encryption is enabled.

Setting this option leaves JTAG on for debugging, which negates all protections of flash encryption and some of the protections of secure boot.

Only set this option in testing environments.

**Default value:**

- No (disabled) if `CONFIG_SECURE_BOOT_INSECURE` || `CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT`

**CONFIG_SECURE_BOOT_ALLOW_SHORT_APP_PARTITION**

Allow app partition length not 64KB aligned

*Found in: Security features > Potentially insecure options*

If not set (default), app partition size must be a multiple of 64KB. App images are padded to 64KB length, and the bootloader checks any trailing bytes after the signature (before the next 64KB boundary) have not been written. This is because flash cache maps entire 64KB pages into the address space. This prevents an attacker from appending unverified data after the app image in the flash, causing it to be mapped into the address space.

Setting this option allows the app partition length to be unaligned, and disables padding of the app image to this length. It is generally not recommended to set this option, unless you have a legacy partitioning scheme which doesn’t support 64KB aligned partition lengths.
CONFIG_SECURE_BOOT_V2_ALLOW_EFUSE_RD_DIS

Allow additional read protecting of efuses

*Found in:* Security features > Potentially insecure options

If not set (default, recommended), on first boot the bootloader will burn the WR_DIS_RD_DIS efuse when Secure Boot is enabled. This prevents any more efuses from being read protected.

If this option is set, it will remain possible to write the EFUSE_RD_DIS efuse field after Secure Boot is enabled. This may allow an attacker to read-protect the BLK2 efuse (for ESP32) and BLOCK4-BLOCK10 (i.e. BLOCK_KEY0-BLOCK_KEY5)(for other chips) holding the public key digest, causing an immediate denial of service and possibly allowing an additional fault injection attack to bypass the signature protection.

**NOTE:** Once a BLOCK is read-protected, the application will read all zeros from that block

**NOTE:** If “UART ROM download mode (Permanently disabled (recommended))” or “UART ROM download mode (Permanently switch to Secure mode (recommended))” is set, then it is **NOT** possible to read/write efuses using espefuse.py utility. However, efuse can be read/written from the application.

CONFIG_SECURE_BOOT_ALLOW_UNUSED_DIGEST_SLOTS

Leave unused digest slots available (not revoke)

*Found in:* Security features > Potentially insecure options

If not set (default), during startup in the app all unused digest slots will be revoked. To revoke unused slot will be called esp_efuse_set_digest_revoke(num_digest) for each digest. Revoking unused digest slots makes ensures that no trusted keys can be added later by an attacker. If set, it means that you have a plan to use unused digests slots later.

**Default value:**

- No (disabled) if `CONFIG_SECURE_BOOT_INSECURE` && `SOC_EFUSE_REVOKE_BOOT_KEY_DIGESTS`

CONFIG_SECURITY_FLASH_UART_BOOTLOADER_ALLOW_ENC

Leave UART bootloader encryption enabled

*Found in:* Security features > Potentially insecure options

If not set (default), the bootloader will permanently disable UART bootloader encryption access on first boot. If set, the UART bootloader will still be able to access hardware encryption.

It is recommended to only set this option in testing environments.

**Default value:**

- No (disabled) if `CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT`

CONFIG_SECURITY_FLASH_UART_BOOTLOADER_ALLOW_DEC

Leave UART bootloader decryption enabled

*Found in:* Security features > Potentially insecure options

If not set (default), the bootloader will permanently disable UART bootloader decryption access on first boot. If set, the UART bootloader will still be able to access hardware decryption.

Only set this option in testing environments. Setting this option allows complete bypass of flash encryption.

**Default value:**

- No (disabled) if `CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT`
**CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_CACHE**

Leave UART bootloader flash cache enabled

*Found in: Security features > Potentially insecure options*

If not set (default), the bootloader will permanently disable UART bootloader flash cache access on first boot. If set, the UART bootloader will still be able to access the flash cache.

Only set this option in testing environments.

*Default value:*
- No (disabled) if `CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT`

**CONFIG_SECURE_FLASH_REQUIRE_ALREADY_ENABLED**

Require flash encryption to be already enabled

*Found in: Security features > Potentially insecure options*

If not set (default), and flash encryption is not yet enabled in eFuses, the 2nd stage bootloader will enable flash encryption: generate the flash encryption key and program eFuses. If this option is set, and flash encryption is not yet enabled, the bootloader will error out and reboot. If flash encryption is enabled in eFuses, this option does not change the bootloader behavior.

Only use this option in testing environments, to avoid accidentally enabling flash encryption on the wrong device. The device needs to have flash encryption already enabled using espfuse.py.

*Default value:*
- No (disabled) if `CONFIG_SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT`

**CONFIG_SECURE_FLASH_SKIP_WRITE_PROTECTION_CACHE**

Skip write-protection of DIS_CACHE (DIS_ICACHE, DIS_DCACHE)

*Found in: Security features > Potentially insecure options*

If not set (default, recommended), on the first boot the bootloader will burn the write-protection of DIS_CACHE (for ESP32) or DIS_ICACHE/DIS_DCACHE (for other chips) eFuse when Flash Encryption is enabled. Write protection for cache disable eFuse prevents the chip from being blocked if it is set by accident. App and bootloader use cache so disabling it makes the chip useless for IDF. Due to other eFuses are linked with the same write protection bit (see the list below) then write-protection will not be done if these SECURE_FLASH_UART_BOOTLOADER_ALLOW_ENC, SECURE_BOOT_ALLOW_JTAG or SECURE_FLASH_UART_BOOTLOADER_ALLOW_CACHE options are selected to give a chance to turn on the chip into the release model later.

List of eFuses with the same write protection bit: ESP32: MAC, MAC_CRC, DISABLE_APP_CPU, DISABLE_BT, DIS_CACHE, VOL_LEVEL_HP_INV.

ESP32-C3: DIS_ICACHE, DIS_USB_JTAG, DIS_DOWNLOAD_ICACHE, DIS_USB_SERIAL_JTAG, DIS_FORCE_DOWNLOAD, DIS_TWAI, JTAG_SEL_ENABLE, DIS_PAD_JTAG, DIS_DOWNLOAD_MANUAL_ENCRYPT.

ESP32-C6: SWAP_UART_SDI0_EN, DIS_ICACHE, DIS_USB_JTAG, DIS_DOWNLOAD_ICACHE, DIS_USB_SERIAL_JTAG, DIS_FORCE_DOWNLOAD, DIS_TWAI, JTAG_SEL_ENABLE, DIS_PAD_JTAG, DIS_DOWNLOAD_MANUAL_ENCRYPT.

ESP32-H2: DIS_ICACHE, DIS_USB_JTAG, POWERGLITCH_EN, DIS_FORCE_DOWNLOAD, SPI_DOWNLOAD_MSPI_DIS, DIS_TWAI, JTAG_SEL_ENABLE, DIS_PAD_JTAG, DIS_DOWNLOAD_MANUAL_ENCRYPT.

ESP32-S2: DIS_ICACHE, DIS_DCACHE, DIS_DOWNLOAD_ICACHE, DIS_DOWNLOAD_DCACHE, DIS_FORCE_DOWNLOAD, DIS_USB, DIS_TWAI, DIS_BOOT_REMAP, SOFT_DIS_JTAG, HARD_DIS_JTAG, DIS_DOWNLOAD_MANUAL_ENCRYPT.
ESP32-S3: DIS_ICACHE, DIS_DCACHE, DIS_DOWNLOAD_ICACHE, DIS_DOWNLOAD_DCACHE, DIS_FORCE_DOWNLOAD, DIS_USB_OTG, DIS_TWAI, DIS_APP_CPU, DIS_PAD_JTAG, DIS_DOWNLOAD_MANUAL_ENCRYPT, DIS_USB_JTAG, DIS_USB_SERIAL_JTAG, STRAP_JTAG_SEL, USB_PHY_SEL.

**CONFIG_SECURE_FLASH_CHECK_ENC_EN_IN_APP**

Check Flash Encryption enabled on app startup

*Found in: Security features*

If set (default), in an app during startup code, there is a check of the flash encryption eFuse bit is on (as the bootloader should already have set it). The app requires this bit is on to continue work otherwise abort.

If not set, the app does not care if the flash encryption eFuse bit is set or not.

**Default value:**

- Yes (enabled) if `CONFIG_SECURE_FLASH_ENC_ENABLED`

**CONFIG_SECURE_UART_ROM_DL_MODE**

UART ROM download mode

*Found in: Security features*

Available options:

- **UART ROM download mode (Permanently disabled (recommended))** (CONFIG_SECURE_DISABLE_ROM_DL_MODE)
  - If set, during startup the app will burn an eFuse bit to permanently disable the UART ROM Download Mode. This prevents any future use of esptool.py, espfuse.py and similar tools.
  - Once disabled, if the SoC is booted with strapping pins set for ROM Download Mode then an error is printed instead.
  - It is recommended to enable this option in any production application where Flash Encryption and/or Secure Boot is enabled and access to Download Mode is not required.
  - It is also possible to permanently disable Download Mode by calling `esp_efuse_disable_rom_download_mode()` at runtime.

- **UART ROM download mode (Permanently switch to Secure mode (recommended))** (CONFIG_SECURE_ENABLE_SECURE_ROM_DL_MODE)
  - If set, during startup the app will burn an eFuse bit to permanently switch the UART ROM Download Mode into a separate Secure Download mode. This option can only work if Download Mode is not already disabled by eFuse.
  - Secure Download mode limits the use of Download Mode functions to update SPI config, changing baud rate, basic flash write and a command to return a summary of currently enabled security features (`get_security_info`).
  - Secure Download mode is not compatible with the esptool.py flasher stub feature, espfuse.py, read/writing memory or registers, encrypted download, or any other features that interact with unsupported Download Mode commands.
  - Secure Download mode should be enabled in any application where Flash Encryption and/or Secure Boot is enabled. Disabling this option does not immediately cancel the benefits of the security features, but it increases the potential “attack surface” for an attacker to try and bypass them with a successful physical attack.
  - It is also possible to enable secure download mode at runtime by calling `esp_efuse_enable_rom_secure_download_mode()`.
  - Note: Secure Download mode is not available for ESP32 (includes revisions till ECO3).

- **UART ROM download mode (Enabled (not recommended))** (CONFIG_SECURE_INSECURE_ALLOW_DL_MODE)
This is a potentially insecure option. Enabling this option will allow the full UART
download mode to stay enabled. This option SHOULD NOT BE ENABLED for pro-
duction use cases.

Application manager

Contains:

- `CONFIG_APP_EXCLUDE_PROJECT_NAME_VAR`
- `CONFIG_APP_EXCLUDE_PROJECT_VER_VAR`
- `CONFIG_APP_PROJECT_VER_FROM_CONFIG`
- `CONFIG_APP_RETRIEVE_LEN_ELF_SHA`
- `CONFIG_APP_COMPILE_TIME_DATE`

**CONFIG_APP_COMPILE_TIME_DATE**

Use time/date stamp for app

*Found in: Application manager*

If set, then the app will be built with the current time/date stamp. It is stored in the app description
structure. If not set, time/date stamp will be excluded from app image. This can be useful for getting
the same binary image files made from the same source, but at different times.

*Default value:*

- Yes (enabled)

**CONFIG_APP_EXCLUDE_PROJECT_VER_VAR**

Exclude PROJECT_VER from firmware image

*Found in: Application manager*

The PROJECT_VER variable from the build system will not affect the firmware image. This value will
not be contained in the esp_app_desc structure.

*Default value:*

- No (disabled)

**CONFIG_APP_EXCLUDE_PROJECT_NAME_VAR**

Exclude PROJECT_NAME from firmware image

*Found in: Application manager*

The PROJECT_NAME variable from the build system will not affect the firmware image. This value will
not be contained in the esp_app_desc structure.

*Default value:*

- No (disabled)

**CONFIG_APP_PROJECT_VER_FROM_CONFIG**

Get the project version from Kconfig

*Found in: Application manager*

If this is enabled, then config item APP_PROJECT_VER will be used for the variable PROJECT_VER.
Other ways to set PROJECT_VER will be ignored.

*Default value:*

- No (disabled)
**CONFIG_APP_PROJECT_VER**

Project version

*Found in: Application manager > CONFIG_APP_PROJECT_VER_FROM_CONFIG*

Default value:

- 1 if `CONFIG_APP_PROJECT_VER_FROM_CONFIG`

**CONFIG_APP RETRIEVE LEN ELF_SHA**

The length of APP ELF SHA is stored in RAM (chars)

*Found in: Application manager*

At startup, the app will read this many hex characters from the embedded APP ELF SHA-256 hash value and store it in static RAM. This ensures the app ELF SHA-256 value is always available if it needs to be printed by the panic handler code. Changing this value will change the size of a static buffer, in bytes.

Range:

- from 8 to 64

Default value:

- 16

**Serial flasher config**

Contains:

- `CONFIG_ESPTOOLPY_AFTER`
- `CONFIG_ESPTOOLPY_BEFORE`
- `CONFIG_ESPTOOLPY_HEADER_FLASHSIZE_UPDATE`
- `CONFIG_ESPTOOLPY_NO_STUB`
- `CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE`
- `CONFIG_ESPTOOLPY_FLASHSIZE`
- `CONFIG_ESPTOOLPY_FLASHMODE`
- `CONFIG_ESPTOOLPY_FLASHFREQ`

**CONFIG_ESPTOOLPY_NO_STUB**

Disable download stub

*Found in: Serial flasher config*

The flasher tool sends a precompiled download stub first by default. That stub allows things like compressed downloads and more. Usually you should not need to disable that feature

Default value:

- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_ESPTOOLPY_FLASHMODE**

Flash SPI mode

*Found in: Serial flasher config*

Mode the flash chip is flashed in, as well as the default mode for the binary to run in.

Available options:

- QIO (CONFIG_ESPTOOLPY_FLASHMODE_QIO)
• QOUT (CONFIG_ESPTOOLPY_FLASHMODE_QOUT)
• DIO (CONFIG_ESPTOOLPY_FLASHMODE_DIO)
• DOUT (CONFIG_ESPTOOLPY_FLASHMODE_DOUT)
• OPI (CONFIG_ESPTOOLPY_FLASHMODE_OPI)

CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE
Flash Sampling Mode

*Found in: Serial flasher config*

Available options:

• STR Mode (CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE_STR)
• DTR Mode (CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE_DTR)

CONFIG_ESPTOOLPY_FLASHFREQ
Flash SPI speed

*Found in: Serial flasher config*

Available options:

• 120 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_120M)
  – Flash 120 MHz SDR mode is stable.
  – Flash 120 MHz DDR mode is an experimental feature, it works when the temperature is stable.
  **Risks:** If your chip powers on at a certain temperature, then after the temperature increases or decreases by approximately 20 Celsius degrees (depending on the chip), the program will crash randomly.
• 80 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_80M)
• 64 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_64M)
• 60 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_60M)
• 48 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_48M)
• 40 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_40M)
• 32 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_32M)
• 30 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_30M)
• 26 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_26M)
• 24 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_24M)
• 20 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_20M)
• 16 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_16M)
• 15 MHz (CONFIG_ESPTOOLPY_FLASHFREQ_15M)

CONFIG_ESPTOOLPY_FLASHSIZE
Flash size

*Found in: Serial flasher config*

SPI flash size, in megabytes

Available options:

• 1 MB (CONFIG_ESPTOOLPY_FLASHSIZE_1MB)
• 2 MB (CONFIG_ESPTOOLPY_FLASHSIZE_2MB)
• 4 MB (CONFIG_ESPTOOLPY_FLASHSIZE_4MB)
• 8 MB (CONFIG_ESPTOOLPY_FLASHSIZE_8MB)
**Chapter 2. API Reference**

- 16 MB (CONFIG_ESPTOOLPY_FLASHSIZE_16MB)
- 32 MB (CONFIG_ESPTOOLPY_FLASHSIZE_32MB)
- 64 MB (CONFIG_ESPTOOLPY_FLASHSIZE_64MB)
- 128 MB (CONFIG_ESPTOOLPY_FLASHSIZE_128MB)

**CONFIG_ESPTOOLPY_HEADER_FLASHSIZE_UPDATE**

Detect flash size when flashing bootloader

*Found in: Serial flasher config*

If this option is set, flashing the project will automatically detect the flash size of the target chip and update the bootloader image before it is flashed.

Enabling this option turns off the image protection against corruption by a SHA256 digest. Updating the bootloader image before flashing would invalidate the digest.

*Default value:*
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_ESPTOOLPY_BEFORE**

Before flashing

*Found in: Serial flasher config*

Configure whether esp tool.py should reset the ESP32 before flashing.

Automatic resetting depends on the RTS & DTR signals being wired from the serial port to the ESP32. Most USB development boards do this internally.

*Available options:*

- Reset to bootloader (CONFIG_ESPTOOLPY_BEFORE_RESET)
- No reset (CONFIG_ESPTOOLPY_BEFORE_NORESET)

**CONFIG_ESPTOOLPY_AFTER**

After flashing

*Found in: Serial flasher config*

Configure whether esp tool.py should reset the ESP32 after flashing.

Automatic resetting depends on the RTS & DTR signals being wired from the serial port to the ESP32. Most USB development boards do this internally.

*Available options:*

- Reset after flashing (CONFIG_ESPTOOLPY_AFTER_RESET)
- Stay in bootloader (CONFIG_ESPTOOLPY_AFTER_NORESET)

**Partition Table**

Contains:

- `CONFIG_PARTITION_TABLE_CUSTOM_FILENAME`
- `CONFIG_PARTITION_TABLE_MD5`
- `CONFIG_PARTITION_TABLE_OFFSET`
- `CONFIG_PARTITION_TABLE_TYPE`
CONFIG_PARTITION_TABLE_TYPE

Partition Table

*Found in: Partition Table*

The partition table to flash to the ESP32. The partition table determines where apps, data and other resources are expected to be found.

The predefined partition table CSV descriptions can be found in the components/partition_table directory. These are mostly intended for example and development use, it’s expect that for production use you will copy one of these CSV files and create a custom partition CSV for your application.

Available options:

- **Single factory app, no OTA (CONFIG_PARTITION_TABLE_SINGLE_APP)**
  This is the default partition table, designed to fit into a 2MB or larger flash with a single 1MB app partition.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_singleapp.csv
  This partition table is not suitable for an app that needs OTA (over the air update) capability.

- **Single factory app (large), no OTA (CONFIG_PARTITION_TABLE_SINGLE_APP_LARGE)**
  This is a variation of the default partition table, that expands the 1MB app partition size to 1.5MB to fit more code.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_singleapp_large.csv
  This partition table is not suitable for an app that needs OTA (over the air update) capability.

- **Factory app, two OTA definitions (CONFIG_PARTITION_TABLE_TWO_OTA)**
  This is a basic OTA-enabled partition table with a factory app partition plus two OTA app partitions. All are 1MB, so this partition table requires 4MB or larger flash size.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_two_ota.csv

- **Custom partition table CSV (CONFIG_PARTITION_TABLE_CUSTOM)**
  Specify the path to the partition table CSV to use for your project.
  Consult the Partition Table section in the ESP-IDF Programmers Guide for more information.

- **Single factory app, no OTA, encrypted NVS (CONFIG_PARTITION_TABLE_SINGLE_APP_ENCRYPTED_NVS)**
  This is a variation of the default “Single factory app, no OTA” partition table that supports encrypted NVS when using flash encryption. See the Flash Encryption section in the ESP-IDF Programmers Guide for more information.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_singleapp_encr_nvs.csv

- **Single factory app (large), no OTA, encrypted NVS (CONFIG_PARTITION_TABLE_SINGLE_APP_LARGE_ENC_NVS)**
  This is a variation of the “Single factory app (large), no OTA” partition table that supports encrypted NVS when using flash encryption. See the Flash Encryption section in the ESP-IDF Programmers Guide for more information.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_singleapp_large_encr_nvs.csv

- **Factory app, two OTA definitions, encrypted NVS (CONFIG_PARTITION_TABLE_TWO_OTA_ENCRYPTED_NVS)**
  This is a variation of the “Factory app, two OTA definitions” partition table that supports encrypted NVS when using flash encryption. See the Flash Encryption section in the ESP-IDF Programmers Guide for more information.
  The corresponding CSV file in the IDF directory is components/partition_table/partitions_two_ota_encr_nvs.csv
**CONFIG_PARTITION_TABLE_CUSTOM_FILENAME**

Custom partition CSV file

*Found in: Partition Table*

Name of the custom partition CSV filename. This path is evaluated relative to the project root directory.

**Default value:**
- "partitions.csv"

**CONFIG_PARTITION_TABLE_OFFSET**

Offset of partition table

*Found in: Partition Table*

The address of partition table (by default 0x8000). Allows you to move the partition table, it gives more space for the bootloader. Note that the bootloader and app will both need to be compiled with the same PARTITION_TABLE_OFFSET value.

This number should be a multiple of 0x1000.

Note that partition offsets in the partition table CSV file may need to be changed if this value is set to a higher value. To have each partition offset adapt to the configured partition table offset, leave all partition offsets blank in the CSV file.

**Default value:**
- "0x8000"

**CONFIG_PARTITION_TABLE_MD5**

Generate an MD5 checksum for the partition table

*Found in: Partition Table*

Generate an MD5 checksum for the partition table for protecting the integrity of the table. The generation should be turned off for legacy bootloaders which cannot recognize the MD5 checksum in the partition table.

**Default value:**
- Yes (enabled) if `CONFIG_APP_COMPATIBLE_PRE_V3_1_BOOTLOADERS`

**Compiler options**

Contains:

- `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL`
- `CONFIG_COMPILER_FLOAT_LIB_FROM`
- `CONFIG_COMPILER_OPTIMIZATION_CHECKS_SILENT`
- `CONFIG_COMPILER_DISABLE_GCC12_WARNINGS`
- `CONFIG_COMPILER_DUMP_RTL_FILES`
- `CONFIG_COMPILER_WARN_WRITE_STRINGS`
- `CONFIG_COMPILER_CXX_EXCEPTIONS`
- `CONFIG_COMPILER_CXX_RTTI`
- `CONFIG_COMPILER_DISABLE_GCC12_WARNINGS`
- `CONFIG_COMPILER_HIDE_PATHS_MACROS`
- `CONFIG_COMPILER_STACK_CHECK_MODE`
**CONFIG_COMPILER_OPTIMIZATION**

Optimization Level

*Found in: Compiler options*

This option sets compiler optimization level (gcc -O argument) for the app.

- The **“Default”** setting will add the -Og flag to CFLAGS.
- The **“Size”** setting will add the -Os flag to CFLAGS.
- The **“Performance”** setting will add the -O2 flag to CFLAGS.
- The **“None”** setting will add the -O0 flag to CFLAGS.

The **“Size”** setting cause the compiled code to be smaller and faster, but may lead to difficulties of correlating code addresses to source file lines when debugging.

The **“Performance”** setting causes the compiled code to be larger and faster, but will be easier to correlated code addresses to source file lines.

**“None”** with -O0 produces compiled code without optimization.

Note that custom optimization levels may be unsupported.

Compiler optimization for the IDF bootloader is set separately, see the `BOOT-LOADER_COMPILER_OPTIMIZATION` setting.

Available options:

- Debug (-Og) (**CONFIG_COMPILER_OPTIMIZATION_DEFAULT**)
- Optimize for size (-Os) (**CONFIG_COMPILER_OPTIMIZATION_SIZE**)
- Optimize for performance (-O2) (**CONFIG_COMPILER_OPTIMIZATION_PERF**)
- Debug without optimization (-O0) (**CONFIG_COMPILER_OPTIMIZATION_NONE**)

**CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL**

Assertion level

*Found in: Compiler options*

Assertions can be:

- Enabled. Failure will print verbose assertion details. This is the default.
- Set to **“silent”** to save code size (failed assertions will abort() but user needs to use the aborting address to find the line number with the failed assertion.)
- Disabled entirely (not recommended for most configurations.) -DNDEBUG is added to CPPFLAGS in this case.

Available options:

- Enabled (**CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_ENABLE**)
  Enable assertions. Assertion content and line number will be printed on failure.
- Silent (saves code size) (**CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_SILENT**)
  Enable silent assertions. Failed assertions will abort(), user needs to use the aborting address to find the line number with the failed assertion.
- Disabled (sets -DNDEBUG) (**CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_DISABLE**)
  If assertions are disabled, -DNDEBUG is added to CPPFLAGS.

**CONFIG_COMPILER_FLOAT_LIB_FROM**

Compiler float lib source

*Found in: Compiler options*
In the soft-fp part of libgcc, riscv version is written in C, and handles all edge cases in IEEE754, which makes it larger and performance is slow.

RVfplib is an optimized RISC-V library for FP arithmetic on 32-bit integer processors, for single and double-precision FP. RVfplib is “fast”, but it has a few exceptions from IEEE 754 compliance.

Available options:

- libgcc (CONFIG_COMPILER_FLOAT_LIB_FROM_GCCLIB)
- librvfp (CONFIG_COMPILER_FLOAT_LIB_FROM_RVFPLIB)

**CONFIG_COMPILER_OPTIMIZATION_CHECKS_SILENT**

Disable messages in ESP_RETURN_ON_* and ESP_EXIT_ON_* macros

*Found in: Compiler options*

If enabled, the error messages will be discarded in following check macros: - ESP_RETURN_ON_ERROR - ESP_RETURN_ON_FALSE - ESP_EXIT_ON_FALSE

*Default value:*
- No (disabled)

**CONFIG_COMPILER_HIDE_PATHS_MACROS**

Replace ESP-IDF and project paths in binaries

*Found in: Compiler options*

When expanding the __FILE__ and __BASE_FILE__ macros, replace paths inside ESP-IDF with paths relative to the placeholder string “IDF”, and convert paths inside the project directory to relative paths.

This allows building the project with assertions or other code that embeds file paths, without the binary containing the exact path to the IDF or project directories.

This option passes -fmacro-prefix-map options to the GCC command line. To replace additional paths in your binaries, modify the project CMakeLists.txt file to pass custom -fmacro-prefix-map or -ffile-prefix-map arguments.

*Default value:*
- Yes (enabled)

**CONFIG_COMPILER_CXX_EXCEPTIONS**

Enable C++ exceptions

*Found in: Compiler options*

Enabling this option compiles all IDF C++ files with exception support enabled.

Disabling this option disables C++ exception support in all compiled files, and any libstdc++ code which throws an exception will abort instead.

Enabling this option currently adds an additional ~500 bytes of heap overhead when an exception is thrown in user code for the first time.

*Default value:*
- No (disabled)

Contains:

- `CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE`
CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE

Emergency Pool Size

*Found in: Compiler options > CONFIG_COMPILER_CXX_EXCEPTIONS*

Size (in bytes) of the emergency memory pool for C++ exceptions. This pool will be used to allocate memory for thrown exceptions when there is not enough memory on the heap.

**Default value:**

- 0 if `CONFIG_COMPILER_CXX_EXCEPTIONS`

CONFIG_COMPILER_CXX_RTTI

Enable C++ run-time type info (RTTI)

*Found in: Compiler options*

Enabling this option compiles all C++ files with RTTI support enabled. This increases binary size (typically by tens of kB) but allows using dynamic_cast conversion and typeid operator.

**Default value:**

- No (disabled)

CONFIG_COMPILER_STACK_CHECK_MODE

Stack smashing protection mode

*Found in: Compiler options*

Stack smashing protection mode. Emit extra code to check for buffer overflows, such as stack smashing attacks. This is done by adding a guard variable to functions with vulnerable objects. The guards are initialized when a function is entered and then checked when the function exits. If a guard check fails, program is halted. Protection has the following modes:

- In NORMAL mode (GCC flag: -fstack-protector) only functions that call alloca, and functions with buffers larger than 8 bytes are protected.
- STRONG mode (GCC flag: -fstack-protector-strong) is like NORMAL, but includes additional functions to be protected –those that have local array definitions, or have references to local frame addresses.
- In OVERALL mode (GCC flag: -fstack-protector-all) all functions are protected.

Modes have the following impact on code performance and coverage:

- performance: NORMAL > STRONG > OVERALL
- coverage: NORMAL < STRONG < OVERALL

The performance impact includes increasing the amount of stack memory required for each task.

Available options:

- None (CONFIG_COMPILER_STACK_CHECK_MODE_NONE)
- Normal (CONFIG_COMPILER_STACK_CHECK_MODE_NORM)
- Strong (CONFIG_COMPILER_STACK_CHECK_MODE_STRONG)
- Overall (CONFIG_COMPILER_STACK_CHECK_MODE_ALL)

CONFIG_COMPILER_WARN_WRITE_STRINGS

Enable -Wwrite-strings warning flag

*Found in: Compiler options*

Adds -Wwrite-strings flag for the C/C++ compilers.
For C, this gives string constants the type `const char[]` so that copying the address of one into a non-const `char *` pointer produces a warning. This warning helps to find at compile time code that tries to write into a string constant.

For C++, this warns about the deprecated conversion from string literals to `char *`.

**Default value:**
- No (disabled)

**CONFIG_COMPILER_DISABLE_GCC12_WARNINGS**

Disable new warnings introduced in GCC 12

*Found in: Compiler options*

Enable this option if use GCC 12 or newer, and want to disable warnings which don’t appear with GCC 11.

**Default value:**
- No (disabled)

**CONFIG_COMPILER_DUMP_RTL_FILES**

Dump RTL files during compilation

*Found in: Compiler options*

If enabled, RTL files will be produced during compilation. These files can be used by other tools, for example to calculate call graphs.

**Component config**

Contains:

- ADC and ADC Calibration
- Application Level Tracing
- Bluetooth
- Common ESP-related
- Core dump
- Driver Configurations
- eFuse Bit Manager
- CONFIG_BLE_MESH
- ESP HTTP client
- ESP HTTPS OTA
- ESP HTTPS server
- ESP NETIF Adapter
- ESP PSRAM
- ESP Ringbuf
- ESP System Settings
- ESP-MQTT Configurations
- ESP-TLS
- Ethernet
- Event Loop Library
- FAT Filesystem support
- FreeRTOS
- GDB Stub
- Hardware Abstraction Layer (HAL) and Low Level (LL)
- Hardware Settings
- Heap memory debugging
- High resolution timer (esp_timer)
- HTTP Server
Chapter 2. API Reference

- IEEE 802.15.4
- IPC (Inter-Processor Call)
- LCD and Touch Panel
- Log output
- LWIP
- mbedtls
- Newlib
- NVS
- OpenThread
- Partition API Configuration
- PHY
- Power Management
- Protocomm
- PThreads
- SoC Settings
- SPI Flash driver
- SPIFFS Configuration
- TCP Transport
- Ultra Low Power (ULP) Co-processor
- Unity unit testing library
- Virtual file system
- Wear Levelling
- Wi-Fi
- Wi-Fi Provisioning Manager
- Wireless Coexistence

Application Level Tracing  Contains:

- CONFIG_APPTRACE_DESTINATION1
- CONFIG_APPTRACE_DESTINATION2
- FreeRTOS SystemView Tracing
- CONFIG_APPTRACE_GCOV_ENABLE
- CONFIG_APPTRACE_BUF_SIZE
- CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX
- CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH
- CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO
- CONFIG_APPTRACE_UART_BAUDRATE
- CONFIG_APPTRACE_UART_RX_GPIO
- CONFIG_APPTRACE_UART_RX_BUFF_SIZE
- CONFIG_APPTRACE_UART_TASK_PRIO
- CONFIG_APPTRACE_UART_TX_MSG_SIZE
- CONFIG_APPTRACE_UART_TX_GPIO
- CONFIG_APPTRACE_UART_TX_BUFF_SIZE

CONFIG_APPTRACE_DESTINATION1

Data Destination 1

*Found in: Component config > Application Level Tracing*

Select destination for application trace: JTAG or none (to disable).

Available options:

- JTAG (CONFIG_APPTRACE_DEST_JTAG)
- None (CONFIG_APPTRACE_DEST_NONE)
Chapter 2. API Reference

CONFIG_APPTRACE_DESTINATION2

Data Destination 2

*Found in: Component config > Application Level Tracing*

Select destination for application trace: UART(XX) or none (to disable).

Available options:

- UART0 (CONFIG_APPTRACE_DEST_UART0)
- UART1 (CONFIG_APPTRACE_DEST_UART1)
- UART2 (CONFIG_APPTRACE_DEST_UART2)
- USB_CDC (CONFIG_APPTRACE_DEST_USB_CDC)
- None (CONFIG_APPTRACE_DEST_UART_NONE)

CONFIG_APPTRACE_UART_TX_GPIO

UART TX on GPIO#

*Found in: Component config > Application Level Tracing*

This GPIO is used for UART TX pin.

CONFIG_APPTRACE_UART_RX_GPIO

UART RX on GPIO#

*Found in: Component config > Application Level Tracing*

This GPIO is used for UART RX pin.

CONFIG_APPTRACE_UART_BAUDRATE

UART baud rate

*Found in: Component config > Application Level Tracing*

This baud rate is used for UART.

The app’s maximum baud rate depends on the UART clock source. If Power Management is disabled, the UART clock source is the APB clock and all baud rates in the available range will be sufficiently accurate. If Power Management is enabled, REF_TICK clock source is used so the baud rate is divided from 1MHz. Baud rates above 1Mbps are not possible and values between 500Kbps and 1Mbps may not be accurate.

CONFIG_APPTRACE_UART_RX_BUFF_SIZE

UART RX ring buffer size

*Found in: Component config > Application Level Tracing*

Size of the UART input ring buffer. This size related to the baudrate, system tick frequency and amount of data to transfer. The data placed to this buffer before sent out to the interface.

CONFIG_APPTRACE_UART_TX_BUFF_SIZE

UART TX ring buffer size

*Found in: Component config > Application Level Tracing*

Size of the UART output ring buffer. This size related to the baudrate, system tick frequency and amount of data to transfer.
Chapter 2. API Reference

CONFIG_APPTRACE_UART_TX_MSG_SIZE

UART TX message size

*Found in: Component config > Application Level Tracing*

Maximum size of the single message to transfer.

CONFIG_APPTRACE_UART_TASK_PRIO

UART Task Priority

*Found in: Component config > Application Level Tracing*

UART task priority. In case of high events rate, this parameter could be changed up to (config-
MAX_PRIORITIES-1).

**Range:**
- from 1 to 32

**Default value:**
- 1

CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO

Timeout for flushing last trace data to host on panic

*Found in: Component config > Application Level Tracing*

Timeout for flushing last trace data to host in case of panic. In ms. Use -1 to disable timeout and wait forever.

CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH

Threshold for flushing last trace data to host on panic

*Found in: Component config > Application Level Tracing*

Threshold for flushing last trace data to host on panic in post-mortem mode. This is minimal amount of data needed to perform flush. In bytes.

CONFIG_APPTRACE_BUF_SIZE

Size of the apptrace buffer

*Found in: Component config > Application Level Tracing*

Size of the memory buffer for trace data in bytes.

CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX

Size of the pending data buffer

*Found in: Component config > Application Level Tracing*

Size of the buffer for events in bytes. It is useful for buffering events from the time critical code (sched-
uler, ISR etc). If this parameter is 0 then events will be discarded when main HW buffer is full.

**FreeRTOS SystemView Tracing** Contains:
- CONFIG_APPTRACE_SV_CPU
- CONFIG_APPTRACE_SV_EVT_ISR_ENTER_ENABLE
- CONFIG_APPTRACE_SV_EVT_ISR_EXIT_ENABLE
- CONFIG_APPTRACE_SV_EVT_ISR_TO_SCHED_ENABLE
- CONFIG_APPTRACE_SV_MAX_TASKS
Chapter 2. API Reference

- `CONFIG_APPTRACE_SV_EVT_IDLE_ENABLE`
- `CONFIG_APPTRACE_SV_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TASK_CREATE_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TASK_START_EXEC_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TASK_START_READY_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TASK_STOP_EXEC_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TASK_STOP_READY_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TASK_TERMINATE_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TIMER_ENTER_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_TIMER_EXIT_ENABLE`
- `CONFIG_APPTRACE_SV_EVT_OVERFLOW_ENABLE`
- `CONFIG_APPTRACE_SV_BUF_WAIT_TMO`

**CONFIG_APPTRACE_SV_ENABLE**

SystemView Tracing Enable

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables support for SEGGER SystemView tracing functionality.

**CONFIG_APPTRACE_SV_DEST**

SystemView destination

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

SystemView with transfer data through defined interface.

Available options:

- Data destination JTAG (CONFIG_APPTRACE_SV_DEST_JTAG)  
  Send SEGGER SystemView events through JTAG interface.
- Data destination UART (CONFIG_APPTRACE_SV_DEST_UART)  
  Send SEGGER SystemView events through UART interface.

**CONFIG_APPTRACE_SV_CPU**

CPU to trace

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Define the CPU to trace by SystemView.

Available options:

- CPU0 (CONFIG_APPTRACE_SV_DEST_CPU_0)  
  Send SEGGER SystemView events for Pro CPU.
- CPU1 (CONFIG_APPTRACE_SV_DEST_CPU_1)  
  Send SEGGER SystemView events for App CPU.

**CONFIG_APPTRACE_SV_TS_SOURCE**

Timer to use as timestamp source

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*
SystemView needs to use a hardware timer as the source of timestamps when tracing. This option selects the timer for it.

Available options:

- CPU cycle counter (CCOUNT) (CONFIG_APPTRACE_SV_TS_SOURCE_CCOUNT)
- General Purpose Timer (Timer Group) (CONFIG_APPTRACE_SV_TS_SOURCE_GPTIMER)
- esp_timer high resolution timer (CONFIG_APPTRACE_SV_TS_SOURCE_ESP_TIMER)

**CONFIG_APPTRACE_SV_MAX_TASKS**

Maximum supported tasks

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Configures maximum supported tasks in sysview debug

**CONFIG_APPTRACE_SV_BUF_WAIT_TMO**

Trace buffer wait timeout

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Configures timeout (in us) to wait for free space in trace buffer. Set to -1 to wait forever and avoid lost events.

**CONFIG_APPTRACE_SV_EVT_OVERFLOW_ENABLE**

Trace Buffer Overflow Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables “Trace Buffer Overflow” event.

**CONFIG_APPTRACE_SV_EVT_ISR_ENTER_ENABLE**

ISR Enter Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables “ISR Enter” event.

**CONFIG_APPTRACE_SV_EVT_ISR_EXIT_ENABLE**

ISR Exit Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables “ISR Exit” event.

**CONFIG_APPTRACE_SV_EVT_ISR_TO_SCHED_ENABLE**

ISR Exit to Scheduler Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables “ISR to Scheduler” event.
Chapter 2. API Reference

**CONFIG_APPTRACE_SV_EVT_TASK_START_EXEC_ENABLE**

Task Start Execution Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Task Start Execution" event.

**CONFIG_APPTRACE_SV_EVT_TASK_STOP_EXEC_ENABLE**

Task Stop Execution Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Task Stop Execution" event.

**CONFIG_APPTRACE_SV_EVT_TASK_START_READY_ENABLE**

Task Start Ready State Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Task Start Ready State" event.

**CONFIG_APPTRACE_SV_EVT_TASK_STOP_READY_ENABLE**

Task Stop Ready State Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Task Stop Ready State" event.

**CONFIG_APPTRACE_SV_EVT_TASK_CREATE_ENABLE**

Task Create Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Task Create" event.

**CONFIG_APPTRACE_SV_EVT_TASK_TERMINATE_ENABLE**

Task Terminate Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Task Terminate" event.

**CONFIG_APPTRACE_SV_EVT_IDLE_ENABLE**

System Idle Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "System Idle" event.

**CONFIG_APPTRACE_SV_EVT_TIMER_ENTER_ENABLE**

Timer Enter Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables "Timer Enter" event.
CONFIG_APPTRACE_SV_EVT_TIMER_EXIT_ENABLE

Timer Exit Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing*

Enables “Timer Exit” event.

CONFIG_APPTRACE_GCOV_ENABLE

GCOV to Host Enable

*Found in: Component config > Application Level Tracing*

Enables support for GCOV data transfer to host.

CONFIG_APPTRACE_GCOV_DUMP_TASK_STACK_SIZE

Gcov dump task stack size

*Found in: Component config > Application Level Tracing > CONFIG_APPTRACE_GCOV_ENABLE*

Configures stack size of Gcov dump task

**Default value:**
- 2048 if `CONFIG_APPTRACE_GCOV_ENABLE`

**Bluetooth**

Contains:

- Bluedroid Options
- `CONFIG_BT_ENABLED`
- Controller Options
- NimBLE Options
- `CONFIG_BT_RELEASE_IRAM`

CONFIG_BT_ENABLED

Bluetooth

*Found in: Component config > Bluetooth*

Select this option to enable Bluetooth and show the submenu with Bluetooth configuration choices.

CONFIG_BT_HOST

Host

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED*

This helps to choose Bluetooth host stack

Available options:

- Bluedroid - Dual-mode (`CONFIG_BT_BLUEDROID_ENABLED`)
  This option is recommended for classic Bluetooth or for dual-mode usecases
- NimBLE - BLE only (`CONFIG_BT_NIMBLE_ENABLED`)
  This option is recommended for BLE only usecases to save on memory
- Disabled (`CONFIG_BT_CONTROLLER_ONLY`)
  This option is recommended when you want to communicate directly with the controller (without any host) or when you are using any other host stack not supported by Espressif (not mentioned here).
Chapter 2. API Reference

**CONFIG_BT_CONTROLLER**

Controller

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED*

This helps to choose Bluetooth controller stack

Available options:

- Enabled (CONFIG_BT_CONTROLLER_ENABLED)
  
  This option is recommended for Bluetooth controller usecases

- Disabled (CONFIG_BT_CONTROLLER_DISABLED)
  
  This option is recommended for Bluetooth Host only usecases

**Bluedroid Options**

Contains:

- `CONFIG_BT_BLE_HOST_QUEUE_CONG_CHECK`
- `CONFIG_BT_BLUEDROID_MEM_DEBUG`
- `CONFIG_BT_BTU_TASK_STACK_SIZE`
- `CONFIG_BT_BTU_TASK_STACK_SIZE`
- `CONFIG_BT_BTC_TASK_STACK_SIZE`
- `CONFIG_BT_BLE_ENABLED`
- `BT_DEBUG_LOG_LEVEL`
- `CONFIG_BT_ACL_CONNECTIONS`
- `CONFIG_BT_ALLOCATION_FROM_SPIRAM_FIRST`
- `CONFIG_BT_CLASSIC_ENABLED`
- `CONFIG_BT_HID_ENABLED`
- `CONFIG_BT_STACK_NO_LOG`
- `CONFIG_BT_BLE_42_FEATURES_SUPPORTED`
- `CONFIG_BT_BLE_50_FEATURES_SUPPORTED`
- `CONFIG_BT_BLE_HIGH_DUTY_ADV_INTERVAL`
- `CONFIG_BT_MULTI_CONNECTION_ENABLE`
- `CONFIG_BT_BLE_FEAT_PERIODIC_ADV_SYNC_TRANSFER`
- `CONFIG_BT_BLE_FEAT_PERIODIC_ADV_ENH`
- `CONFIG_BT_MAX_DEVICE_NAME_LEN`
- `CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN`
- `CONFIG_BT_SSP_ENABLED`
- `CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE`
- `CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT`
- `CONFIG_BT_BLE_RPA_TIMEOUT`
- `CONFIG_BT_BLE_RPA_SUPPORTED`
- `CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY`
- `CONFIG_BT_HFP_WBS_ENABLE`

**CONFIG_BT_BTC_TASK_STACK_SIZE**

Bluetooth event (callback to application) task stack size

*Found in: Component config > Bluetooth > Bluedroid Options*

This select btc task stack size

**Default value:**

- 3072 if `CONFIG_BT_BLUEDROID_ENABLED` & `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE**

The cpu core which Bluedroid run

*Found in: Component config > Bluetooth > Bluedroid Options*
Which the cpu core to run Bluedroid. Can choose core0 and core1. Can not specify no-affinity.

Available options:

- Core 0 (PRO CPU) (CONFIG_BT_BLUEDROID_PINNED_TO_CORE_0)
- Core 1 (APP CPU) (CONFIG_BT_BLUEDROID_PINNED_TO_CORE_1)

**CONFIG_BT_BTU_TASK_STACK_SIZE**

Bluetooth Bluedroid Host Stack task stack size

*Found in: Component config > Bluetooth > Bluedroid Options*

This select btu task stack size

**Default value:**

- 4096 if `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_BLUEDROID_MEM_DEBUG**

Bluedroid memory debug

*Found in: Component config > Bluetooth > Bluedroid Options*

Bluedroid memory debug

**Default value:**

- No (disabled) if `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_CLASSIC_ENABLED**

Classic Bluetooth

*Found in: Component config > Bluetooth > Bluedroid Options*

For now this option needs “SMP_ENABLE” to be set to yes

**Default value:**

- No (disabled) if `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_CLASSIC_BQB_ENABLED**

Host Qualification support for Classic Bluetooth

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED*

This enables functionalities of Host qualification for Classic Bluetooth.

**Default value:**

- No (disabled) if `CONFIG_BT_CLASSIC_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_A2DP_ENABLE**

A2DP

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED*

Advanced Audio Distribution Profile

**Default value:**
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_SPP_ENABLED

SPP

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

This enables the Serial Port Profile

Default value:
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_L2CAP_ENABLED

BT L2CAP

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

This enables the Logical Link Control and Adaptation Layer Protocol. Only supported classic bluetooth.

Default value:
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_HFP_ENABLE

Hands Free/Handset Profile

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED

Default value:
• No (disabled) if CONFIG_BT_CLASSIC_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_HFP_ROLE

Hands-free Profile Role configuration

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED > CONFIG_BT_HFP_ENABLE

Available options:

• Hands Free Unit (CONFIG_BT_HFP_CLIENT_ENABLE)
• Audio Gateway (CONFIG_BT_HFP_AG_ENABLE)

CONFIG_BT_HFP_AUDIO_DATA_PATH

audio(SCO) data path

Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_CLASSIC_ENABLED > CONFIG_BT_HFP_ENABLE

SCO data path, i.e. HCI or PCM. This option is set using API “esp_bredr_sco_datapath_set” in Bluetooth host. Default SCO data path can also be set in Bluetooth Controller.

Available options:

• PCM (CONFIG_BT_HFP_AUDIO_DATA_PATH_PCM)
• HCI (CONFIG_BT_HFP_AUDIO_DATA_PATH_HCI)

**CONFIG_BT_HFP_WBS_ENABLE**

Wide Band Speech

*Found in: Component config > Bluetooth > Bluedroid Options*

This enables Wide Band Speech. Should disable it when SCO data path is PCM. Otherwise there will be no data transmitted via GPIOs.

**Default value:**

- Yes (enabled) if
  - CONFIG_BT_HFP_AUDIO_DATA_PATH_HCI
  - CONFIG_BT_HFP_WBS_ENABLE

**CONFIG_BT_HID_ENABLED**

Classic BT HID

*Found in: Component config > Bluetooth > Bluedroid Options*

This enables the BT HID Host

**Default value:**

- No (disabled) if
  - CONFIG_BT_CLASSIC_ENABLED
  - CONFIG_BT_HID_ENABLED

**CONFIG_BT_HID_ROLE**

Profile Role configuration

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_HID_ENABLED*

Available options:

- Classic BT HID Host (CONFIG_BT_HID_HOST_ENABLED)
  This enables the BT HID Host
- Classic BT HID Device (CONFIG_BT_HID_DEVICE_ENABLED)
  This enables the BT HID Device

**CONFIG_BT_SSP_ENABLED**

Secure Simple Pairing

*Found in: Component config > Bluetooth > Bluedroid Options*

This enables the Secure Simple Pairing. If disable this option, Bluedroid will only support Legacy Pairing

**Default value:**

- Yes (enabled) if
  - CONFIG_BT_CLASSIC_ENABLED
  - CONFIG_BT_SSP_ENABLED

**CONFIG_BT_BLE_ENABLED**

Bluetooth Low Energy

*Found in: Component config > Bluetooth > Bluedroid Options*

This enables Bluetooth Low Energy

**Default value:**

- Yes (enabled) if
  - CONFIG_BT_BLE_ENABLED
**CONFIG_BT_GATTS_ENABLE**

Include GATT server module (GATTS)

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED*

This option can be disabled when the app work only on gatt client mode

**Default value:**
- Yes (enabled) if `CONFIG_BT_BLE_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_GATTS_PPCP_CHAR_GAP**

Enable Peripheral Preferred Connection Parameters characteristic in GAP service

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

This enables “Peripheral Preferred Connection Parameters” characteristic (UUID: 0x2A04) in GAP service that has connection parameters like min/max connection interval, slave latency and supervision timeout multiplier

**Default value:**
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_BLE_BLUFI_ENABLE**

Include blufi function

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

This option can be close when the app does not require blufi function.

**Default value:**
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_GATT_MAX_SR_PROFILES**

Max GATT Server Profiles

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

Maximum GATT Server Profiles Count

**Range:**
- from 1 to 32 if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**Default value:**
- 8 if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_GATT_MAX_SR_ATTRIBUTES**

Max GATT Service Attributes

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

Maximum GATT Service Attributes Count

**Range:**
- from 1 to 500 if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`
Default value:
- 100 if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLE_ENABLED` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_GATTS_SEND_SERVICE_CHANGE_MODE**

GATTs Service Change Mode

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

Service change indication mode for GATT Server.

Available options:

- GATTs manually send service change indication (CONFIG_BT_GATTS_SEND_SERVICE_CHANGE_MANUAL)
  Manually send service change indication through API `esp_ble_gatts_send_service_change_indication()`
- GATTs automatically send service change indication (CONFIG_BT_GATTS_SEND_SERVICE_CHANGE_AUTO)
  Let Bluedroid handle the service change indication internally

**CONFIG_BT_GATTS_ROBUST_CACHING_ENABLED**

Enable Robust Caching on Server Side

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

This option enable gatt robust caching feature on server

Default value:
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLE_ENABLED` &

**CONFIG_BT_GATTS_DEVICE_NAME_WRITABLE**

Allow to write device name by GATT clients

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

Enabling this option allows remote GATT clients to write device name

Default value:
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLE_ENABLED`

**CONFIG_BT_GATTS_APPEARANCE_WRITABLE**

Allow to write appearance by GATT clients

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTS_ENABLE*

Enabling this option allows remote GATT clients to write appearance

Default value:
- No (disabled) if `CONFIG_BT_GATTS_ENABLE` && `CONFIG_BT_BLE_ENABLED`
CONFIG_BT_GATTC_ENABLE
Include GATT client module(GATTC)

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED*

This option can be close when the app work only on gatt server mode

**Default value:**

* Yes (enabled) if CONFIG_BT_BLE_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_GATTC_MAX_CACHE_CHAR
Max gatt cache characteristic for discover

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTC_ENABLE*

Maximum GATTC cache characteristic count

**Range:**

* from 1 to 500 if CONFIG_BT_GATTC_ENABLE && CONFIG_BT_BLUEDROID_ENABLED

**Default value:**

* 40 if CONFIG_BT_GATTC_ENABLE && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_GATTC_CACHE_NVS_FLASH
Save gatt cache data to nvs flash

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTC_ENABLE*

This select can save gatt cache data to nvs flash

**Default value:**

* No (disabled) if CONFIG_BT_GATTC_ENABLE && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_GATTC_CONNECT_RETRY_COUNT
The number of attempts to reconnect if the connection establishment failed

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTC_ENABLE*

The number of attempts to reconnect if the connection establishment failed

**Range:**

* from 0 to 7 if CONFIG_BT_GATTC_ENABLE && CONFIG_BT_BLUEDROID_ENABLED

**Default value:**

* 3 if CONFIG_BT_GATTC_ENABLE && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_BLE_SMP_ENABLE
Include BLE security module(SMP)

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED*

This option can be close when the app not used the ble security connect.

**Default value:**

* Yes (enabled) if CONFIG_BT_BLE_ENABLED && CONFIG_BT_BLUEDROID_ENABLED
CONFIG_BT_SMP_SLAVE_CON_PARAMS_UPD_ENABLE

Slave enable connection parameters update during pairing

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_BLE_SMP_ENABLE*

In order to reduce the pairing time, slave actively initiates connection parameters update during pairing.

**Default value:**

- No (disabled) if CONFIG_BT_BLE_SMP_ENABLE && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_STACK_NO_LOG

Disable BT debug logs (minimize bin size)

*Found in: Component config > Bluetooth > Bluedroid Options*

This select can save the rodata code size

**Default value:**

- No (disabled) if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

BT DEBUG LOG LEVEL

Contains:

- CONFIG_BT_LOG_A2D_TRACE_LEVEL
- CONFIG_BT_LOG_APPL_TRACE_LEVEL
- CONFIG_BT_LOG_AVCT_TRACE_LEVEL
- CONFIG_BT_LOG_AVDT_TRACE_LEVEL
- CONFIG_BT_LOG_AVRC_TRACE_LEVEL
- CONFIG_BT_LOG_AVDT_TRACE_LEVEL
- CONFIG_BT_LOG_BLUFI_TRACE_LEVEL
- CONFIG_BT_LOG_BNEP_TRACE_LEVEL
- CONFIG_BT_LOG_BTIF_TRACE_LEVEL
- CONFIG_BT_LOG_BTM_TRACE_LEVEL
- CONFIG_BT_LOG_GAP_TRACE_LEVEL
- CONFIG_BT_LOG_GATT_TRACE_LEVEL
- CONFIG_BT_LOG_HCI_TRACE_LEVEL
- CONFIG_BT_LOG_HID_TRACE_LEVEL
- CONFIG_BT_LOG_L2CAP_TRACE_LEVEL
- CONFIG_BT_LOG_MCA_TRACE_LEVEL
- CONFIG_BT_LOG_OSI_TRACE_LEVEL
- CONFIG_BT_LOG_PAN_TRACE_LEVEL
- CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL
- CONFIG_BT_LOG_SDP_TRACE_LEVEL
- CONFIG_BT_LOG_SMP_TRACE_LEVEL

CONFIG_BT_LOG_HCI_TRACE_LEVEL

HCI layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for HCI layer

Available options:

- NONE (CONFIG_BT_LOG_HCI_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_HCI_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_HCI_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_HCI_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_HCI_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_HCI_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_HCI_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_BTM_TRACE_LEVEL**

BTM layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for BTM layer

Available options:

• NONE (CONFIG_BT_LOG_BTM_TRACE_LEVEL_NONE)
• ERROR (CONFIG_BT_LOG_BTM_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_BTM_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_BTM_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_BTM_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_BTM_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_BTM_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_L2CAP_TRACE_LEVEL**

L2CAP layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for L2CAP layer

Available options:

• NONE (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_NONE)
• ERROR (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL**

RFCOMM layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for RFCOMM layer

Available options:

• NONE (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_NONE)
• ERROR (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL_VERBOSE)
**CONFIG_BT_LOG_SDP_TRACE_LEVEL**

SDP layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for SDP layer

Available options:

- NONE (CONFIG_BT_LOG_SDP_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_SDP_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_SDP_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_SDP_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_SDP_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_SDP_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_SDP_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_GAP_TRACE_LEVEL**

GAP layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for GAP layer

Available options:

- NONE (CONFIG_BT_LOG_GAP_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_GAP_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_GAP_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_GAP_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_GAP_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_GAP_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_GAP_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_BNEP_TRACE_LEVEL**

BNEP layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for BNEP layer

Available options:

- NONE (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_BNEP_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_PAN_TRACE_LEVEL**

PAN layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*
Define BT trace level for PAN layer

Available options:

- NONE (CONFIG_BT_LOG_PAN_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_PAN_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_PAN_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_PAN_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_PAN_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_PAN_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_PAN_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_A2D_TRACE_LEVEL**

A2D layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for A2D layer

Available options:

- NONE (CONFIG_BT_LOG_A2D_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_A2D_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_A2D_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_A2D_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_A2D_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_A2D_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_A2D_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_AVDT_TRACE_LEVEL**

AVDT layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for AVDT layer

Available options:

- NONE (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_AVDT_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_AVCT_TRACE_LEVEL**

AVCT layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for AVCT layer

Available options:
Chapter 2. API Reference

- NONE (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_AVCT_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_AVRC_TRACE_LEVEL**

AVRC layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for AVRC layer

Available options:

- NONE (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_AVRC_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_MCA_TRACE_LEVEL**

MCA layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for MCA layer

Available options:

- NONE (CONFIG_BT_LOG_MCA_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_MCA_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_MCA_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_MCA_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_MCA_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_MCA_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_MCA_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_HID_TRACE_LEVEL**

HID layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for HID layer

Available options:

- NONE (CONFIG_BT_LOG_HID_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_HID_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_HID_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_HID_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_HID_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_HID_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_HID_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_APPL_TRACE_LEVEL
APPL layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for APPL layer

Available options:

• NONE (CONFIG_BT_LOG_APPL_TRACE_LEVEL_NONE)
• ERROR (CONFIG_BT_LOG_APPL_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_APPL_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_APPL_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_APPL_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_APPL_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_APPL_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_GATT_TRACE_LEVEL
GATT layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for GATT layer

Available options:

• NONE (CONFIG_BT_LOG_GATT_TRACE_LEVEL_NONE)
• ERROR (CONFIG_BT_LOG_GATT_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_GATT_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_GATT_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_GATT_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_GATT_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_GATT_TRACE_LEVEL_VERBOSE)

CONFIG_BT_LOG_SMP_TRACE_LEVEL
SMP layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for SMP layer

Available options:

• NONE (CONFIG_BT_LOG_SMP_TRACE_LEVEL_NONE)
• ERROR (CONFIG_BT_LOG_SMP_TRACE_LEVEL_ERROR)
• WARNING (CONFIG_BT_LOG_SMP_TRACE_LEVEL_WARNING)
• API (CONFIG_BT_LOG_SMP_TRACE_LEVEL_API)
• EVENT (CONFIG_BT_LOG_SMP_TRACE_LEVEL_EVENT)
• DEBUG (CONFIG_BT_LOG_SMP_TRACE_LEVEL_DEBUG)
• VERBOSE (CONFIG_BT_LOG_SMP_TRACE_LEVEL_VERBOSE)
**CONFIG_BT_LOG_BTIF_TRACE_LEVEL**

BTIF layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for BTIF layer

Available options:

- NONE (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_BTIF_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_BTC_TRACE_LEVEL**

BTC layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for BTC layer

Available options:

- NONE (CONFIG_BT_LOG_BTC_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_BTC_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_BTC_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_BTC_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_BTC_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_BTC_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_BTC_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_OSI_TRACE_LEVEL**

OSI layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*

Define BT trace level for OSI layer

Available options:

- NONE (CONFIG_BT_LOG_OSI_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_OSI_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_OSI_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_OSI_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_OSI_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_OSI_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_OSI_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_BLUFI_TRACE_LEVEL**

BLUFI layer

*Found in: Component config > Bluetooth > Bluedroid Options > BT DEBUG LOG LEVEL*
Define BT trace level for BLUFI layer

Available options:

- NONE (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_WARNING)
- API (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_API)
- EVENT (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_EVENT)
- DEBUG (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BT_LOG_BLUFI_TRACE_LEVEL_VERBOSE)

CONFIG_BT_ACL_CONNECTIONS

BT/BLE MAX ACL CONNECTIONS(1~9)

Found in: Component config > Bluetooth > Bluedroid Options

Maximum BT/BLE connection count. The ESP32-C3/S3 chip supports a maximum of 10 instances, including ADV, SCAN and connections. The ESP32-C3/S3 chip can connect up to 9 devices if ADV or SCAN uses only one. If ADV and SCAN are both used, the ESP32-C3/S3 chip is connected to a maximum of 8 devices. Because Bluetooth cannot reclaim used instances once ADV or SCAN is used.

Range:
- from 1 to 9 if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

Default value:
- 4 if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_MULTI_CONNECTION_ENBALE

Enable BLE multi-conections

Found in: Component config > Bluetooth > Bluedroid Options

Enable this option if there are multiple connections

Default value:
- Yes (enabled) if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_ALLOCATION_FROM_SPIRAM_FIRST

BT/BLE will first malloc the memory from the PSRAM

Found in: Component config > Bluetooth > Bluedroid Options

This select can save the internal RAM if there have the PSRAM

Default value:
- No (disabled) if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLUEDROID_ENABLED

CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY

Use dynamic memory allocation in BT/BLE stack

Found in: Component config > Bluetooth > Bluedroid Options

This select can make the allocation of memory will become more flexible

Default value:
Chapter 2. API Reference

• No (disabled) if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}

**CONFIG_BT_BLE_HOST_QUEUE_CONG_CHECK**

BLE queue congestion check

*Found in: Component config > Bluetooth > Bluedroid Options*

When scanning and scan duplicate is not enabled, if there are a lot of adv packets around or application layer handling adv packets is slow, it will cause the controller memory to run out. if enabled, adv packets will be lost when host queue is congested.

*Default value:*

- No (disabled) if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}

**CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN**

Report adv data and scan response individually when BLE active scan

*Found in: Component config > Bluetooth > Bluedroid Options*

Originally, when doing BLE active scan, Bluedroid will not report adv to application layer until receive scan response. This option is used to disable the behavior. When enable this option, Bluedroid will report adv data or scan response to application layer immediately.

# Memory reserved at start of DRAM for Bluetooth stack

*Default value:*

- No (disabled) if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLE_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}

**CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT**

Timeout of BLE connection establishment

*Found in: Component config > Bluetooth > Bluedroid Options*

Bluetooth Connection establishment maximum time, if connection time exceeds this value, the connection establishment fails, ESP_GATTC_OPEN_EVT or ESP_GATTS_OPEN_EVT is triggered.

*Range:*

- from 1 to 60 if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}

*Default value:*

- 30 if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}

**CONFIG_BT_MAX_DEVICE_NAME_LEN**

length of bluetooth device name

*Found in: Component config > Bluetooth > Bluedroid Options*

Bluetooth Device name length shall be no larger than 248 octets, If the broadcast data cannot contain the complete device name, then only the shortname will be displayed, the rest parts that can’t fit in will be truncated.

*Range:*

- from 32 to 248 if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}

*Default value:*

- 32 if \texttt{CONFIG_BT_BLUEDROID_ENABLED} \&\& \texttt{CONFIG_BT_BLUEDROID_ENABLED}
CONFIG_BT_BLE_RPA_SUPPORTED

Update RPA to Controller

*Found in:* Component config > Bluetooth > Bluedroid Options

This enables controller RPA list function. For ESP32, ESP32 only support network privacy mode. If this option is enabled, ESP32 will only accept advertising packets from peer devices that contain private address, HW will not receive the advertising packets contain identity address after IRK changed. If this option is disabled, address resolution will be performed in the host, so the functions that require controller to resolve address in the white list cannot be used. This option is disabled by default on ESP32, please enable or disable this option according to your own needs.

For other BLE chips, devices support network privacy mode and device privacy mode, users can switch the two modes according to their own needs. So this option is enabled by default.

**Default value:**
- No (disabled) if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLE_RPA_SUPPORTED

CONFIG_BT_BLE_RPA_TIMEOUT

Timeout of resolvable private address

*Found in:* Component config > Bluetooth > Bluedroid Options

This set RPA timeout of Controller and Host. Default is 900 s (15 minutes). Range is 1 s to 1 hour (3600 s).

**Range:**
- from 1 to 3600 if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLE_RPA_TIMEOUT

**Default value:**
- 900 if CONFIG_BT_BLUEDROID_ENABLED && CONFIG_BT_BLE_RPA_TIMEOUT

CONFIG_BT_BLE_50_FEATURES_SUPPORTED

Enable BLE 5.0 features

*Found in:* Component config > Bluetooth > Bluedroid Options

This enables BLE 5.0 features, this option only support esp32c3/esp32s3 chip

**Default value:**
- Yes (enabled) if CONFIG_BT_BLUEDROID_ENABLED && SOC_ESP_NIMBLE_CONTROLLER && CONFIG_BT_BLE_50_FEATURES_SUPPORTED

CONFIG_BT_BLE_42_FEATURES_SUPPORTED

Enable BLE 4.2 features

*Found in:* Component config > Bluetooth > Bluedroid Options

This enables BLE 4.2 features.

**Default value:**
- No (disabled) if CONFIG_BT_BLUEDROID_ENABLED && SOC_ESP_NIMBLE_CONTROLLER && CONFIG_BT_BLE_42_FEATURES_SUPPORTED

CONFIG_BT_BLEFeatPeriodicAdvSyncTransfer

Enable BLE periodic advertising sync transfer feature

*Found in:* Component config > Bluetooth > Bluedroid Options
This enables BLE periodic advertising sync transfer feature

**Default value:**
- No (disabled) if `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLE_50_FEATURES_SUPPORTED` && `SOC_ESP_NIMBLE_CONTROLLER` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_BLE_FEAT_PERIODIC_ADV_ENH**

Enable periodic adv enhancements(adi support)

*Found in: Component config > Bluetooth > Bluedroid Options*

Enable the periodic advertising enhancements

**Default value:**
- No (disabled) if `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLE_50_FEATURES_SUPPORTED` && `SOC_ESP_NIMBLE_CONTROLLER` && `CONFIG_BT_BLUEDROID_ENABLED`

**CONFIG_BT_BLE_HIGH_DUTY_ADV_INTERVAL**

Enable BLE high duty advertising interval feature

*Found in: Component config > Bluetooth > Bluedroid Options*

This enable BLE high duty advertising interval feature

**Default value:**
- No (disabled) if `CONFIG_BT_BLUEDROID_ENABLED` && `CONFIG_BT_BLE_50_FEATURES_SUPPORTED` && `SOC_ESP_NIMBLE_CONTROLLER` && `CONFIG_BT_BLUEDROID_ENABLED`

**NimBLE Options**

Contains:
- `CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_NAME`
- `CONFIG_BT_NIMBLE_HS_STOP_TIMEOUT_MS`
- `CONFIG_BT_NIMBLE_HOST_QUEUE_CONF_CHECK`
- `CONFIG_BT_NIMBLE_WHITELIST_SIZE`
- `CONFIG_BT_NIMBLE_BLE_GATT_BLOB_TRANSFER`
- `CONFIG_BT_NIMBLE_COEX_PHY_CODED_TX_RX_TLIM`
- `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT`
- `CONFIG_BT_NIMBLE_ROLE_BROADCASTER`
- `CONFIG_BT_NIMBLE_ROLE_CENTRAL`
- `CONFIG_BT_NIMBLE_HIGH_DUTY_ADV_ITVL`
- `CONFIG_BT_NIMBLE_MESH`
- `CONFIG_BT_NIMBLE_ROLE_OBSERVER`
- `CONFIG_BT_NIMBLE_ROLE_PERIPHERAL`
- `CONFIG_BT_NIMBLE_SECURITY_ENABLE`
- `CONFIG_BT_NIMBLE_BLELUFI_ENABLE`
- `CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT`
- `CONFIG_BT_NIMBLE_DYNAMIC_SERVICE`
- `CONFIG_BT_NIMBLE_USE_ESP_TIMER`
- `CONFIG_BT_NIMBLE_DEBUG`
- `CONFIG_BT_NIMBLE_HOST_BASED_PRIVACY`
- `CONFIG_BT_NIMBLE_HS_FLOW_CTRL`
- `CONFIG_BT_NIMBLE_VS_SUPPORT`
- `CONFIG_BT_NIMBLE_OPTIMIZE_MULTI_CONN`
- `CONFIG_BT_NIMBLE_ENC_ADV_DATA`
- `CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE`
- `CONFIG_BT_NIMBLE_GAP_DEVICE_NAME_MAX_LEN`
- `CONFIG_BT_NIMBLE_MAX_BONDS`
Chapter 2. API Reference

- `CONFIG_BT_NIMBLE_MAX_CCCDS`
- `CONFIG_BT_NIMBLE_MAX_CONNECTIONS`
- `CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM`
- `CONFIG_BT_NIMBLE_GATT_MAX_PROCS`
- `CONFIG_BT_NIMBLE_MEM_ALLOC_MODE`

**Memory Settings**
- `CONFIG_BT_NIMBLE_LOG_LEVEL`
- `CONFIG_BT_NIMBLE_HOST_TASK_STACK_SIZE`
- `CONFIG_BT_NIMBLE_CRYPTO_STACK_MBEDTLS`
- `CONFIG_BT_NIMBLE_NVS_PERSIST`
- `CONFIG_BT_NIMBLE_ATT_PREFERRED_MTU`
- `CONFIG_BT_NIMBLE_RPA_TIMEOUT`
- `CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE`
- `CONFIG_BT_NIMBLE_TEST_THROUGHPUT_TEST`

### `CONFIG_BT_NIMBLE_MEM_ALLOC_MODE`

Memory allocation strategy

*Found in: Component config > Bluetooth > NimBLE Options*

Allocation strategy for NimBLE host stack, essentially provides ability to allocate all required dynamic allocations from,

- Internal DRAM memory only
- External SPIRAM memory only
- Either internal or external memory based on default malloc() behavior in ESP-IDF
- Internal IRAM memory wherever applicable else internal DRAM

Available options:

- Internal memory (`CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_INTERNAL`)
- External SPIRAM (`CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_EXTERNAL`)
- Default alloc mode (`CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_DEFAULT`)
- Internal IRAM (`CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_IRAM_8BIT`)
  
  Allows to use IRAM memory region as 8bit accessible region.
  Every unaligned (8bit or 16bit) access will result in an exception and incur penalty of certain clock cycles per unaligned read/write.

### `CONFIG_BT_NIMBLE_LOG_LEVEL`

NimBLE Host log verbosity

*Found in: Component config > Bluetooth > NimBLE Options*

Select NimBLE log level. Please make a note that the selected NimBLE log verbosity can not exceed the level set in “Component config -> Log output -> Default log verbosity”.

Available options:

- No logs (`CONFIG_BT_NIMBLE_LOG_LEVEL_NONE`)
- Error logs (`CONFIG_BT_NIMBLE_LOG_LEVEL_ERROR`)
- Warning logs (`CONFIG_BT_NIMBLE_LOG_LEVEL_WARNING`)
- Info logs (`CONFIG_BT_NIMBLE_LOG_LEVEL_INFO`)
- Debug logs (`CONFIG_BT_NIMBLE_LOG_LEVEL_DEBUG`)

Espressif Systems 1504 Release v5.1.2
CONFIG_BT_NIMBLE_MAX_CONNECTIONS

Maximum number of concurrent connections

*Found in: Component config > Bluetooth > NimBLE Options*

Defines maximum number of concurrent BLE connections. For ESP32, user is expected to configure BTDM_CTRL_BLE_MAX_CONN from controller menu along with this option. Similarly for ESP32-C3 or ESP32-S3, user is expected to configure BT_CTRL_BLE_MAX_ACT from controller menu. For ESP32C2, ESP32C6 and ESP32H2, each connection will take about 1k DRAM.

*Range:*
  • from 1 to 9 if \texttt{CONFIG_BT_NIMBLE_ENABLED} && \texttt{CONFIG_BT_NIMBLE_ENABLED}

*Default value:*
  • 3 if \texttt{CONFIG_BT_NIMBLE_ENABLED} && \texttt{CONFIG_BT_NIMBLE_ENABLED}

CONFIG_BT_NIMBLE_MAX_BONDS

Maximum number of bonds to save across reboots

*Found in: Component config > Bluetooth > NimBLE Options*

Defines maximum number of bonds to save for peer security and our security

*Default value:*
  • 3 if \texttt{CONFIG_BT_NIMBLE_ENABLED} && \texttt{CONFIG_BT_NIMBLE_ENABLED}

CONFIG_BT_NIMBLE_MAX_CCCDS

Maximum number of CCC descriptors to save across reboots

*Found in: Component config > Bluetooth > NimBLE Options*

Defines maximum number of CCC descriptors to save

*Default value:*
  • 8 if \texttt{CONFIG_BT_NIMBLE_ENABLED} && \texttt{CONFIG_BT_NIMBLE_ENABLED}

CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM

Maximum number of connection oriented channels

*Found in: Component config > Bluetooth > NimBLE Options*

Defines maximum number of BLE Connection Oriented Channels. When set to (0), BLE COC is not compiled in

*Range:*
  • from 0 to 9 if \texttt{CONFIG_BT_NIMBLE_ENABLED} && \texttt{CONFIG_BT_NIMBLE_ENABLED}

*Default value:*
  • 0 if \texttt{CONFIG_BT_NIMBLE_ENABLED} && \texttt{CONFIG_BT_NIMBLE_ENABLED}

CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE

The CPU core on which NimBLE host will run

*Found in: Component config > Bluetooth > NimBLE Options*

The CPU core on which NimBLE host will run. You can choose Core 0 or Core 1. Cannot specify no-affinity

*Available options:*
  • Core 0 (PRO CPU) (\texttt{CONFIG_BT_NIMBLE_PINNED_TO_CORE_0})
• Core 1 (APP CPU) (CONFIG_BT_NIMBLE_PINNED_TO_CORE_1)

CONFIG_BT_NIMBLE_HOST_TASK_STACK_SIZE

NimBLE Host task stack size

*Found in: Component config > Bluetooth > NimBLE Options*

This configures stack size of NimBLE host task

**Default value:**

- 5120 if `CONFIG_BLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`
- 4096 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ROLE_CENTRAL

Enable BLE Central role

*Found in: Component config > Bluetooth > NimBLE Options*

Enables central role

**Default value:**

- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ROLE_PERIPHERAL

Enable BLE Peripheral role

*Found in: Component config > Bluetooth > NimBLE Options*

Enable peripheral role

**Default value:**

- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ROLE_BROADCASTER

Enable BLE Broadcaster role

*Found in: Component config > Bluetooth > NimBLE Options*

Enables broadcaster role

**Default value:**

- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ROLE_OBSERVER

Enable BLE Observer role

*Found in: Component config > Bluetooth > NimBLE Options*

Enables observer role

**Default value:**

- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`
**CONFIG_BT_NIMBLE_NVS_PERSIST**

Persist the BLE Bonding keys in NVS

*Found in: Component config > Bluetooth > NimBLE Options*

Enable this flag to make bonding persistent across device reboots

**Default value:**
- No (disabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_SECURITY_ENABLE**

Enable BLE SM feature

*Found in: Component config > Bluetooth > NimBLE Options*

Enable BLE SM feature

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

Contains:
- `CONFIG_BT_NIMBLE_LL_CFG_FEAT_LE_ENCRYPTION`
- `CONFIG_BT_NIMBLE_SM_LEGACY`
- `CONFIG_BT_NIMBLE_SM_SC`

**CONFIG_BT_NIMBLE_SM_LEGACY**

Security manager legacy pairing

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_SECURITY_ENABLE*

Enable security manager legacy pairing

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_SECURITY_ENABLE` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_SM_SC**

Security manager secure connections (4.2)

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_SECURITY_ENABLE*

Enable security manager secure connections

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_SECURITY_ENABLE` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS**

Use predefined public-private key pair

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_SECURITY_ENABLE > CONFIG_BT_NIMBLE_SM_SC*

If this option is enabled, SM uses predefined DH key pair as described in Core Specification, Vol. 3, Part H, 2.3.5.6.1. This allows to decrypt air traffic easily and thus should only be used for debugging.

**Default value:**
• No (disabled) if `CONFIG_BT_NIMBLE_SECURITY_ENABLE` && `CONFIG_BT_NIMBLE_SM_SC` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_LL_CFG_FEAT_LE_ENCRYPTION**

Enable LE encryption

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_SECURITY_ENABLE*

Enable encryption connection

**Default value:**

• Yes (enabled) if `CONFIG_BT_NIMBLE_SECURITY_ENABLE` && `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_DEBUG**

Enable extra runtime asserts and host debugging

*Found in: Component config > Bluetooth > NimBLE Options*

This enables extra runtime asserts and host debugging

**Default value:**

• No (disabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_DYNAMIC_SERVICE**

Enable dynamic services

*Found in: Component config > Bluetooth > NimBLE Options*

This enables user to add/remove Gatt services at runtime

**CONFIG_BT_NIMBLE_SVC_GAPDEVICE_NAME**

BLE GAP default device name

*Found in: Component config > Bluetooth > NimBLE Options*

The Device Name characteristic shall contain the name of the device as an UTF-8 string. This name can be changed by using API ble_svc_gap_device_name_set()

**Default value:**

• “nimble” if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_GAPDEVICE_NAME_MAX_LEN**

Maximum length of BLE device name in octets

*Found in: Component config > Bluetooth > NimBLE Options*

Device Name characteristic value shall be 0 to 248 octets in length

**Default value:**

• 31 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`
Chapter 2. API Reference

CONFIG_BT_NIMBLE_ATT_PREFERRED_MTU

Preferred MTU size in octets

*Found in: Component config > Bluetooth > NimBLE Options*

This is the default value of ATT MTU indicated by the device during an ATT MTU exchange. This value can be changed using API ble_att_set_preferred_mtu()

*Default value:*
  - 256 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE

External appearance of the device

*Found in: Component config > Bluetooth > NimBLE Options*

Standard BLE GAP Appearance value in HEX format e.g. 0x02C0

*Default value:*
  - 0 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

Memory Settings

Contains:

- CONFIG_BT_NIMBLE_TRANSPORT_ACL_FROM_LL_COUNT
- CONFIG_BT_NIMBLE_TRANSPORT_EVT_DISCARD_COUNT
- CONFIG_BT_NIMBLE_MSYS_BUF_FROM_HEAP
- CONFIG_BT_NIMBLE_MSYS_1_BLOCK_COUNT
- CONFIG_BT_NIMBLE_MSYS_1_BLOCK_SIZE
- CONFIG_BT_NIMBLE_MSYS_2_BLOCK_COUNT
- CONFIG_BT_NIMBLE_MSYS_2_BLOCK_SIZE
- CONFIG_BT_NIMBLE_TRANSPORT_ACL_SIZE
- CONFIG_BT_NIMBLE_TRANSPORT_EVT_COUNT
- CONFIG_BT_NIMBLE_TRANSPORT_EVT_SIZE

CONFIG_BT_NIMBLE_MSYS_1_BLOCK_COUNT

MSYS_1 Block Count

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

MSYS is a system level mbuf registry. For prepare write & prepare responses MBUFs are allocated out of msys_1 pool. For NIMBLE_MESH enabled cases, this block count is increased by 8 than user defined count.

*Default value:*
  - 24 if SOC_ESP_NIMBLE_CONTROLLER && CONFIG_BT_NIMBLE_ENABLED
  - 12 if SOC_ESP_NIMBLE_CONTROLLER && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MSYS_1_BLOCK_SIZE

MSYS_1 Block Size

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

Dynamic memory size of block 1

*Default value:*
  - 128 if SOC_ESP_NIMBLE_CONTROLLER && CONFIG_BT_NIMBLE_ENABLED
  - 256 if SOC_ESP_NIMBLE_CONTROLLER && CONFIG_BT_NIMBLE_ENABLED
Chapter 2. API Reference

**CONFIG_BT_NIMBLE_MSYS_2_BLOCK_COUNT**

MSYS_2 Block Count

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

Dynamic memory count

**Default value:**

- 24 if `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_MSYS_2_BLOCK_SIZE**

MSYS_2 Block Size

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

Dynamic memory size of block 2

**Default value:**

- 320 if `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_MSYS_BUF_FROM_HEAP**

Get Msys Mbuf from heap

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

This option sets the source of the shared msys mbuf memory between the Host and the Controller. Allocate the memory from the heap if this option is set, from the mempool otherwise.

**Default value:**

- Yes (enabled) if `BT_LE_MSYS_INIT_IN_CONTROLLER` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_TRANSPORT_ACL_FROM_LL_COUNT**

ACL Buffer count

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

The number of ACL data buffers allocated for host.

**Default value:**

- 24 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_TRANSPORT_ACL_SIZE**

Transport ACL Buffer size

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

This is the maximum size of the data portion of HCI ACL data packets. It does not include the HCI data header (of 4 bytes)

**Default value:**

- 255 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_TRANSPORT_EVT_SIZE**

Transport Event Buffer size

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

This is the size of each HCI event buffer in bytes. In case of extended advertising, packets can be fragmented. 257 bytes is the maximum size of a packet.
Default value:
- 257 if CONFIG_BT_NIMBLE_EXT_ADV && CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED
- 70 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_TRANSPORT_EVT_COUNT**

Transport Event Buffer count

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

This is the high priority HCI events’ buffer size. High-priority event buffers are for everything except advertising reports. If there are no free high-priority event buffers then host will try to allocate a low-priority buffer instead

Default value:
- 30 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_TRANSPORT_EVT_DISCARD_COUNT**

Discardable Transport Event Buffer count

*Found in: Component config > Bluetooth > NimBLE Options > Memory Settings*

This is the low priority HCI events’ buffer size. Low-priority event buffers are only used for advertising reports. If there are no free low-priority event buffers, then an incoming advertising report will get dropped

Default value:
- 8 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_GATT_MAX_PROCS**

Maximum number of GATT client procedures

*Found in: Component config > Bluetooth > NimBLE Options*

Maximum number of GATT client procedures that can be executed.

Default value:
- 4 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_HS_FLOW_CTRL**

Enable Host Flow control

*Found in: Component config > Bluetooth > NimBLE Options*

Enable Host Flow control

Default value:
- Yes (enabled) if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED
- No (disabled) if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_HS_FLOW_CTRL_ITVL**

Host Flow control interval

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_HS_FLOW_CTRL*

Host flow control interval in msecs

Default value:
- 1000 if CONFIG_BT_NIMBLE_HS_FLOW_CTRL && CONFIG_BT_NIMBLE_ENABLED
CONFIG_BT_NIMBLE_HS_FLOW_CTRL_THRESH

Host Flow control threshold

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_HS_FLOW_CTRL*

Host flow control threshold, if the number of free buffers are at or below this threshold, send an immediate number-of-completed-packets event

**Default value:**
- 2 if `CONFIG_BT_NIMBLE_HS_FLOW_CTRL` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_HS_FLOW_CTRL_TX_ON_DISCONNECT

Host Flow control on disconnect

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_HS_FLOW_CTRL*

Enable this option to send number-of-completed-packets event to controller after disconnection

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_HS_FLOW_CTRL` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_RPA_TIMEOUT

RPA timeout in seconds

*Found in: Component config > Bluetooth > NimBLE Options*

Time interval between RPA address change. This is applicable in case of Host based RPA

**Range:**
- from 1 to 41400 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

**Default value:**
- 900 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MESH

Enable BLE mesh functionality

*Found in: Component config > Bluetooth > NimBLE Options*

Enable BLE Mesh example present in upstream mynewt-nimble and not maintained by Espressif.

IDF maintains ESP-BLE-MESH as the official Mesh solution. Please refer to ESP-BLE-MESH guide at: :doc:`../esp32/api-guides/esp-ble-mesh/ble-mesh-index`

**Default value:**
- No (disabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

Contains:
- `CONFIG_BT_NIMBLE_MESH_PROVISIONER`
- `CONFIG_BT_NIMBLE_MESH_PROV`
- `CONFIG_BT_NIMBLE_MESH_GATT_PROXY`
- `CONFIG_BT_NIMBLE_MESH_FRIEND`
- `CONFIG_BT_NIMBLE_MESH_LOW_POWER`
- `CONFIG_BT_NIMBLE_MESH_PROXY`
- `CONFIG_BT_NIMBLE_MESH_RELAY`
- `CONFIG_BT_NIMBLE_MESH_DEVICE_NAME`
- `CONFIG_BT_NIMBLE_MESH_NODE_COUNT`
CONFIG_BT_NIMBLE_MESH_PROXY
Enable mesh proxy functionality

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH

Enable proxy. This is automatically set whenever NIMBLE_MESH_PB_GATT or NIMBLE_MESH_GATT_PROXY is set

**Default value:**
- No (disabled) if CONFIG_BT_NIMBLE_MESH && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_PROV
Enable BLE mesh provisioning

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH

Enable mesh provisioning

**Default value:**
- Yes (enabled) if CONFIG_BT_NIMBLE_MESH && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_PB_ADV
Enable mesh provisioning over advertising bearer

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH > CONFIG_BT_NIMBLE_MESH_PROV

Enable this option to allow the device to be provisioned over the advertising bearer

**Default value:**
- Yes (enabled) if CONFIG_BT_NIMBLE_MESH_PROV && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_PB_GATT
Enable mesh provisioning over GATT bearer

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH > CONFIG_BT_NIMBLE_MESH_PROV

Enable this option to allow the device to be provisioned over the GATT bearer

**Default value:**
- Yes (enabled) if CONFIG_BT_NIMBLE_MESH_PROV && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_MESH_GATT_PROXY
Enable GATT Proxy functionality

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH

This option enables support for the Mesh GATT Proxy Service, i.e. the ability to act as a proxy between a Mesh GATT Client and a Mesh network

**Default value:**
- Yes (enabled) if CONFIG_BT_NIMBLE_MESH && CONFIG_BT_NIMBLE_ENABLED
Chapter 2. API Reference

CONFIG_BT_NIMBLE_MESH_RELAY
Enable mesh relay functionality

- Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH
- Support for acting as a Mesh Relay Node

**Default value:**
- No (disabled) if `CONFIG_BT_NIMBLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MESH_LOW_POWER
Enable mesh low power mode

- Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH
- Enable this option to be able to act as a Low Power Node

**Default value:**
- No (disabled) if `CONFIG_BT_NIMBLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MESH_FRIEND
Enable mesh friend functionality

- Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH
- Enable this option to be able to act as a Friend Node

**Default value:**
- No (disabled) if `CONFIG_BT_NIMBLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MESH_DEVICE_NAME
Set mesh device name

- Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH
- This value defines Bluetooth Mesh device/node name

**Default value:**
- “nimble-mesh-node” if `CONFIG_BT_NIMBLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MESH_NODE_COUNT
Set mesh node count

- Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH
- Defines mesh node count.

**Default value:**
- 1 if `CONFIG_BT_NIMBLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MESH_PROVISIONER
Enable BLE mesh provisioner

- Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH
- Enable mesh provisioner.

**Default value:**
- 0 if `CONFIG_BT_NIMBLE_MESH` && `CONFIG_BT_NIMBLE_ENABLED`
CONFIG_BT_NIMBLE_CRYPTO_STACK_MBEDTLS
Override TinyCrypt with mbedTLS for crypto computations

*Found in:* Component config > Bluetooth > NimBLE Options

Enable this option to choose mbedTLS instead of TinyCrypt for crypto computations.

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_HS_STOP_TIMEOUT_MS
BLE host stop timeout in msec

*Found in:* Component config > Bluetooth > NimBLE Options

BLE Host stop procedure timeout in milliseconds.

**Default value:**
- 2000 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_HOST_BASED_PRIVACY
Enable host based privacy for random address.

*Found in:* Component config > Bluetooth > NimBLE Options

Use this option to do host based Random Private Address resolution. If this option is disabled then controller based privacy is used.

**Default value:**
- No (disabled) if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT
Enable connection reattempts on connection establishment error

*Found in:* Component config > Bluetooth > NimBLE Options

Enable to make the NimBLE host to reattempt GAP connection on connection establishment failure.

**Default value:**
- Yes (enabled) if `SOC_ESP_NIMBLE_CONTROLLER` && `CONFIG_BT_NIMBLE_ENABLED`
- No (disabled) if `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_MAX_CONN_REATTEMPT
Maximum number connection reattempts

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT

Defines maximum number of connection reattempts.

**Range:**
- from 1 to 7 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT` && `CONFIG_BT_NIMBLE_ENABLED`

**Default value:**
- 3 if `CONFIG_BT_NIMBLE_ENABLED` && `CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT` && `CONFIG_BT_NIMBLE_ENABLED`
CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT

Enable BLE 5 feature

Default value:
- Yes (enabled) if CONFIG_BT_NIMBLE_ENABLED && (SOC_BLE_50_SUPPORTED || CONFIG_BT_CONTROLLER_ENABLED) && CONFIG_BT_NIMBLE_ENABLED

Contains:
- CONFIG_BT_NIMBLE_LL_CFG_FEAT_LE_2M_PHY
- CONFIG_BT_NIMBLE_LL_CFG_FEAT_LE_CODED_PHY
- CONFIG_BT_NIMBLE_EXT_ADV
- CONFIG_BT_NIMBLE_BLE_POWER_CONTROL
- CONFIG_BT_NIMBLE_MAX_PERIODIC_ADVERTISER_LIST
- CONFIG_BT_NIMBLE_MAX_PERIODIC_SYNCS
- CONFIG_BT_NIMBLE_PERIODIC_ADV_ENH

CONFIG_BT_NIMBLE_LL_CFG_FEAT_LE_2M_PHY

Enable 2M Phy

Default value:
- Yes (enabled) if CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_LL_CFG_FEAT_LE_CODED_PHY

Enable coded Phy

Default value:
- Yes (enabled) if CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT && CONFIG_BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_EXT_ADV

Enable extended advertising

Default value:
- No (disabled) if CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT && CONFIG_BT_NIMBLE_ENABLED
CONFIG_BT_NIMBLE_MAX_EXT_ADV_INSTANCES

Maximum number of extended advertising instances.

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT > CONFIG_BT_NIMBLE_EXT_ADV

Change this option to set maximum number of extended advertising instances. Minimum there is always one instance of advertising. Enter how many more advertising instances you want. For ESP32C2, ESP32C6 and ESP32H2, each extended advertising instance will take about 0.5k DRAM.

**Range:**
- from 0 to 4 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` & & `CONFIG_BT_NIMBLE_ENABLED`

**Default value:**
- 1 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` & & `CONFIG_BT_NIMBLE_ENABLED`
- 0 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` & & `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_EXT_ADV_MAX_SIZE

Maximum length of the advertising data.

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT > CONFIG_BT_NIMBLE_EXT_ADV

Defines the length of the extended adv data. The value should not exceed 1650.

**Range:**
- from 0 to 1650 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_ENABLED`

**Default value:**
- 1650 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_ENABLED`
- 0 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV

Enable periodic advertisement.

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT > CONFIG_BT_NIMBLE_EXT_ADV

Enable this option to start periodic advertisement.

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_PERIODIC_ADV_SYNC_TRANSFER

Enable Transer Sync Events

*Found in:* Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT > CONFIG_BT_NIMBLE_EXT_ADV > CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV

This enables controller transfer periodic sync events to host

**Default value:**
- Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_ENABLED`
**CONFIG_BT_NIMBLE_MAX_PERIODIC_SYNCS**

Maximum number of periodic advertising syncs

Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT

Set this option to set the upper limit for number of periodic sync connections. This should be less than maximum connections allowed by controller.

Range:
- from 0 to 8 if `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `CONFIG_BT_NIMBLE_ENABLED`

Default value:
- 1 if `CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV` && `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `CONFIG_BT_NIMBLE_ENABLED`
- 0 if `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_MAX_PERIODIC_ADVERTISER_LIST**

Maximum number of periodic advertiser list

Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT

Set this option to set the upper limit for number of periodic advertiser list.

Range:
- from 1 to 5 if `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `SOC_ESP_NIMBLE_CONTROLLER` && `CONFIG_BT_NIMBLE_ENABLED`

Default value:
- 5 if `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `SOC_ESP_NIMBLE_CONTROLLER` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_BLE_POWER_CONTROL**

Enable support for BLE Power Control

Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT

Set this option to enable the Power Control feature

Default value:
- No (disabled) if `CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT` && `SOC_BLE_POWER_CONTROL_SUPPORTED` && `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG_BT_NIMBLE_PERIODIC_ADV_ENH**

Periodic adv enhancements(adi support)

Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_50_FEATURE_SUPPORT

Enable the periodic advertising enhancements

**CONFIG_BT_NIMBLE_COEX_PHY_CODED_TX_RX_TLIM**

Coexistence: limit on MAX Tx/Rx time for coded-PHY connection

Found in: Component config > Bluetooth > NimBLE Options
When using PHY-Coded in BLE connection, limitation on max tx/rx time can be applied to better avoid dramatic performance deterioration of Wi-Fi.

Available options:

- Force Enable (CONFIG_BT_NIMBLE_COEX_PHY_CODED_TX_RX_TLIM_EN)
  Always enable the limitation on max tx/rx time for Coded-PHY connection
- Force Disable (CONFIG_BT_NIMBLE_COEX_PHY_CODED_TX_RX_TLIM_DIS)
  Disable the limitation on max tx/rx time for Coded-PHY connection

**CONFIG_BT_NIMBLE_WHITELIST_SIZE**

BLE white list size

*Found in: Component config > Bluetooth > NimBLE Options*

BLE list size

*Range:*
  - from 1 to 15 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

*Default value:*
  - 12 if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_TEST_THROUGHPUT_TEST**

Throughput Test Mode enable

*Found in: Component config > Bluetooth > NimBLE Options*

Enable the throughput test mode

*Default value:*
  - No (disabled) if CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_BLUFI_ENABLE**

Enable blufi functionality

*Found in: Component config > Bluetooth > NimBLE Options*

Set this option to enable blufi functionality.

*Default value:*
  - No (disabled) if CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_USE_ESP_TIMER**

Enable Esp Timer for Nimble

*Found in: Component config > Bluetooth > NimBLE Options*

Set this option to use Esp Timer which has higher priority timer instead of FreeRTOS timer

*Default value:*
  - Yes (enabled) if CONFIG_BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_BLE_GATT_BLOB_TRANSFER**

Blob transfer

*Found in: Component config > Bluetooth > NimBLE Options*

This option is used when data to be sent is more than 512 bytes. For peripheral role, BT_NIMBLE_MSYS_1_BLOCK_COUNT needs to be increased according to the need.
CONFIG_BT_NIMBLE_VS_SUPPORT

Enable support for VSC and VSE

*Found in: Component config > Bluetooth > NimBLE Options*

This option is used to enable support for sending Vendor Specific HCI commands and handling Vendor Specific HCI Events.

CONFIG_BT_NIMBLE_OPTIMIZE_MULTI_CONN

Enable the optimization of multi-connection

*Found in: Component config > Bluetooth > NimBLE Options*

This option enables the use of vendor-specific APIs for multi-connections, which can greatly enhance the stability of coexistence between numerous central and peripheral devices. It will prohibit the usage of standard APIs.

**Default value:**

- No (disabled) if `SOC_BLE_MULTI_CONN_OPTIMIZATION && CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_ENC_ADV_DATA

Encrypted Advertising Data

*Found in: Component config > Bluetooth > NimBLE Options*

This option is used to enable encrypted advertising data.

CONFIG_BT_NIMBLE_MAX_EADS

Maximum number of EAD devices to save across reboots

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_ENC_ADV_DATA*

 Defines maximum number of encrypted advertising data key material to save

**Default value:**

- 10 if `CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENC_ADV_DATA && CONFIG_BT_NIMBLE_ENABLED`

CONFIG_BT_NIMBLE_HIGH_DUTY_ADV_ITVL

Enable BLE high duty advertising interval feature

*Found in: Component config > Bluetooth > NimBLE Options*

This enable BLE high duty advertising interval feature

CONFIG_BT_NIMBLE_HOST_QUEUE_CONG_CHECK

BLE queue congestion check

*Found in: Component config > Bluetooth > NimBLE Options*

When scanning and scan duplicate is not enabled, if there are a lot of adv packets around or application layer handling adv packets is slow, it will cause the controller memory to run out. if enabled, adv packets will be lost when host queue is congested.

**Default value:**

- No (disabled) if `CONFIG_BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLED`
Controller Options  Contains:

- CONFIG_BTDM_CTRL_AUTO_LATENCY
- CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP
- CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED
- CONFIG_BTDM_CTRL_BLE_MAX_CONN
- CONFIG_BTDM_BLE_SCAN_DUPL
- CONFIG_BTDM_BLE_SLEEP_CLOCK_ACCURACY
- CONFIG_BTDM_CTRL_MODE
- CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN
- CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH
- CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN
- CONFIG_BTDM_CTRL_HCI_MODE_CHOICE
- HCI UART(H4) Options
- CONFIG_BTDM_CTRL_HLI
- CONFIG_BTDM_CTRL_LEGACY_AUTH_VENDOR_EVT
- MODEM SLEEP Options
- CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG
- CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE

CONFIG_BTDM_CTRL_MODE
Bluetooth controller mode (BR/EDR/BLE/DUALMODE)

*Found in: Component config > Bluetooth > Controller Options*

Specify the Bluetooth controller mode (BR/EDR, BLE or dual mode).

Available options:

- BLE Only (CONFIG_BTDM_CTRL_MODE_BLE_ONLY)
- BR/EDR Only (CONFIG_BTDM_CTRL_MODE_BR_EDR_ONLY)
- Bluetooth Dual Mode (CONFIG_BTDM_CTRL_MODE_BTDM)

CONFIG_BTDM_CTRL_BLE_MAX_CONN
BLE Max Connections

*Found in: Component config > Bluetooth > Controller Options*

BLE maximum connections of Bluetooth controller. Each connection uses 1KB static DRAM whenever the BT controller is enabled.

Range:
- from 1 to 9 if (CONFIG_BTDM_CTRL_MODE_BLE_ONLY || CONFIG_BTDM_CTRL_MODE_BTDM) && CONFIG_BT_CONTROLLER_ENABLED

Default value:
- 3 if (CONFIG_BTDM_CTRL_MODE_BLE_ONLY || CONFIG_BTDM_CTRL_MODE_BTDM) && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN
BR/EDR ACL Max Connections

*Found in: Component config > Bluetooth > Controller Options*

BR/EDR ACL maximum connections of Bluetooth controller. Each connection uses 1.2 KB DRAM whenever the BT controller is enabled.

Range:
• from 1 to 7 if \((\text{CONFIG_BTDM_CTRL_MODE_BR_EDR_ONLY} \lor \text{CONFIG_BTDM_CTRL_MODE_BTDM}) \&\& \text{CONFIG_BT_CONTROLLER_ENABLED}\)

**Default value:**
• 2 if \((\text{CONFIG_BTDM_CTRL_MODE_BR_EDR_ONLY} \lor \text{CONFIG_BTDM_CTRL_MODE_BTDM}) \&\& \text{CONFIG_BT_CONTROLLER_ENABLED}\)

**CONFIG_BTDM_CTRL_BR_EDR_MAX_SYNC_CONN**

BR/EDR Sync(SCO/eSCO) Max Connections

*Found in: Component config > Bluetooth > Controller Options*

BR/EDR Synchronize maximum connections of bluetooth controller. Each connection uses 2 KB DRAM whenever the BT controller is enabled.

**Range:**
• from 0 to 3 if \((\text{CONFIG_BTDM_CTRL_MODE_BR_EDR_ONLY} \lor \text{CONFIG_BTDM_CTRL_MODE_BTDM}) \&\& \text{CONFIG_BT_CONTROLLER_ENABLED}\)

**Default value:**
• 0 if \((\text{CONFIG_BTDM_CTRL_MODE_BR_EDR_ONLY} \lor \text{CONFIG_BTDM_CTRL_MODE_BTDM}) \&\& \text{CONFIG_BT_CONTROLLER_ENABLED}\)

**CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH**

BR/EDR Sync(SCO/eSCO) default data path

*Found in: Component config > Bluetooth > Controller Options*

SCO data path, i.e. HCI or PCM. SCO data can be sent/received through HCI synchronous packets, or the data can be routed to on-chip PCM module on ESP32. PCM input/output signals can be “matrixed” to GPIOs. The default data path can also be set using API `esp_bredr_sco_datapath_set`.

**Available options:**
• HCI (CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH_HCI)
• PCM (CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH_PCM)

**CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG**

PCM Signal Config (Role and Polar)

*Found in: Component config > Bluetooth > Controller Options*

**Default value:**
• Yes (enabled) if \(\text{CONFIG_BTDM_CTRL_BR_EDR_SCO_DATA_PATH_PCM} \&\& \text{CONFIG_BT_CONTROLLER_ENABLED}\)

**Contains:**
• \text{CONFIG_BTDM_CTRL_PCM_POLAR}
• \text{CONFIG_BTDM_CTRL_PCM_ROLE}

**CONFIG_BTDM_CTRL_PCM_ROLE**

PCM Role

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG*

PCM role can be configured as PCM master or PCM slave

**Available options:**
- PCM Master (CONFIG_BTDM_CTRL_PCM_ROLE_MASTER)
- PCM Slave (CONFIG_BTDM_CTRL_PCM_ROLE_SLAVE)

**CONFIG_BTDM_CTRL_PCM_POLAR**

PCM Polar

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_CTRL_PCM_ROLE_EDGE_CONFIG*

PCM polarity can be configured as Falling Edge or Rising Edge

Available options:

- Falling Edge (CONFIG_BTDM_CTRL_PCM_POLAR_FALLING_EDGE)
- Rising Edge (CONFIG_BTDM_CTRL_PCM_POLAR_RISING_EDGE)

**CONFIG_BTDM_CTRL_AUTO_LATENCY**

Auto latency

*Found in: Component config > Bluetooth > Controller Options*

BLE auto latency, used to enhance classic BT performance while classic BT and BLE are enabled at the same time.

**Default value:**

- No (disabled) if CONFIG_BTDM_CTRL_MODE_BTDM && CONFIG_BT_CONTROLLER_ENABLED

**CONFIG_BTDM_CTRL_LEGACY_AUTH_VENDOR_EVT**

Legacy Authentication Vendor Specific Event Enable

*Found in: Component config > Bluetooth > Controller Options*

To protect from BIAS attack during Legacy authentication, Legacy authentication Vendor specific event should be enabled

**Default value:**

- Yes (enabled) if (CONFIG_BTDM_CTRL_MODE_BR_EDR_ONLY || CONFIG_BTDM_CTRL_MODE_BTDM) && CONFIG_BT_CONTROLLER_ENABLED

**CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE**

The cpu core which bluetooth controller run

*Found in: Component config > Bluetooth > Controller Options*

Specify the cpu core to run bluetooth controller. Can not specify no-affinity.

Available options:

- Core 0 (PRO CPU) (CONFIG_BTDM_CTRL_PINNED_TO_CORE_0)
- Core 1 (APP CPU) (CONFIG_BTDM_CTRL_PINNED_TO_CORE_1)
CONFIG_BTDM_CTRL_HCI_MODE_CHOICE

HCI mode

Found in: Component config > Bluetooth > Controller Options

Specify HCI mode as VHCI or UART(H4)

Available options:

- VHCI (CONFIG_BTDM_CTRL_HCI_MODE_VHCI)
  Normal option. Mostly, choose this VHCI when bluetooth host run on ESP32, too.
- UART(H4) (CONFIG_BTDM_CTRL_HCI_MODE_UART_H4)
  If use external bluetooth host which run on other hardware and use UART as the HCI interface, choose this option.

HCI UART(H4) Options  Contains:

- CONFIG_BTDM_CTRL_HCI_UART_BAUDRATE
- CONFIG_BTDM_CTRL_HCI_UART_NO

CONFIG_BTDM_CTRL_HCI_UART_NO

UART Number for HCI

Found in: Component config > Bluetooth > Controller Options > HCI UART(H4) Options

Uart number for HCI. The available uart is UART1 and UART2.

Range:
- from 1 to 2 if CONFIG_BTDM_CTRL_HCI_MODE_UART_H4 && CONFIG_BT_CONTROLLER_ENABLED

Default value:
- 1 if CONFIG_BTDM_CTRL_HCI_MODE_UART_H4 && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BTDM_CTRL_HCI_UART_BAUDRATE

UART Baudrate for HCI

Found in: Component config > Bluetooth > Controller Options > HCI UART(H4) Options

UART Baudrate for HCI. Please use standard baudrate.

Range:
- from 115200 to 921600 if CONFIG_BTDM_CTRL_HCI_MODE_UART_H4 && CONFIG_BT_CONTROLLER_ENABLED

Default value:
- 921600 if CONFIG_BTDM_CTRL_HCI_MODE_UART_H4 && CONFIG_BT_CONTROLLER_ENABLED

MODEM SLEEP Options  Contains:

- CONFIG_BTDM_CTRL_LOW_POWER_CLOCK
- CONFIG_BTDM_CTRL_MODEM_SLEEP
CONFIG_BTDM_CTRL_MODEM_SLEEP

Bluetooth modem sleep

*Found in: Component config > Bluetooth > Controller Options > MODEM SLEEP Options*

Enable/disable bluetooth controller low power mode.

**Default value:**
- Yes (enabled) if `CONFIG_BT_CONTROLLER_ENABLED`

CONFIG_BTDM_CTRL_MODEM_SLEEP_MODE

Bluetooth Modem sleep mode

*Found in: Component config > Bluetooth > Controller Options > MODEM SLEEP Options > CONFIG_BTDM_CTRL_MODEM_SLEEP*

To select which strategy to use for modem sleep

Available options:

- **ORIG Mode** (sleep with low power clock) (`CONFIG_BTDM_CTRL_MODEM_SLEEP_MODE_ORIG`)
  ORIG mode is a bluetooth sleep mode that can be used for dual mode controller. In this mode, bluetooth controller sleeps between BR/EDR frames and BLE events. A low power clock is used to maintain bluetooth reference clock.
- **EVED Mode** (For internal test only) (`CONFIG_BTDM_CTRL_MODEM_SLEEP_MODE_EVED`)
  EVED mode is for BLE only and is only for internal test. Do not use it for production. This mode is not compatible with DFS nor light sleep

CONFIG_BTDM_CTRL_LOW_POWER_CLOCK

Bluetooth low power clock

*Found in: Component config > Bluetooth > Controller Options > MODEM SLEEP Options*

Select the low power clock source for bluetooth controller. Bluetooth low power clock is the clock source to maintain time in sleep mode.

- “Main crystal” option provides good accuracy and can support Dynamic Frequency Scaling to be used with Bluetooth modem sleep. Light sleep is not supported.
- “External 32kHz crystal” option allows user to use a 32.768kHz crystal as Bluetooth low power clock. This option is allowed as long as External 32kHz crystal is configured as the system RTC clock source. This option provides good accuracy and supports Bluetooth modem sleep to be used alongside Dynamic Frequency Scaling or light sleep.

Available options:

- **Main crystal** (`CONFIG_BTDM_CTRL_LPCLK_SEL_MAIN_XTAL`)
  Main crystal can be used as low power clock for bluetooth modem sleep. If this option is selected, bluetooth modem sleep can work under Dynamic Frequency Scaling (DFS) enabled, but cannot work when light sleep is enabled. Main crystal has a good performance in accuracy as the bluetooth low power clock source.
- **External 32kHz crystal** (`CONFIG_BTDM_CTRL_LPCLK_SEL_EXT_32K_XTAL`)
  External 32kHz crystal has a nominal frequency of 32.768kHz and provides good frequency stability. If used as Bluetooth low power clock, External 32kHz can support Bluetooth modem sleep to be used with both DFS and light sleep.
**CONFIG_BTDM_BLE_SLEEP_CLOCK_ACCURACY**

BLE Sleep Clock Accuracy

*Found in: Component config > Bluetooth > Controller Options*

BLE Sleep Clock Accuracy (SCA) for the local device is used to estimate window widening in BLE connection events. With a lower level of clock accuracy (e.g., 500 ppm over 250 ppm), the slave needs a larger RX window to synchronize with master in each anchor point, thus resulting in an increase of power consumption but a higher level of robustness in keeping connected. According to the requirements of Bluetooth Core specification 4.2, the worst-case accuracy of Classic Bluetooth low power oscillator (LPO) is +/-250 ppm in STANDBY and in low power modes such as sniff. For BLE the worst-case SCA is +/-500 ppm.

- “151 ppm to 250 ppm” option is the default value for Bluetooth Dual mode
- “251 ppm to 500 ppm” option can be used in BLE only mode when using external 32kHz crystal as low power clock. This option is provided in case that BLE sleep clock has a lower level of accuracy, or other error sources contribute to the inaccurate timing during sleep.

Available options:

- 251 ppm to 500 ppm (CONFIG_BTDM_BLE_DEFAULT_SCA_500PPM)
- 151 ppm to 250 ppm (CONFIG_BTDM_BLE_DEFAULT_SCA_250PPM)

**CONFIG_BTDM_BLE_SCAN_DUPL**

BLE Scan Duplicate Options

*Found in: Component config > Bluetooth > Controller Options*

This select enables parameters setting of BLE scan duplicate.

**Default value:**

- Yes (enabled) if (CONFIG_BTDM_CTRL_MODE_BTDM || CONFIG_BTDM_CTRL_MODE_BLE_ONLY) && CONFIG_BT_CONTROLLER_ENABLED

**CONFIG_BTDM_SCAN_DUPL_TYPE**

Scan Duplicate Type

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_SCAN_DUPL*

Scan duplicate have three ways. One is “Scan Duplicate By Device Address”. This way is to use advertiser address filtering. The adv packet of the same address is only allowed to be reported once. Another way is “Scan Duplicate By Device Address And Advertising Data”. This way is to use advertising data and device address filtering. All different adv packets with the same address are allowed to be reported. The last way is “Scan Duplicate By Advertising Data”. This way is to use advertising data filtering. All same advertising data only allow to be reported once even though they are from different devices.

Available options:

- Scan Duplicate By Device Address (CONFIG_BTDM_SCAN_DUPL_TYPE_DEVICE)
  This way is to use advertiser address filtering. The adv packet of the same address is only allowed to be reported once
- Scan Duplicate By Advertising Data (CONFIG_BTDM_SCAN_DUPL_TYPE_DATA)
  This way is to use advertising data filtering. All same advertising data only allow to be reported once even though they are from different devices.
- Scan Duplicate By Device Address And Advertising Data (CONFIG_BTDM_SCAN_DUPL_TYPE_DATA_DEVICE)
  This way is to use advertising data and device address filtering. All different adv packets with the same address are allowed to be reported.
CONFIG_BTDM_SCAN_DUPL_CACHE_SIZE

Maximum number of devices in scan duplicate filter

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_SCAN_DUPL*

Maximum number of devices which can be recorded in scan duplicate filter. When the maximum amount of device in the filter is reached, the cache will be refreshed.

*Range:*
- from 10 to 1000 if `CONFIG_BTDM_BLE_SCAN_DUPL` && `CONFIG_BT_CONTROLLER_ENABLED`

*Default value:*
- 100 if `CONFIG_BTDM_BLE_SCAN_DUPL` && `CONFIG_BT_CONTROLLER_ENABLED`

CONFIG_BTDM_SCAN_DUPL_CACHE_REFRESH_PERIOD

Duplicate scan list refresh period (seconds)

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_SCAN_DUPL*

If the period value is non-zero, the controller will periodically clear the device information stored in the scan duplicate filter. If it is 0, the scan duplicate filter will not be cleared until the scanning is disabled. Duplicate advertisements for this period should not be sent to the Host in advertising report events. There are two scenarios where the ADV packet will be repeatedly reported: 1. The duplicate scan cache is full, the controller will delete the oldest device information and add new device information. 2. When the refresh period is up, the controller will clear all device information and start filtering again.

*Range:*
- from 0 to 1000 if `CONFIG_BTDM_BLE_SCAN_DUPL` && `CONFIG_BT_CONTROLLER_ENABLED`

*Default value:*
- 0 if `CONFIG_BTDM_BLE_SCAN_DUPL` && `CONFIG_BT_CONTROLLER_ENABLED`

CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN

Special duplicate scan mechanism for BLE Mesh scan

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_SCAN_DUPL*

This enables the BLE scan duplicate for special BLE Mesh scan.

*Default value:*
- No (disabled) if `CONFIG_BTDM_BLE_SCAN_DUPL` && `CONFIG_BT_CONTROLLER_ENABLED`

CONFIG_BTDM_MESH_DUPL_SCAN_CACHE_SIZE

Maximum number of Mesh adv packets in scan duplicate filter

*Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_SCAN_DUPL > CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN*

Maximum number of adv packets which can be recorded in duplicate scan cache for BLE Mesh. When the maximum amount of device in the filter is reached, the cache will be refreshed.

*Range:*
- from 10 to 1000 if `CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN` && `CONFIG_BT_CONTROLLER_ENABLED`

*Default value:*
- 100 if `CONFIG_BTDM_BLE_MESH_SCAN_DUPL_EN` && `CONFIG_BT_CONTROLLER_ENABLED`
CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED

BLE full scan feature supported

Found in: Component config > Bluetooth > Controller Options

The full scan function is mainly used to provide BLE scan performance. This is required for scenes with high scan performance requirements, such as BLE Mesh scenes.

Default value:
- Yes (enabled) if (CONFIG_BTDM_CTRL_MODE_BLE_ONLY || CONFIG_BTDM_CTRL_MODE_BTDM) && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP

BLE adv report flow control supported

Found in: Component config > Bluetooth > Controller Options

The function is mainly used to enable flow control for advertising reports. When it is enabled, advertising reports will be discarded by the controller if the number of unprocessed advertising reports exceeds the size of BLE adv report flow control.

Default value:
- Yes (enabled) if (CONFIG_BTDM_CTRL_MODE_BTDM || CONFIG_BTDM_CTRL_MODE_BLE_ONLY) && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM

BLE adv report flow control number

Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP

The number of unprocessed advertising report that Bluedroid can save. If you set BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM to a small value, this may cause adv packets lost. If you set BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM to a large value, Bluedroid may cache a lot of adv packets and this may cause system memory run out. For example, if you set it to 50, the maximum memory consumed by host is 35 * 50 bytes. Please set BTDM_BLE_ADV_REPORT_FLOW_CTRL_NUM according to your system free memory and handle adv packets as fast as possible, otherwise it will cause adv packets lost.

Range:
- from 50 to 1000 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_CONTROLLER_ENABLED

Default value:
- 100 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BTDM_BLE_ADV_REPORT_DISCARD_THRESHOLD

BLE adv lost event threshold value

Found in: Component config > Bluetooth > Controller Options > CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP

When adv report flow control is enabled, The ADV lost event will be generated when the number of ADV packets lost in the controller reaches this threshold. It is better to set a larger value. If you set BTDM_BLE_ADV_REPORT_DISCARD_THRESHOLD to a small value or printf every adv lost event, it may cause adv packets lost more.

Range:
- from 1 to 1000 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_CONTROLLER_ENABLED
Default value:
- 20 if CONFIG_BTDM_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BTDM_CTRL_HLI

High level interrupt

Found in: Component config > Bluetooth > Controller Options

Using Level 4 interrupt for Bluetooth.

Default value:
- Yes (enabled) if CONFIG_BT_ENABLED && CONFIG_BT_CONTROLLER_ENABLED

CONFIG_BT_RELEASE_IRAM

Release Bluetooth text (READ DOCS FIRST)

Found in: Component config > Bluetooth

This option release Bluetooth text section and merge Bluetooth data, bss & text into a large free heap region when esp_bt_mem_release is called, total saving ~21kB or more of IRAM. ESP32-C2 only 3 configurable PMP entries available, rest of them are hard-coded. We cannot split the memory into 3 different regions (IRAM, BLE-IRAM, DRAM). So this option will disable the PMP (ESP_SYSTEM_PMP_IDRAM_SPLIT)

Default value:
- No (disabled) if CONFIG_BT_ENABLED && BT_LE_RELEASE_IRAM_SUPPORTED

CONFIG_BLE_MESH

ESP BLE Mesh Support

Found in: Component config

This option enables ESP BLE Mesh support. The specific features that are available may depend on other features that have been enabled in the stack, such as Bluetooth Support, Bluedroid Support & GATT support.

Contains:
- BLE Mesh and BLE coexistence support
- CONFIG_BLE_MESH_GATT_PROXY_CLIENT
- CONFIG_BLE_MESH_GATT_PROXY_SERVER
- BLE Mesh NET BUF DEBUG LOG LEVEL
- CONFIG_BLE_MESH_PROV
- CONFIG_BLE_MESH_PROXY
- BLE Mesh specific test option
- BLE Mesh STACK DEBUG LOG LEVEL
- CONFIG_BLE_MESH_NO_LOG
- CONFIG_BLE_MESH_IVU_DIVIDER
- CONFIG_BLE_MESH_FAST_PROV
- CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC
- CONFIG_BLE_MESH_CRPL
- CONFIG_BLE_MESH_RX_SDU_MAX
- CONFIG_BLE_MESH_MODEL_KEY_COUNT
- CONFIG_BLE_MESH_APP_KEY_COUNT
- CONFIG_BLE_MESH_MODEL_GROUP_COUNT
- CONFIG_BLE_MESH_LABEL_COUNT
- CONFIG_BLE_MESH_TX_SEG_MAX
- `CONFIG_BLE_MESH_RX_SEG_MSG_COUNT`
- `CONFIG_BLE_MESH_TX_SEG_MSG_COUNT`
- `CONFIG_BLE_MESH_MEM_ALLOC_MODE`
- `CONFIG_BLE_MESH_MSG_CACHE_SIZE`
- `CONFIG_BLE_MESH_ADV_BUF_COUNT`
- `CONFIG_BLE_MESH_PB_GATT`
- `CONFIG_BLE_MESH_PB_ADV`
- `CONFIG_BLE_MESH_IVU_RECOVERY_IVI`
- `CONFIG_BLE_MESH_RELAY`
- `CONFIG_BLE_MESH_SETTINGS`
- `CONFIG_BLE_MESH_DEINIT`
- `CONFIG_BLE_MESH_USE_DUPLICATE_SCAN`
- Support for BLE Mesh Client/Server models
- Support for BLE Mesh Foundation models
- `CONFIG_BLE_MESH_NODE`
- `CONFIG_BLE_MESH_PROVISIONER`
- `CONFIG_BLE_MESH_FRIEND`
- `CONFIG_BLE_MESH_LOW_POWER`
- `CONFIG_BLE_MESH_HCI_5_0`
- `CONFIG_BLE_MESH_IV_UPDATE_TEST`
- `CONFIG_BLE_MESH_CLIENT_MSG_TIMEOUT`

### `CONFIG_BLE_MESH_HCI_5_0`

Support sending 20ms non-connectable adv packets

*Found in: Component config > CONFIG_BLE_MESH*

It is a temporary solution and needs further modifications.

Default value:
- Yes (enabled) if `CONFIG_BLE_MESH`

### `CONFIG_BLE_MESH_USE_DUPLICATESCAN`

Support Duplicate Scan in BLE Mesh

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to allow using specific duplicate scan filter in BLE Mesh, and Scan Duplicate Type must be set by choosing the option in the Bluetooth Controller section in menuconfig, which is “Scan Duplicate By Device Address and Advertising Data”.

Default value:
- Yes (enabled) if `CONFIG_BLE_MESH`

### `CONFIG_BLE_MESH_MEM_ALLOC_MODE`

Memory allocation strategy

*Found in: Component config > CONFIG_BLE_MESH*

Allocation strategy for BLE Mesh stack, essentially provides ability to allocate all required dynamic allocations from,
- Internal DRAM memory only
- External SPIRAM memory only
- Either internal or external memory based on default malloc() behavior in ESP-IDF
- Internal IRAM memory wherever applicable else internal DRAM

Recommended mode here is always internal (*), since that is most preferred from security perspective. But if application requirement does not allow sufficient free internal memory then alternate mode can be selected.
(*) In case of ESP32-S2/ESP32-S3, hardware allows encryption of external SPIRAM contents provided hardware flash encryption feature is enabled. In that case, using external SPIRAM allocation strategy is also safe choice from security perspective.

Available options:

- Internal DRAM (CONFIG_BLE_MESH_MEM_ALLOC_MODE_INTERNAL)
- External SPIRAM (CONFIG_BLE_MESH_MEM_ALLOC_MODE_EXTERNAL)
- Default alloc mode (CONFIG_BLE_MESH_MEM_ALLOC_MODE_DEFAULT) Enable this option to use the default memory allocation strategy when external SPIRAM is enabled. See the SPIRAM options for more details.
- Internal IRAM (CONFIG_BLE_MESH_MEM_ALLOC_MODE_IRAM_8BIT) Allows to use IRAM memory region as 8bit accessible region. Every unaligned (8bit or 16bit) access will result in an exception and incur penalty of certain clock cycles per unaligned read/write.

CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC
Enable FreeRTOS static allocation

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to use FreeRTOS static allocation APIs for BLE Mesh, which provides the ability to use different dynamic memory (i.e. SPIRAM or IRAM) for FreeRTOS objects. If this option is disabled, the FreeRTOS static allocation APIs will not be used, and internal DRAM will be allocated for FreeRTOS objects.

*Default value:*

- No (disabled) if (CONFIG_SPIRAM || CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY) && CONFIG_BLE_MESH

CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC_MODE
Memory allocation for FreeRTOS objects

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC*

Choose the memory to be used for FreeRTOS objects.

Available options:

- External SPIRAM (CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC_EXTERNAL) If enabled, BLE Mesh allocates dynamic memory from external SPIRAM for FreeRTOS objects, i.e. mutex, queue, and task stack. External SPIRAM can only be used for task stack when SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY is enabled. See the SPIRAM options for more details.
- Internal IRAM (CONFIG_BLE_MESH_FREERTOS_STATIC_ALLOC_IRAM_8BIT) If enabled, BLE Mesh allocates dynamic memory from internal IRAM for FreeRTOS objects, i.e. mutex, queue. Note: IRAM region cannot be used as task stack.

CONFIG_BLE_MESH_DEINIT
Support de-initialize BLE Mesh stack

*Found in: Component config > CONFIG_BLE_MESH*

If enabled, users can use the function esp_ble_mesh_deinit() to de-initialize the whole BLE Mesh stack.

*Default value:*
Chapter 2. API Reference

• Yes (enabled) if CONFIG_BLE_MESH

BLE Mesh and BLE coexistence support Contains:

• CONFIG_BLE_MESH_SUPPORT_BLE_SCAN
• CONFIG_BLE_MESH_SUPPORT_BLE_ADV

CONFIG_BLE_MESH_SUPPORT_BLE_ADV
Support sending normal BLE advertising packets

Found in: Component config > CONFIG_BLE_MESH > BLE Mesh and BLE coexistence support

When selected, users can send normal BLE advertising packets with specific API.

Default value:
• No (disabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_BLE_ADV_BUF_COUNT
Number of advertising buffers for BLE advertising packets

Found in: Component config > CONFIG_BLE_MESH > BLE Mesh and BLE coexistence support > CONFIG_BLE_MESH_SUPPORT_BLE_ADV

Number of advertising buffers for BLE packets available.

Range:
• from 1 to 255 if CONFIG_BLE_MESH_SUPPORT_BLE_ADV && CONFIG_BLE_MESH

Default value:
• 3 if CONFIG_BLE_MESH_SUPPORT_BLE_ADV && CONFIG_BLE_MESH

CONFIG_BLE_MESH_SUPPORT_BLE_SCAN
Support scanning normal BLE advertising packets

Found in: Component config > CONFIG_BLE_MESH > BLE Mesh and BLE coexistence support

When selected, users can register a callback and receive normal BLE advertising packets in the application layer.

Default value:
• No (disabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_FAST_PROV
Enable BLE Mesh Fast Provisioning

Found in: Component config > CONFIG_BLE_MESH

Enable this option to allow BLE Mesh fast provisioning solution to be used. When there are multiple unprovisioned devices around, fast provisioning can greatly reduce the time consumption of the whole provisioning process. When this option is enabled, and after an unprovisioned device is provisioned into a node successfully, it can be changed to a temporary Provisioner.

Default value:
• No (disabled) if CONFIG_BLE_MESH
CONFIG_BLE_MESH_NODE

Support for BLE Mesh Node

*Found in: Component config > CONFIG_BLE_MESH*

Enable the device to be provisioned into a node. This option should be enabled when an unprovisioned device is going to be provisioned into a node and communicate with other nodes in the BLE Mesh network.

CONFIG_BLE_MESH_PROVISIONER

Support for BLE Mesh Provisioner

*Found in: Component config > CONFIG_BLE_MESH*

Enable the device to be a Provisioner. The option should be enabled when a device is going to act as a Provisioner and provision unprovisioned devices into the BLE Mesh network.

CONFIG_BLE_MESH_WAIT_FOR_PROV_MAX_DEV_NUM

Maximum number of unprovisioned devices that can be added to device queue

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER*

This option specifies how many unprovisioned devices can be added to device queue for provisioning. Users can use this option to define the size of the queue in the bottom layer which is used to store unprovisioned device information (e.g. Device UUID, address).

**Range:**
- from 1 to 100 if `CONFIG_BLE_MESH_PROVISIONER` && `CONFIG_BLE_MESH`

**Default value:**
- 10 if `CONFIG_BLE_MESH_PROVISIONER` && `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_MAX_PROV_NODES

Maximum number of devices that can be provisioned by Provisioner

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER*

This option specifies how many devices can be provisioned by a Provisioner. This value indicates the maximum number of unprovisioned devices which can be provisioned by a Provisioner. For instance, if the value is 6, it means the Provisioner can provision up to 6 unprovisioned devices. Theoretically a Provisioner without the limitation of its memory can provision up to 32766 unprovisioned devices, here we limit the maximum number to 100 just to limit the memory used by a Provisioner. The bigger the value is, the more memory it will cost by a Provisioner to store the information of nodes.

**Range:**
- from 1 to 1000 if `CONFIG_BLE_MESH_PROVISIONER` && `CONFIG_BLE_MESH`

**Default value:**
- 10 if `CONFIG_BLE_MESH_PROVISIONER` && `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_PBA_SAME_TIME

Maximum number of PB-ADV running at the same time by Provisioner

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER*

This option specifies how many devices can be provisioned at the same time using PB-ADV. For examples, if the value is 2, it means a Provisioner can provision two unprovisioned devices with PB-ADV at the same time.

**Range:**
• from 1 to 10 if CONFIG_BLE_MESH_PB_ADV && CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

Default value:
• 2 if CONFIG_BLE_MESH_PB_ADV && CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_PBG_SAME_TIME

Maximum number of PB-GATT running at the same time by Provisioner

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER

This option specifies how many devices can be provisioned at the same time using PB-GATT. For example, if the value is 2, it means a Provisioner can provision two unprovisioned devices with PB-GATT at the same time.

Range:
• from 1 to 5 if CONFIG_BLE_MESH_PB_GATT && CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

Default value:
• 1 if CONFIG_BLE_MESH_PB_GATT && CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_PROVISIONER_SUBNET_COUNT

Maximum number of mesh subnets that can be created by Provisioner

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER

This option specifies how many subnets per network a Provisioner can create. Indeed, this value decides the number of network keys which can be added by a Provisioner.

Range:
• from 1 to 4096 if CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

Default value:
• 3 if CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_PROVISIONER_APP_KEY_COUNT

Maximum number of application keys that can be owned by Provisioner

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER

This option specifies how many application keys the Provisioner can have. Indeed, this value decides the number of the application keys which can be added by a Provisioner.

Range:
• from 1 to 4096 if CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

Default value:
• 3 if CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_PROVISIONER_RECV_HB

Support receiving Heartbeat messages

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER

When this option is enabled, Provisioner can call specific functions to enable or disable receiving Heartbeat messages and notify them to the application layer.

Default value:
• No (disabled) if CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH
CONFIG_BLE_MESH_PROVISIONER_RECV_HB_FILTER_SIZE

Maximum number of filter entries for receiving Heartbeat messages

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PROVISIONER > CONFIG_BLE_MESH_PROVISIONER_RECV_HB*

This option specifies how many heartbeat filter entries Provisioner supports. The heartbeat filter (acceptlist or rejectlist) entries are used to store a list of SRC and DST which can be used to decide if a heartbeat message will be processed and notified to the application layer by Provisioner. Note: The filter is an empty rejectlist by default.

**Range:**
- from 1 to 1000 if CONFIG_BLE_MESH_PROVISIONER_RECV_HB && CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

**Default value:**
- 3 if CONFIG_BLE_MESH_PROVISIONER_RECV_HB && CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_PROV

BLE Mesh Provisioning support

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to support BLE Mesh Provisioning functionality. For BLE Mesh, this option should be always enabled.

**Default value:**
- Yes (enabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_PB_ADV

Provisioning support using the advertising bearer (PB-ADV)

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to allow the device to be provisioned over the advertising bearer. This option should be enabled if PB-ADV is going to be used during provisioning procedure.

**Default value:**
- Yes (enabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_UNPROVISIONED_BEACON_INTERVAL

Interval between two consecutive Unprovisioned Device Beacon

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_PB_ADV*

This option specifies the interval of sending two consecutive unprovisioned device beacon, users can use this option to change the frequency of sending unprovisioned device beacon. For example, if the value is 5, it means the unprovisioned device beacon will send every 5 seconds. When the option of BLE_MESH_FAST_PROV is selected, the value is better to be 3 seconds, or less.

**Range:**
- from 1 to 100 if CONFIG_BLE_MESH_NODE && CONFIG_BLE_MESH_PB_ADV && CONFIG_BLE_MESH

**Default value:**
- 5 if CONFIG_BLE_MESH_NODE && CONFIG_BLE_MESH_PB_ADV && CONFIG_BLE_MESH
- 3 if CONFIG_BLE_MESH_FAST_PROV && CONFIG_BLE_MESH_NODE && CONFIG_BLE_MESH_PB_ADV && CONFIG_BLE_MESH
**CONFIG_BLE_MESH_PB_GATT**

Provisioning support using GATT (PB-GATT)

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to allow the device to be provisioned over GATT. This option should be enabled if PB-GATT is going to be used during provisioning procedure.

# Virtual option enabled whenever any Proxy protocol is needed

**CONFIG_BLE_MESH_PROXY**

BLE Mesh Proxy protocol support

*Found in: Component config > CONFIG_BLE_MESH*

Enable this option to support BLE Mesh Proxy protocol used by PB-GATT and other proxy pdu transmission.

*Default value:*
  - Yes (enabled) if CONFIG_BLE_MESH

**CONFIG_BLE_MESH_GATT_PROXY_SERVER**

BLE Mesh GATT Proxy Server

*Found in: Component config > CONFIG_BLE_MESH*

This option enables support for Mesh GATT Proxy Service, i.e. the ability to act as a proxy between a Mesh GATT Client and a Mesh network. This option should be enabled if a node is going to be a Proxy Server.

*Default value:*
  - Yes (enabled) if CONFIG_BLE_MESH_NODE && CONFIG_BLE_MESH

**CONFIG_BLE_MESH_NODE_ID_TIMEOUT**

Node Identity advertising timeout

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_GATT_PROXY_SERVER*

This option determines for how long the local node advertises using Node Identity. The given value is in seconds. The specification limits this to 60 seconds and lists it as the recommended value as well. So leaving the default value is the safest option. When an unprovisioned device is provisioned successfully and becomes a node, it will start to advertise using Node Identity during the time set by this option. And after that, Network ID will be advertised.

*Range:*
  - from 1 to 60 if CONFIG_BLE_MESH_GATT_PROXY_SERVER && CONFIG_BLE_MESH

*Default value:*
  - 60 if CONFIG_BLE_MESH_GATT_PROXY_SERVER && CONFIG_BLE_MESH

**CONFIG_BLE_MESH_PROXY_FILTER_SIZE**

Maximum number of filter entries per Proxy Client

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_GATT_PROXY_SERVER*

This option specifies how many Proxy Filter entries the local node supports. The entries of Proxy filter (whitelist or blacklist) are used to store a list of addresses which can be used to decide which messages will be forwarded to the Proxy Client by the Proxy Server.

*Range:*

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Release v5.1.2
• from 1 to 32767 if \texttt{CONFIG_BLE_MESH_GATT_PROXY_SERVER} \&\& \texttt{CONFIG_BLE_MESH}

Default value:
• 4 if \texttt{CONFIG_BLE_MESH_GATT_PROXY_SERVER} \&\& \texttt{CONFIG_BLE_MESH}

\textbf{CONFIG\_BLE\_MESH\_GATT\_PROXY\_CLIENT}

BLE Mesh GATT Proxy Client

\textit{Found in: Component config > CONFIG\_BLE\_MESH}

This option enables support for Mesh GATT Proxy Client. The Proxy Client can use the GATT bearer to send mesh messages to a node that supports the advertising bearer.

Default value:
• No (disabled) if \texttt{CONFIG\_BLE\_MESH}

\textbf{CONFIG\_BLE\_MESH\_SETTINGS}

Store BLE Mesh configuration persistently

\textit{Found in: Component config > CONFIG\_BLE\_MESH}

When selected, the BLE Mesh stack will take care of storing/restoring the BLE Mesh configuration persistently in flash. If the device is a BLE Mesh node, when this option is enabled, the configuration of the device will be stored persistently, including unicast address, NetKey, AppKey, etc. And if the device is a BLE Mesh Provisioner, the information of the device will be stored persistently, including the information of provisioned nodes, NetKey, AppKey, etc.

Default value:
• No (disabled) if \texttt{CONFIG\_BLE\_MESH}

\textbf{CONFIG\_BLE\_MESH\_STORE\_TIMEOUT}

Delay (in seconds) before storing anything persistently

\textit{Found in: Component config > CONFIG\_BLE\_MESH > CONFIG\_BLE\_MESH\_SETTINGS}

This value defines in seconds how soon any pending changes are actually written into persistent storage (flash) after a change occurs. The option allows nodes to delay a certain period of time to save proper information to flash. The default value is 0, which means information will be stored immediately once there are updates.

Range:
• from 0 to 1000000 if \texttt{CONFIG\_BLE\_MESH\_SETTINGS} \&\& \texttt{CONFIG\_BLE\_MESH}

Default value:
• 0 if \texttt{CONFIG\_BLE\_MESH\_SETTINGS} \&\& \texttt{CONFIG\_BLE\_MESH}

\textbf{CONFIG\_BLE\_MESH\_SEQ\_STORE\_RATE}

How often the sequence number gets updated in storage

\textit{Found in: Component config > CONFIG\_BLE\_MESH > CONFIG\_BLE\_MESH\_SETTINGS}

This value defines how often the local sequence number gets updated in persistent storage (i.e. flash), e.g. a value of 100 means that the sequence number will be stored to flash on every 100th increment. If the node sends messages very frequently a higher value makes more sense, whereas if the node sends infrequently a value as low as 0 (update storage for every increment) can make sense. When the stack gets initialized it will add sequence number to the last stored one, so that it starts off with a value that’s guaranteed to be larger than the last one used before power off.

Range:
• from 0 to 1000000 if \texttt{CONFIG\_BLE\_MESH\_SETTINGS} \&\& \texttt{CONFIG\_BLE\_MESH}
Default value:
• 0 if CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

CONFIG_BLE_MESH_RPL_STORE_TIMEOUT
Minimum frequency that the RPL gets updated in storage

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SETTINGS

This value defines in seconds how soon the RPL (Replay Protection List) gets written to persistent storage after a change occurs. If the node receives messages frequently, then a large value is recommended. If the node receives messages rarely, then the value can be as low as 0 (which means the RPL is written into the storage immediately). Note that if the node operates in a security-sensitive case, and there is a risk of sudden power-off, then a value of 0 is strongly recommended. Otherwise, a power loss before RPL being written into the storage may introduce message replay attacks and system security will be in a vulnerable state.

Range:
• from 0 to 1000000 if CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

Default value:
• 0 if CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

CONFIG_BLE_MESH_SETTINGS_BACKWARD_COMPATIBILITY
A specific option for settings backward compatibility

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SETTINGS

This option is created to solve the issue of failure in recovering node information after mesh stack updates. In the old version mesh stack, there is no key of “mesh/role” in nvs. In the new version mesh stack, key of “mesh/role” is added in nvs, recovering node information needs to check “mesh/role” key in nvs and implements selective recovery of mesh node information. Therefore, there may be failure in recovering node information during node restarting after OTA.

The new version mesh stack adds the option of “mesh/role” because we have added the support of storing Provisioner information, while the old version only supports storing node information.

If users are updating their nodes from old version to new version, we recommend enabling this option, so that system could set the flag in advance before recovering node information and make sure the node information recovering could work as expected.

Default value:
• No (disabled) if CONFIG_BLE_MESH_NODE && CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

CONFIG_BLE_MESH_SPECIFIC_PARTITION
Use a specific NVS partition for BLE Mesh

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SETTINGS

When selected, the mesh stack will use a specified NVS partition instead of default NVS partition. Note that the specified partition must be registered with NVS using nvs_flash_init_partition() API, and the partition must exists in the csv file. When Provisioner needs to store a large amount of nodes’ information in the flash (e.g. more than 20), this option is recommended to be enabled.

Default value:
• No (disabled) if CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH
**CONFIG_BLE_MESH_PARTITION_NAME**

Name of the NVS partition for BLE Mesh

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SETTINGS > CONFIG_BLE_MESH_SPECIFIC_PARTITION*

This value defines the name of the specified NVS partition used by the mesh stack.

*Default value:*

- “ble_mesh” if CONFIG_BLE_MESH_SPECIFIC_PARTITION && CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

**CONFIG_BLE_MESH_USE_MULTIPLE_NAMESPACE**

Support using multiple NVS namespaces by Provisioner

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SETTINGS*

When selected, Provisioner can use different NVS namespaces to store different instances of mesh information. For example, if in the first room, Provisioner uses NetKey A, AppKey A and provisions three devices, these information will be treated as mesh information instance A. When the Provisioner moves to the second room, it uses NetKey B, AppKey B and provisions two devices, then the information will be treated as mesh information instance B. Here instance A and instance B will be stored in different namespaces. With this option enabled, Provisioner needs to use specific functions to open the corresponding NVS namespace, restore the mesh information, release the mesh information or erase the mesh information.

*Default value:*

- No (disabled) if CONFIG_BLE_MESH_PROVISIONER && CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

**CONFIG_BLE_MESH_MAX_NVS_NAMESPACE**

Maximum number of NVS namespaces

*Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_SETTINGS > CONFIG_BLE_MESH_USE_MULTIPLE_NAMESPACE*

This option specifies the maximum NVS namespaces supported by Provisioner.

*Range:*

- from 1 to 255 if CONFIG_BLE_MESH_USE_MULTIPLE_NAMESPACE && CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

*Default value:*

- 2 if CONFIG_BLE_MESH_USE_MULTIPLE_NAMESPACE && CONFIG_BLE_MESH_SETTINGS && CONFIG_BLE_MESH

**CONFIG_BLE_MESH_SUBNET_COUNT**

Maximum number of mesh subnets per network

*Found in: Component config > CONFIG_BLE_MESH*

This option specifies how many subnets a Mesh network can have at the same time. Indeed, this value decides the number of the network keys which can be owned by a node.

*Range:*

- from 1 to 4096 if CONFIG_BLE_MESH

*Default value:*

- 3 if CONFIG_BLE_MESH
CONFIG_BLE_MESH_APP_KEY_COUNT

Maximum number of application keys per network

*Found in: Component config > CONFIG_BLE_MESH*

This option specifies how many application keys the device can store per network. Indeed, this value decides the number of the application keys which can be owned by a node.

**Range:**
- from 1 to 4096 if `CONFIG_BLE_MESH`

**Default value:**
- 3 if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_MODEL_KEY_COUNT

Maximum number of application keys per model

*Found in: Component config > CONFIG_BLE_MESH*

This option specifies the maximum number of application keys to which each model can be bound.

**Range:**
- from 1 to 4096 if `CONFIG_BLE_MESH`

**Default value:**
- 3 if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_MODEL_GROUP_COUNT

Maximum number of group address subscriptions per model

*Found in: Component config > CONFIG_BLE_MESH*

This option specifies the maximum number of addresses to which each model can be subscribed.

**Range:**
- from 1 to 4096 if `CONFIG_BLE_MESH`

**Default value:**
- 3 if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_LABEL_COUNT

Maximum number of Label UUIDs used for Virtual Addresses

*Found in: Component config > CONFIG_BLE_MESH*

This option specifies how many Label UUIDs can be stored. Indeed, this value decides the number of the Virtual Addresses can be supported by a node.

**Range:**
- from 0 to 4096 if `CONFIG_BLE_MESH`

**Default value:**
- 3 if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_CRPL

Maximum capacity of the replay protection list

*Found in: Component config > CONFIG_BLE_MESH*

This option specifies the maximum capacity of the replay protection list. It is similar to Network message cache size, but has a different purpose. The replay protection list is used to prevent a node from replay attack, which will store the source address and sequence number of the received mesh messages. For Provisioner, the replay protection list size should not be smaller than the maximum number of nodes whose information can be stored. And the element number of each node should also be taken into account.
consideration. For example, if Provisioner can provision up to 20 nodes and each node contains two
elements, then the replay protection list size of Provisioner should be at least 40.

**Range:**
- from 2 to 65535 if `CONFIG_BLE_MESH`

**Default value:**
- 10 if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_MSG_CACHE_SIZE**

Network message cache size

*Found in: Component config > CONFIG_BLE_MESH*

Number of messages that are cached for the network. This helps prevent unnecessary decryption opera-
tions and unnecessary relays. This option is similar to Replay protection list, but has a different purpose.
A node is not required to cache the entire Network PDU and may cache only part of it for tracking, such
as values for SRC/SEQ or others.

**Range:**
- from 2 to 65535 if `CONFIG_BLE_MESH`

**Default value:**
- 10 if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_ADV_BUF_COUNT**

Number of advertising buffers

*Found in: Component config > CONFIG_BLE_MESH*

Number of advertising buffers available. The transport layer reserves ADV_BUF_COUNT - 3 buffers
for outgoing segments. The maximum outgoing SDU size is 12 times this value (out of which 4 or 8
bytes are used for the Transport Layer MIC). For example, 5 segments means the maximum SDU size
is 60 bytes, which leaves 56 bytes for application layer data using a 4-byte MIC, or 52 bytes using an
8-byte MIC.

**Range:**
- from 6 to 256 if `CONFIG_BLE_MESH`

**Default value:**
- 60 if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_IVU_DIVIDER**

Divider for IV Update state refresh timer

*Found in: Component config > CONFIG_BLE_MESH*

When the IV Update state enters Normal operation or IV Update in Progress, we need to keep track of
how many hours has passed in the state, since the specification requires us to remain in the state at least
for 96 hours (Update in Progress has an additional upper limit of 144 hours).

In order to fulfill the above requirement, even if the node might be powered off once in a while, we need
to store persistently how many hours the node has been in the state. This doesn’t necessarily need to
happen every hour (thanks to the flexible duration range). The exact cadence will depend a lot on the
ways that the node will be used and what kind of power source it has.

Since there is no single optimal answer, this configuration option allows specifying a divider, i.e. how
many intervals the 96 hour minimum gets split into. After each interval the duration that the node has
been in the current state gets stored to flash. E.g. the default value of 4 means that the state is saved
every 24 hours (96 / 4).

**Range:**
- from 2 to 96 if `CONFIG_BLE_MESH`
Chapter 2. API Reference

Default value:
- 4 if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_IVU_RECOVERY_IVI**

Recovery the IV index when the latest whole IV update procedure is missed

*Found in: Component config > CONFIG_BLE_MESH*

According to Section 3.10.5 of Mesh Specification v1.0.1. If a node in Normal Operation receives a Secure Network beacon with an IV index equal to the last known IV index+1 and the IV Update Flag set to 0, the node may update its IV without going to the IV Update in Progress state, or it may initiate an IV Index Recovery procedure (Section 3.10.6), or it may ignore the Secure Network beacon. The node makes the choice depending on the time since last IV update and the likelihood that the node has missed the Secure Network beacons with the IV update Flag. When the above situation is encountered, this option can be used to decide whether to perform the IV index recovery procedure.

Default value:
- No (disabled) if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_TX_SEG_MSG_COUNT**

Maximum number of simultaneous outgoing segmented messages

*Found in: Component config > CONFIG_BLE_MESH*

Maximum number of simultaneous outgoing multi-segment and/or reliable messages. The default value is 1, which means the device can only send one segmented message at a time. And if another segmented message is going to be sent, it should wait for the completion of the previous one. If users are going to send multiple segmented messages at the same time, this value should be configured properly.

**Range:**
- from 1 to if `CONFIG_BLE_MESH`

**Default value:**
- 1 if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_RX_SEG_MSG_COUNT**

Maximum number of simultaneous incoming segmented messages

*Found in: Component config > CONFIG_BLE_MESH*

Maximum number of simultaneous incoming multi-segment and/or reliable messages. The default value is 1, which means the device can only receive one segmented message at a time. And if another segmented message is going to be received, it should wait for the completion of the previous one. If users are going to receive multiple segmented messages at the same time, this value should be configured properly.

**Range:**
- from 1 to 255 if `CONFIG_BLE_MESH`

**Default value:**
- 1 if `CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_RX_SDU_MAX**

Maximum incoming Upper Transport Access PDU length

*Found in: Component config > CONFIG_BLE_MESH*

Maximum incoming Upper Transport Access PDU length. Leave this to the default value, unless you really need to optimize memory usage.

**Range:**
CONFIG_BLE_MESH_TX_SEG_MAX

Maximum number of segments in outgoing messages

Found in: Component config > CONFIG_BLE_MESH

Maximum number of segments supported for outgoing messages. This value should typically be fine-tuned based on what models the local node supports, i.e. what’s the largest message payload that the node needs to be able to send. This value affects memory and call stack consumption, which is why the default is lower than the maximum that the specification would allow (32 segments).

The maximum outgoing SDU size is 12 times this number (out of which 4 or 8 bytes is used for the Transport Layer MIC). For example, 5 segments means the maximum SDU size is 60 bytes, which leaves 56 bytes for application layer data using a 4-byte MIC and 52 bytes using an 8-byte MIC.

Be sure to specify a sufficient number of advertising buffers when setting this option to a higher value. There must be at least three more advertising buffers (BLE_MESH_ADV_BUF_COUNT) as there are outgoing segments.

Range:
• from 2 to 32 if CONFIG_BLE_MESH

Default value:
• 32 if CONFIG_BLE_MESH

CONFIG_BLE_MESH_RELAY

Relay support

Found in: Component config > CONFIG_BLE_MESH

Support for acting as a Mesh Relay Node. Enabling this option will allow a node to support the Relay feature, and the Relay feature can still be enabled or disabled by proper configuration messages. Disabling this option will let a node not support the Relay feature.

Default value:
• Yes (enabled) if CONFIG_BLE_MESH_NODE & CONFIG_BLE_MESH

CONFIG_BLE_MESH_RELAY_ADV_BUF

Use separate advertising buffers for relay packets

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_RELAY

When selected, self-send packets will be put in a high-priority queue and relay packets will be put in a low-priority queue.

Default value:
• No (disabled) if CONFIG_BLE_MESH_RELAY & CONFIG_BLE_MESH

CONFIG_BLE_MESH_RELAY_ADV_BUF_COUNT

Number of advertising buffers for relay packets

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_RELAY > CONFIG_BLE_MESH_RELAY_ADV_BUF

Number of advertising buffers for relay packets available.

Range:
• from 6 to 256 if CONFIG_BLE_MESH_RELAY_ADV_BUF && CONFIG_BLE_MESH_RELAY && CONFIG_BLE_MESH

Default value:
• 60 if CONFIG_BLE_MESH_RELAY_ADV_BUF && CONFIG_BLE_MESH_RELAY && CONFIG_BLE_MESH

CONFIG_BLE_MESH_LOWPOWER

Support for Low Power features

Found in: Component config > CONFIG_BLE_MESH

Enable this option to operate as a Low Power Node. If low power consumption is required by a node, this option should be enabled. And once the node enters the mesh network, it will try to find a Friend node and establish a friendship.

CONFIG_BLE_MESH_LPN_ESTABLISHMENT

Perform Friendship establishment using low power

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOWPOWER

Perform the Friendship establishment using low power with the help of a reduced scan duty cycle. The downside of this is that the node may miss out on messages intended for it until it has successfully set up Friendship with a Friend node. When this option is enabled, the node will stop scanning for a period of time after a Friend Request or Friend Poll is sent, so as to reduce more power consumption.

Default value:
• No (disabled) if CONFIG_BLE_MESH_LOWPOWER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_AUTO

Automatically start looking for Friend nodes once provisioned

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOWPOWER

Once provisioned, automatically enable LPN functionality and start looking for Friend nodes. If this option is disabled LPN mode needs to be manually enabled by calling bt_mesh_lpn_set(true). When an unprovisioned device is provisioned successfully and becomes a node, enabling this option will trigger the node starts to send Friend Request at a certain period until it finds a proper Friend node.

Default value:
• No (disabled) if CONFIG_BLE_MESH_LOWPOWER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_AUTO_TIMEOUT

Time from last received message before going to LPN mode

Found in: Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOWPOWER > CONFIG_BLE_MESH_LPN_AUTO

Time in seconds from the last received message, that the node waits out before starting to look for Friend nodes.

Range:
• from 0 to 3600 if CONFIG_BLE_MESH_LPN_AUTO && CONFIG_BLE_MESH_LOWPOWER && CONFIG_BLE_MESH

Default value:
• 15 if CONFIG_BLE_MESH_LPN_AUTO && CONFIG_BLE_MESH_LOWPOWER && CONFIG_BLE_MESH
CONFIG_BLE_MESH_LPN_RETRY_TIMEOUT

Retry timeout for Friend requests

*Found in:* Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER

Time in seconds between Friend Requests, if a previous Friend Request did not yield any acceptable Friend Offers.

**Range:**
- from 1 to 3600 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

**Default value:**
- 6 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_RSSI_FACTOR

RSSI Factor, used in Friend Offer Delay calculation

*Found in:* Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER

The contribution of the RSSI, measured by the Friend node, used in Friend Offer Delay calculations. 0 = 1, 1 = 1.5, 2 = 2, 3 = 2.5. RSSIFactor, one of the parameters carried by Friend Request sent by Low Power node, which is used to calculate the Friend Offer Delay.

**Range:**
- from 0 to 3 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

**Default value:**
- 0 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_RECV_WIN_FACTOR

Receive Window Factor, used in Friend Offer Delay calculation

*Found in:* Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER

The contribution of the supported Receive Window used in Friend Offer Delay calculations. 0 = 1, 1 = 1.5, 2 = 2, 3 = 2.5. ReceiveWindowFactor, one of the parameters carried by Friend Request sent by Low Power node, which is used to calculate the Friend Offer Delay.

**Range:**
- from 0 to 3 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

**Default value:**
- 0 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_MIN_QUEUE_SIZE

Minimum size of the acceptable friend queue (MinQueueSizeLog)

*Found in:* Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER

The MinQueueSizeLog field is defined as log_2(N), where N is the minimum number of maximum size Lower Transport PDUs that the Friend node can store in its Friend Queue. As an example, MinQueueSizeLog value 1 gives N = 2, and value 7 gives N = 128.

**Range:**
- from 1 to 7 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

**Default value:**
- 1 if CONFIG_BLE_MESH_LOW_POWER &amp; CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_RECV_DELAY
Receive delay requested by the local node

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER`

The ReceiveDelay is the time between the Low Power node sending a request and listening for a response. This delay allows the Friend node time to prepare the response. The value is in units of milliseconds.

**Range:**
- from 10 to 255 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**Default value:**
- 100 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

### CONFIG_BLE_MESH_LPN_POLL_TIMEOUT

The value of the PollTimeout timer

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER`

PollTimeout timer is used to measure time between two consecutive requests sent by a Low Power node. If no requests are received the Friend node before the PollTimeout timer expires, then the friendship is considered terminated. The value is in units of 100 milliseconds, so e.g. a value of 300 means 30 seconds. The smaller the value, the faster the Low Power node tries to get messages from corresponding Friend node and vice versa.

**Range:**
- from 10 to 244735 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**Default value:**
- 300 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

### CONFIG_BLE_MESH_LPN_INIT_POLL_TIMEOUT

The starting value of the PollTimeout timer

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER`

The initial value of the PollTimeout timer when Friendship is to be established for the first time. After this, the timeout gradually grows toward the actual PollTimeout, doubling in value for each iteration. The value is in units of 100 milliseconds, so e.g. a value of 300 means 30 seconds.

**Range:**
- from 10 to if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**Default value:**
- if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

### CONFIG_BLE_MESH_LPN_SCAN_LATENCY

Latency for enabling scanning

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER`

Latency (in milliseconds) is the time it takes to enable scanning. In practice, it means how much time in advance of the Receive Window, the request to enable scanning is made.

**Range:**
- from 0 to 50 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**Default value:**
- 10 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

### CONFIG_BLE_MESH_LPN_GROUPS

Number of groups the LPN can subscribe to

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER`
Maximum number of groups to which the LPN can subscribe.

**Range:**
- from 0 to 16384 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**Default value:**
- 8 if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_LPNUSUB_ALL_NODES_ADDR**

Automatically subscribe all nodes address

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_LOW_POWER`

Automatically subscribe all nodes address when friendship established.

**Default value:**
- No (disabled) if `CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_FRIEND**

Support for Friend feature

*Found in:* `Component config > CONFIG_BLE_MESH`

Enable this option to be able to act as a Friend Node.

**CONFIG_BLE_MESH_FRIEND_RECV_WIN**

Friend Receive Window

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FRIEND`

Receive Window in milliseconds supported by the Friend node.

**Range:**
- from 1 to 255 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

**Default value:**
- 255 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_FRIEND_QUEUE_SIZE**

Minimum number of buffers supported per Friend Queue

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FRIEND`

Minimum number of buffers available to be stored for each local Friend Queue. This option decides the size of each buffer which can be used by a Friend node to store messages for each Low Power node.

**Range:**
- from 2 to 65536 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

**Default value:**
- 16 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_FRIEND_SUB_LIST_SIZE**

Friend Subscription List Size

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FRIEND`

Size of the Subscription List that can be supported by a Friend node for a Low Power node. And Low Power node can send Friend Subscription List Add or Friend Subscription List Remove messages to the Friend node to add or remove subscription addresses.

**Range:**
- from 0 to 1023 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`
Default value:
- 3 if `CONFIG_BLE_MESH_FRIEND` && `CONFIG_BLE_MESH`
BLE Mesh NET BUF DEBUG LOG LEVEL Contains:

- CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL

CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL

BLE_MESH_NET_BUF

Found in: Component config > CONFIG_BLE_MESH > BLE Mesh NET BUF DEBUG LOG LEVEL

Define BLE Mesh trace level for BLE Mesh net buffer.

Available options:

- NONE (CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL_NONE)
- ERROR (CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL_ERROR)
- WARNING (CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL_WARNING)
- INFO (CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL_INFO)
- DEBUG (CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL_DEBUG)
- VERBOSE (CONFIG_BLE_MESH_NET_BUF_TRACE_LEVEL_VERBOSE)

CONFIG_BLE_MESH_CLIENT_MSG_TIMEOUT

Timeout(ms) for client message response

Found in: Component config > CONFIG_BLE_MESH

Timeout value used by the node to get response of the acknowledged message which is sent by the client model. This value indicates the maximum time that a client model waits for the response of the sent acknowledged messages. If a client model uses 0 as the timeout value when sending acknowledged messages, then the default value will be used which is four seconds.

Range:
- from 100 to 1200000 if CONFIG_BLE_MESH

Default value:
- 4000 if CONFIG_BLE_MESH

Support for BLE Mesh Foundation models Contains:

- CONFIG_BLE_MESH_CFG_CLI
- CONFIG_BLE_MESH_HEALTH_CLI
- CONFIG_BLE_MESH_HEALTH_SRV

CONFIG_BLE_MESH_CFG_CLI

Configuration Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Foundation models

Enable support for Configuration Client model.

CONFIG_BLE_MESH_HEALTH_CLI

Health Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Foundation models

Enable support for Health Client model.
CONFIG_BLE_MESH_HEALTH_SRV

Health Server model

*Found in:* Component config > CONFIG_BLE_MESH > Support for BLE Mesh Foundation models

Enable support for Health Server model.

**Default value:**
- Yes (enabled) if CONFIG_BLE_MESH

Support for BLE Mesh Client/Server models

Contains:
- CONFIG_BLE_MESH_GENERIC_BATTERY_CLI
- CONFIG_BLE_MESH_GENERIC_DEF_TRANS_TIME_CLI
- CONFIG_BLE_MESH_GENERIC_LEVEL_CLI
- CONFIG_BLE_MESH_GENERIC_LOCATION_CLI
- CONFIG_BLE_MESH_GENERIC_ONOFF_CLI
- CONFIG_BLE_MESH_GENERIC_POWER_LEVEL_CLI
- CONFIG_BLE_MESH_GENERIC_POWER_ONOFF_CLI
- CONFIG_BLE_MESH_GENERIC_PROPERTY_CLI
- CONFIG_BLE_MESH_GENERIC_SERVER
- CONFIG_BLE_MESH_LIGHT_CTL_CLI
- CONFIG_BLE_MESH_LIGHT_HSL_CLI
- CONFIG_BLE_MESH_LIGHT_LC_CLI
- CONFIG_BLE_MESH_LIGHT_LIGHTNESS_CLI
- CONFIG_BLE_MESH_LIGHT_XYL_CLI
- CONFIG_BLE_MESH_LIGHT_LIGHTNESS_CLI
- CONFIG_BLE_MESH_SCHADING_SERVER
- CONFIG_BLE_MESH_SENSOR_CLI
- CONFIG_BLE_MESH_SENSOR_SERVER
- CONFIG_BLE_MESH_TIME_SCENE_SERVER
- CONFIG_BLE_MESH_TIME_CLI

CONFIG_BLE_MESH_GENERIC_ONOFF_CLI

Generic OnOff Client model

*Found in:* Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models

Enable support for Generic OnOff Client model.

CONFIG_BLE_MESH_GENERIC_LEVEL_CLI

Generic Level Client model

*Found in:* Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models

Enable support for Generic Level Client model.

CONFIG_BLE_MESH_GENERIC_DEF_TRANS_TIME_CLI

Generic Default Transition Time Client model

*Found in:* Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models

Enable support for Generic Default Transition Time Client model.
CONFIG_BLE_MESH_GENERIC_POWER_ONOFF_CLI

Generic Power OnOff Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Generic Power OnOff Client model.

CONFIG_BLE_MESH_GENERIC_POWER_LEVEL_CLI

Generic Power Level Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Generic Power Level Client model.

CONFIG_BLE_MESH_GENERIC_BATTERY_CLI

Generic Battery Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Generic Battery Client model.

CONFIG_BLE_MESH_GENERIC_LOCATION_CLI

Generic Location Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Generic Location Client model.

CONFIG_BLE_MESH_GENERIC_PROPERTY_CLI

Generic Property Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Generic Property Client model.

CONFIG_BLE_MESH_SENSOR_CLI

Sensor Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Sensor Client model.

CONFIG_BLE_MESH_TIME_CLI

Time Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Time Client model.

CONFIG_BLE_MESH_SCENE_CLI

Scene Client model

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Scene Client model.
CONFIG_BLE_MESH_SCHEDULER_CLI
Scheduler Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Scheduler Client model.

CONFIG_BLE_MESH_LIGHT_LIGHTNESS_CLI
Light Lightness Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Light Lightness Client model.

CONFIG_BLE_MESH_LIGHT_CTL_CLI
Light CTL Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Light CTL Client model.

CONFIG_BLE_MESH_LIGHT_HSL_CLI
Light HSL Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Light HSL Client model.

CONFIG_BLE_MESH_LIGHT_XYL_CLI
Light XYL Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Light XYL Client model.

CONFIG_BLE_MESH_LIGHT_LC_CLI
Light LC Client model

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Light LC Client model.

CONFIG_BLE_MESH_GENERIC_SERVER
Generic server models

Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models
Enable support for Generic server models.

Default value:
- Yes (enabled) if CONFIG_BLE_MESH
CONFIG_BLE_MESH_SENSOR_SERVER

Sensor server models

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Sensor server models.

**Default value:**
- Yes (enabled) if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_TIME_SCENE_SERVER

Time and Scenes server models

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Time and Scenes server models.

**Default value:**
- Yes (enabled) if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_LIGHTING.Server

Lighting server models

*Found in: Component config > CONFIG_BLE_MESH > Support for BLE Mesh Client/Server models*

Enable support for Lighting server models.

**Default value:**
- Yes (enabled) if `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_IV_UPDATE_TEST

Test the IV Update Procedure

*Found in: Component config > CONFIG_BLE_MESH*

This option removes the 96 hour limit of the IV Update Procedure and lets the state to be changed at any time. If IV Update test mode is going to be used, this option should be enabled.

**Default value:**
- No (disabled) if `CONFIG_BLE_MESH`

**BLE Mesh specific test option**  Contains:

- `CONFIG_BLE_MESH_DEBUG`
- `CONFIG_BLE_MESH_SHELL`
- `CONFIG_BLE_MESH_BQB_TEST`
- `CONFIG_BLE_MESH_SELF_TEST`
- `CONFIG_BLE_MESH_TEST_AUTO_ENTER_NETWORK`
- `CONFIG_BLE_MESH_TEST_USE_WHITE_LIST`

CONFIG_BLE_MESH_SELF_TEST

Perform BLE Mesh self-tests

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option*

This option adds extra self-tests which are run every time BLE Mesh networking is initialized.

**Default value:**
- No (disabled) if `CONFIG_BLE_MESH`
CONFIG_BLE_MESH_BQB_TEST
Enable BLE Mesh specific internal test

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option*

This option is used to enable some internal functions for auto-pts test.

**Default value:**
- No (disabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_TEST_AUTO_ENTER_NETWORK
Unprovisioned device enters mesh network automatically

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option*

With this option enabled, an unprovisioned device can automatically enters mesh network using a specific test function without the provisioning procedure. And on the Provisioner side, a test function needs to be invoked to add the node information into the mesh stack.

**Default value:**
- Yes (enabled) if CONFIG_BLE_MESH_SELF_TEST && CONFIG_BLE_MESH

CONFIG_BLE_MESH_TEST_USE_WHITE_LIST
Use white list to filter mesh advertising packets

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option*

With this option enabled, users can use white list to filter mesh advertising packets while scanning.

**Default value:**
- No (disabled) if CONFIG_BLE_MESH_SELF_TEST && CONFIG_BLE_MESH

CONFIG_BLE_MESH_SHELL
Enable BLE Mesh shell

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option*

Activate shell module that provides BLE Mesh commands to the console.

**Default value:**
- No (disabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_DEBUG
Enable BLE Mesh debug logs

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option*

Enable debug logs for the BLE Mesh functionality.

**Default value:**
- No (disabled) if CONFIG_BLE_MESH

CONFIG_BLE_MESH_DEBUG_NET
Network layer debug

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG*

Enable Network layer debug logs for the BLE Mesh functionality.
CONFIG_BLE_MESH_DEBUG_TRANS
Transport layer debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Transport layer debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_BEACON
Beacon debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Beacon-related debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_CRYPTO
Crypto debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable cryptographic debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_PROV
Provisioning debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Provisioning debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_ACCESS
Access layer debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Access layer debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_MODEL
Foundation model debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Foundation Models debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_ADV
Advertising debug

*Found in:* Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable advertising debug logs for the BLE Mesh functionality.
CONFIG_BLE_MESH_DEBUG_LOW_POWER

Low Power debug

*Found in:*  Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Low Power debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_FRIEND

Friend debug

*Found in:*  Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Friend debug logs for the BLE Mesh functionality.

CONFIG_BLE_MESH_DEBUG_PROXY

Proxy debug

*Found in:*  Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_DEBUG

Enable Proxy protocol debug logs for the BLE Mesh functionality.

Driver Configurations  Contains:

- Analog Comparator Configuration
- DAC Configuration
- GPIO Configuration
- GPTimer Configuration
- I2S Configuration
- Legacy ADC Configuration
- MCPWM Configuration
- Parallel IO Configuration
- PCNT Configuration
- RMT Configuration
- Sigma Delta Modulator Configuration
- SPI Configuration
- Temperature sensor Configuration
- TWAI Configuration
- UART Configuration
- USB Serial/JTAG Configuration

Legacy ADC Configuration  Contains:

- CONFIG_ADC_DISABLE_DAC
- Legacy ADC Calibration Configuration
- CONFIG_ADC_SUPPRESS_DEPRECATE_WARN

CONFIG_ADC_DISABLE_DAC

Disable DAC when ADC2 is used on GPIO 25 and 26

*Found in:*  Component config > Driver Configurations > Legacy ADC Configuration

If this is set, the ADC2 driver will disable the output of the DAC corresponding to the specified channel. This is the default value.

For testing, disable this option so that we can measure the output of DAC by internal ADC.
**Default value:**
- Yes (enabled)

**CONFIG_ADC_SUPPRESS_DEPRECATE_WARN**

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > Legacy ADC Configuration*

Whether to suppress the deprecation warnings when using legacy adc driver (driver/adc.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

**Legacy ADC Calibration Configuration**

Contains:
- **CONFIG_ADC_CALI_SUPPRESS_DEPRECATE_WARN**
- **CONFIG_ADC_CAL_EFUSE_VREF_ENABLE**
- **CONFIG_ADC_CAL_LUT_ENABLE**
- **CONFIG_ADC_CAL_EFUSE_TP_ENABLE**

**CONFIG_ADC_CAL_EFUSE_TP_ENABLE**

Use Two Point Values

*Found in: Component config > Driver Configurations > Legacy ADC Configuration > Legacy ADC Calibration Configuration*

Some ESP32s have Two Point calibration values burned into eFuse BLOCK3. This option will allow the ADC calibration component to characterize the ADC-Voltage curve using Two Point values if they are available.

**Default value:**
- Yes (enabled)

**CONFIG_ADC_CAL_EFUSE_VREF_ENABLE**

Use eFuse Vref

*Found in: Component config > Driver Configurations > Legacy ADC Configuration > Legacy ADC Calibration Configuration*

Some ESP32s have Vref burned into eFuse BLOCK0. This option will allow the ADC calibration component to characterize the ADC-Voltage curve using eFuse Vref if it is available.

**Default value:**
- Yes (enabled)

**CONFIG_ADC_CAL_LUT_ENABLE**

Use Lookup Tables

*Found in: Component config > Driver Configurations > Legacy ADC Configuration > Legacy ADC Calibration Configuration*

This option will allow the ADC calibration component to use Lookup Tables to correct for non-linear behavior in 11db attenuation. Other attenuations do not exhibit non-linear behavior hence will not be affected by this option.

**Default value:**
- Yes (enabled)
CONFIG_ADC_CALI_SUPPRESS_DEPRECATED_WARN

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > Legacy ADC Configuration > Legacy ADC Calibration Configuration*

Whether to suppress the deprecation warnings when using legacy adc calibration driver (esp_adc_cal.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

SPI Configuration

Contains:
- `CONFIG_SPI_MASTER_ISR_IN_IRAM`
- `CONFIG_SPI_SLAVE_ISR_IN_IRAM`
- `CONFIG_SPI_MASTER_IN_IRAM`
- `CONFIG_SPI_SLAVE_IN_IRAM`

.CONFIG_SPI_MASTER_IN_IRAM

Place transmitting functions of SPI master into IRAM

*Found in: Component config > Driver Configurations > SPI Configuration*

Normally only the ISR of SPI master is placed in the IRAM, so that it can work without the flash when interrupt is triggered. For other functions, there’s some possibility that the flash cache miss when running inside and out of SPI functions, which may increase the interval of SPI transactions. Enable this to put `queue\_trans,get\_trans\_result` and `transmit` functions into the IRAM to avoid possible cache miss.

This configuration won’t be available if `CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH` is enabled.

During unit test, this is enabled to measure the ideal case of api.

**Default value:**
- No (disabled) if `CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH`

CONFIG_SPI_MASTER_ISR_IN_IRAM

Place SPI master ISR function into IRAM

*Found in: Component config > Driver Configurations > SPI Configuration*

Place the SPI master ISR in to IRAM to avoid possible cache miss.

Enabling this configuration is possible only when `HEAP_PLACE_FUNCTION_INTO_FLASH` is disabled since the spi master uses can allocate transactions buffers into DMA memory section using the heap component API that ipso facto has to be placed in IRAM.

Also you can forbid the ISR being disabled during flash writing access, by add `ESP_INTR_FLAG_IRAM` when initializing the driver.

**Default value:**
- Yes (enabled) if `CONFIG_HEAP_PLACE_FUNCTION_INTO_FLASH`

CONFIG_SPI_SLAVE_IN_IRAM

Place transmitting functions of SPI slave into IRAM

*Found in: Component config > Driver Configurations > SPI Configuration*
Normally only the ISR of SPI slave is placed in the IRAM, so that it can work without the flash when interrupt is triggered. For other functions, there’s some possibility that the flash cache miss when running inside and out of SPI functions, which may increase the interval of SPI transactions. Enable this to put queue\_trans, get\_trans\_result and transmit functions into the IRAM to avoid possible cache miss.

**Default value:**
- No (disabled)

**CONFIG_SPI_SLAVE_ISR_IN_IRAM**

Place SPI slave ISR function into IRAM

**Found in:** Component config > Driver Configurations > SPI Configuration

Place the SPI slave ISR in to IRAM to avoid possible cache miss.

Also you can forbid the ISR being disabled during flash writing access, by add ESP\_INTR\_FLAG\_IRAM when initializing the driver.

**Default value:**
- Yes (enabled)

**TWAI Configuration**

Contains:

- `CONFIG_TWAI_ERRATA_FIX_RX_FRAME_INVALID`
- `CONFIG_TWAI_ERRATA_FIX_LISTEN_ONLY_DOM`
- `CONFIG_TWAI_ERRATA_FIX_BUS_OFF_REC`
- `CONFIG_TWAI_ERRATA_FIX_RX_FIFO_CORRUPT`
- `CONFIG_TWAI_ERRATA_FIX_TX_INTR_LOST`
- `CONFIG_TWAI_ISR_IN_IRAM`

**CONFIG_TWAI_ISR_IN_IRAM**

Place TWAI ISR function into IRAM

**Found in:** Component config > Driver Configurations > TWAI Configuration

Place the TWAI ISR in to IRAM. This will allow the ISR to avoid cache misses, and also be able to run whilst the cache is disabled (such as when writing to SPI Flash). Note that if this option is enabled:
- Users should also set the ESP\_INTR\_FLAG\_IRAM in the driver configuration structure when installing the driver (see docs for specifics).
- Alert logging (i.e., setting of the TWAI\_ALERT\_AND\_LOG flag) will have no effect.

**Default value:**
- No (disabled)

**CONFIG_TWAI_ERRATA_FIX_BUS_OFF_REC**

Add SW workaround for REC change during bus-off

**Found in:** Component config > Driver Configurations > TWAI Configuration

When the bus-off condition is reached, the REC should be reset to 0 and frozen (via LOM) by the driver’s ISR. However on the ESP32, there is an edge case where the REC will increase before the driver’s ISR can respond in time (e.g., due to the rapid occurrence of bus errors), thus causing the REC to be non-zero after bus-off. A non-zero REC can prevent bus-off recovery as the bus-off recovery condition is that both TEC and REC become 0. Enabling this option will add a workaround in the driver to forcibly reset REC to zero on reaching bus-off.

**Default value:**
- Yes (enabled)
Chapter 2. API Reference

CONFIG_TWAI_ERRATA_FIX_TX_INTR_LOST
Add SW workaround for TX interrupt lost errata

Found in: Component config > Driver Configurations > TWAI Configuration

On the ESP32, when a transmit interrupt occurs, and interrupt register is read on the same APB clock cycle, the transmit interrupt could be lost. Enabling this option will add a workaround that checks the transmit buffer status bit to recover any lost transmit interrupt.

Default value:
• Yes (enabled)

CONFIG_TWAI_ERRATA_FIX_RX_FRAME_INVALID
Add SW workaround for invalid RX frame errata

Found in: Component config > Driver Configurations > TWAI Configuration

On the ESP32, when receiving a data or remote frame, if a bus error occurs in the data or CRC field, the data of the next received frame could be invalid. Enabling this option will add a workaround that will reset the peripheral on detection of this errata condition. Note that if a frame is transmitted on the bus whilst the reset is ongoing, the message will not be receive by the peripheral sent on the bus during the reset, the message will be lost.

Default value:
• Yes (enabled)

CONFIG_TWAI_ERRATA_FIX_RX_FIFO_CORRUPT
Add SW workaround for RX FIFO corruption errata

Found in: Component config > Driver Configurations > TWAI Configuration

On the ESP32, when the RX FIFO overruns and the RX message counter maxes out at 64 messages, the entire RX FIFO is no longer recoverable. Enabling this option will add a workaround that resets the peripheral on detection of this errata condition. Note that if a frame is being sent on the bus during the reset bus during the reset, the message will be lost.

Default value:
• Yes (enabled)

CONFIG_TWAI_ERRATA_FIX_LISTEN_ONLY_DOM
Add SW workaround for listen only transmits dominant bit errata

Found in: Component config > Driver Configurations > TWAI Configuration

When in the listen only mode, the TWAI controller must not influence the TWAI bus (i.e., must not send any dominant bits). However, while in listen only mode on the ESP32/ESP32-S2/ESP32-S3/ESP32-C3, the TWAI controller will still transmit dominant bits when it detects an error (i.e., as part of an active error frame). Enabling this option will add a workaround that forces the TWAI controller into an error passive state on initialization, thus preventing any dominant bits from being sent.

Default value:
• Yes (enabled)

Temperature sensor Configuration Contains:
• CONFIG_TEMP_SENSOR_ENABLE_DEBUG_LOG
• CONFIG_TEMP_SENSOR_SUPPRESS_DEPRECATE_WARN
• CONFIG_TEMP_SENSOR_ISR_IRAM_SAFE
CONFIG_TEMP_SENSOR_SUPPRESS_DEPRECATE_WARN

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > Temperature sensor Configuration*

Wether to suppress the deprecation warnings when using legacy temperature sensor driver (driver/temp_sensor.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled) if SOC_TEMP_SENSOR_SUPPORTED

CONFIG_TEMP_SENSOR_ENABLE_DEBUG_LOG

Enable debug log

*Found in: Component config > Driver Configurations > Temperature sensor Configuration*

Wether to enable the debug log message for temperature sensor driver. Note that, this option only controls the temperature sensor driver log, won’t affect other drivers.

**Default value:**
- No (disabled) if SOC_TEMP_SENSOR_SUPPORTED

CONFIG_TEMP_SENSOR_ISR_IRAM_SAFE

Temperature sensor ISR IRAM-Safe

*Found in: Component config > Driver Configurations > Temperature sensor Configuration*

Ensure the Temperature Sensor interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**
- No (disabled) if SOC_TEMPERATURE_SENSOR_INTR_SUPPORT && SOC_TEMP_SENSOR_SUPPORTED

UART Configuration  Contains:

- CONFIG_UART_ISR_IN_IRAM

CONFIG_UART_ISR_IN_IRAM

Place UART ISR function into IRAM

*Found in: Component config > Driver Configurations > UART Configuration*

If this option is not selected, UART interrupt will be disabled for a long time and may cause data lost when doing spi flash operation.

**Default value:**
- No (disabled) if CONFIG_RINGBUF_PLACE_ISR_FUNCTIONS_INTO_FLASH

GPIO Configuration  Contains:

- CONFIG_GPIO_CTRL_FUNC_IN_IRAM
- CONFIG_GPIO_ESP32_SUPPORT_SWITCH_SLP_PULL
**CONFIG_GPIO_ESP32_SUPPORT_SWITCH_SLP_PULL**

Support light sleep GPIO pullup/pulldown configuration for ESP32

*Found in: Component config > Driver Configurations > GPIO Configuration*

This option is intended to fix the bug that ESP32 is not able to switch to configured pullup/pulldown mode in sleep. If this option is selected, chip will automatically emulate the behaviour of switching, and about 450B of source codes would be placed into IRAM.

**CONFIG_GPIO_CTRL_FUNC_IN_IRAM**

Place GPIO control functions into IRAM

*Found in: Component config > Driver Configurations > GPIO Configuration*

Place GPIO control functions (like intr_disable/set_level) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context.

**Default value:**
- No (disabled)

**Sigma Delta Modulator Configuration**

Contains:

- **CONFIG_SDM_ENABLE_DEBUG_LOG**
- **CONFIG_SDM_CTRL_FUNC_IN_IRAM**
- **CONFIG_SDM_SUPPRESS_DEPRECAT_WARN**

**CONFIG_SDM_CTRL_FUNC_IN_IRAM**

Place SDM control functions into IRAM

*Found in: Component config > Driver Configurations > Sigma Delta Modulator Configuration*

Place SDM control functions (like set_duty) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context. Enabling this option can improve driver performance as well.

**Default value:**
- No (disabled)

**CONFIG_SDM_SUPPRESS_DEPRECAT_WARN**

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > Sigma Delta Modulator Configuration*

Wether to suppress the deprecation warnings when using legacy sigma delta driver. If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

**CONFIG_SDM_ENABLE_DEBUG_LOG**

Enable debug log

*Found in: Component config > Driver Configurations > Sigma Delta Modulator Configuration*

Wether to enable the debug log message for SDM driver. Note that, this option only controls the SDM driver log, won’t affect other drivers.

**Default value:**
- No (disabled)
Analog Comparator Configuration  Contains:

- CONFIG_ANA_CMPR_ISR_IRAM_SAFE
- CONFIG_ANA_CMPR_ENABLE_DEBUG_LOG
- CONFIG_ANA_CMPR_CTRL_FUNC_IN_IRAM

**CONFIG_ANA_CMPR_ISR_IRAM_SAFE**

Analog comparator ISR IRAM-Safe

*Found in: Component config > Driver Configurations > Analog Comparator Configuration*

Ensure the Analog Comparator interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**

- No (disabled) if SOC_ANA_CMPR_SUPPORTED

**CONFIG_ANA_CMPR_CTRL_FUNC_IN_IRAM**

Place Analog Comparator control functions into IRAM

*Found in: Component config > Driver Configurations > Analog Comparator Configuration*

Place Analog Comparator control functions (like ana_cmpr_set_internal_reference) into IRAM, so that these functions can be IRAM-safe and able to be called in an IRAM interrupt context. Enabling this option can improve driver performance as well.

**Default value:**

- No (disabled) if SOC_ANA_CMPR_SUPPORTED

**CONFIG_ANA_CMPR_ENABLE_DEBUG_LOG**

Enable debug log

*Found in: Component config > Driver Configurations > Analog Comparator Configuration*

Wether to enable the debug log message for Analog Comparator driver. Note that, this option only controls the Analog Comparator driver log, won’t affect other drivers.

**Default value:**

- No (disabled) if SOC_ANA_CMPR_SUPPORTED

GPTimer Configuration  Contains:

- CONFIG_GPTIMER_ENABLE_DEBUG_LOG
- CONFIG_GPTIMER_ISR_IRAM_SAFE
- CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM
- CONFIG_GPTIMER_ISR_HANDLER_IN_IRAM
- CONFIG_GPTIMERSuppress_Deprecate_Warn

**CONFIG_GPTIMER_ISR_HANDLER_IN_IRAM**

Place GPTimer ISR handler into IRAM

*Found in: Component config > Driver Configurations > GPTimer Configuration*

Place GPTimer ISR handler into IRAM for better performance and fewer cache misses.

**Default value:**

- Yes (enabled)
**CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM**

Place GPTimer control functions into IRAM

*Found in: Component config > Driver Configurations > GPTimer Configuration*

Place GPTimer control functions (like start/stop) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context. Enabling this option can improve driver performance as well.

**Default value:**
- No (disabled)

**CONFIG_GPTIMER_ISR_IRAM_SAFE**

GPTimer ISR IRAM-Safe

*Found in: Component config > Driver Configurations > GPTimer Configuration*

Ensure the GPTimer interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**
- No (disabled)

**CONFIG_GPTIMER_SUPPRESS_DEPRECATE_WARN**

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > GPTimer Configuration*

Whether to suppress the deprecation warnings when using legacy timer group driver (driver/timer.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

**CONFIG_GPTIMER_ENABLE_DEBUG_LOG**

Enable debug log

*Found in: Component config > Driver Configurations > GPTimer Configuration*

Whether to enable the debug log message for GPTimer driver. Note that, this option only controls the GPTimer driver log, won’t affect other drivers.

**Default value:**
- No (disabled)

**PCNT Configuration**

Contains:

- **CONFIG_PCNT_ENABLE_DEBUG_LOG**
- **CONFIG_PCNT_ISR_IRAM_SAFE**
- **CONFIG_PCNT_CTRL_FUNC_IN_IRAM**
- **CONFIG_PCNT_SUPPRESS_DEPRECATE_WARN**

**CONFIG_PCNT_CTRL_FUNC_IN_IRAM**

Place PCNT control functions into IRAM

*Found in: Component config > Driver Configurations > PCNT Configuration*
Place PCNT control functions (like start/stop) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context. Enabling this option can improve driver performance as well.

**Default value:**
- No (disabled)

**CONFIG_PCNT_ISR_IRAM_SAFE**

PCNT ISR IRAM-Safe

*Found in: Component config > Driver Configurations > PCNT Configuration*

Ensure the PCNT interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**
- No (disabled)

**CONFIG_PCNT_SUPPRESS_DEPRECATE_WARN**

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > PCNT Configuration*

Whether to suppress the deprecation warnings when using legacy PCNT driver (driver/pcnt.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

**CONFIG_PCNT_ENABLE_DEBUG_LOG**

Enable debug log

*Found in: Component config > Driver Configurations > PCNT Configuration*

Whether to enable the debug log message for PCNT driver. Note that, this option only controls the PCNT driver log, won’t affect other drivers.

**Default value:**
- No (disabled)

**RMT Configuration**

Contains:

- **CONFIG_RMT_ENABLE_DEBUG_LOG**
- **CONFIG_RMT_ISR_IRAM_SAFE**
- **CONFIG_RMT_SUPPRESS_DEPRECATE_WARN**

**CONFIG_RMT_ISR_IRAM_SAFE**

RMT ISR IRAM-Safe

*Found in: Component config > Driver Configurations > RMT Configuration*

Ensure the RMT interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**
- No (disabled)
CONFIG_RMT_SUPPRESS_DEPRECATE_WARN

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > RMT Configuration*

Whether to suppress the deprecation warnings when using legacy rmt driver (driver/rmt.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

CONFIG_RMT_ENABLE_DEBUG_LOG

Enable debug log

*Found in: Component config > Driver Configurations > RMT Configuration*

Whether to enable the debug log message for RMT driver. Note that, this option only controls the RMT driver log, won’t affect other drivers.

**Default value:**
- No (disabled)

MCPWM Configuration

Contains:

- CONFIG_MCPWM_ENABLE_DEBUG_LOG
- CONFIG_MCPWM_CTRL_FUNC_IN_IRAM
- CONFIG_MCPWM_ISR_IRAM_SAFE
- CONFIG_MCPWM_SUPPRESS_DEPRECATE_WARN

CONFIG_MCPWM_ISR_IRAM_SAFE

Place MCPWM ISR function into IRAM

*Found in: Component config > Driver Configurations > MCPWM Configuration*

This will ensure the MCPWM interrupt handle is IRAM-Safe, allow to avoid flash cache misses, and also be able to run whilst the cache is disabled. (e.g. SPI Flash write)

**Default value:**
- No (disabled)

CONFIG_MCPWM_CTRL_FUNC_IN_IRAM

Place MCPWM control functions into IRAM

*Found in: Component config > Driver Configurations > MCPWM Configuration*

Place MCPWM control functions (like set_compare_value) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context. Enabling this option can improve driver performance as well.

**Default value:**
- No (disabled)

CONFIG_MCPWM_SUPPRESS_DEPRECATE_WARN

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > MCPWM Configuration*
Wether to suppress the deprecation warnings when using legacy MCPWM driver (driver/mcpwm.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**
- No (disabled)

**CONFIG_MCPWM_ENABLE_DEBUG_LOG**

Enable debug log

*Found in: Component config > Driver Configurations > MCPWM Configuration*

Wether to enable the debug log message for MCPWM driver. Note that, this option only controls the MCPWM driver log, won’t affect other drivers.

**Default value:**
- No (disabled)

**I2S Configuration**

Contains:

- `CONFIG_I2S_ENABLE_DEBUG_LOG`
- `CONFIG_I2S_ISR_IRAM_SAFE`
- `CONFIG_I2S_SUPPRESS_DEPRECATE_WARN`

**CONFIG_I2S_ISR_IRAM_SAFE**

I2S ISR IRAM-Safe

*Found in: Component config > Driver Configurations > I2S Configuration*

Ensure the I2S interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**
- No (disabled)

**CONFIG_I2S_SUPPRESS_DEPRECATE_WARN**

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > I2S Configuration*

Enable this option will suppress the deprecation warnings of using APIs in legacy I2S driver.

**Default value:**
- No (disabled)

**CONFIG_I2S_ENABLE_DEBUG_LOG**

Enable I2S debug log

*Found in: Component config > Driver Configurations > I2S Configuration*

Wether to enable the debug log message for I2S driver. Note that, this option only controls the I2S driver log, will not affect other drivers.

**Default value:**
- No (disabled)
**DAC Configuration** Contains:

- `CONFIG_DAC_DMA_AUTO_16BIT_ALIGN`
- `CONFIG_DAC_ISR_IRAM_SAFE`
- `CONFIG_DAC_ENABLE_DEBUG_LOG`
- `CONFIG_DAC_CTRL_FUNC_IN_IRAM`
- `CONFIG_DAC_SUPPRESS_DEPRECATE_WARN`

**CONFIG_DAC_CTRL_FUNC_IN_IRAM**

Place DAC control functions into IRAM

*Found in: Component config > Driver Configurations > DAC Configuration*

Place DAC control functions (e.g. `dac_oneshot_output_voltage`) into IRAM, so that this function can be IRAM-safe and able to be called in the other IRAM interrupt context. Enabling this option can improve driver performance as well.

**Default value:**

- No (disabled)

**CONFIG_DAC_ISR_IRAM_SAFE**

DAC ISR IRAM-Safe

*Found in: Component config > Driver Configurations > DAC Configuration*

Ensure the DAC interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**

- No (disabled)

**CONFIG_DAC_SUPPRESS_DEPRECATE_WARN**

Suppress legacy driver deprecated warning

*Found in: Component config > Driver Configurations > DAC Configuration*

Whether to suppress the deprecation warnings when using legacy DAC driver (driver/dac.h). If you want to continue using the legacy driver, and don’t want to see related deprecation warnings, you can enable this option.

**Default value:**

- No (disabled)

**CONFIG_DAC_ENABLE_DEBUG_LOG**

Enable debug log

*Found in: Component config > Driver Configurations > DAC Configuration*

Whether to enable the debug log message for DAC driver. Note that, this option only controls the DAC driver log, won’t affect other drivers.

**Default value:**

- No (disabled)
CONFIG_DAC_DMA_AUTO_16BIT_ALIGN

Align the continuous data to 16 bit automatically

*Found in: Component config > Driver Configurations > DAC Configuration*

Whether to left shift the continuous data to align every byte to 16 bits in the driver. On ESP32, although the DAC resolution is only 8 bits, the hardware requires 16 bits data in continuous mode. By enabling this option, the driver will left shift 8 bits for the input data automatically. Only disable this option when you decide to do this step by yourself. Note that the driver will allocate a new piece of memory to save the converted data.

**Default value:**
- Yes (enabled)

USB Serial/JTAG Configuration  Contains:
- CONFIG_USJ_NO_AUTO_LS_ON_CONNECTION

CONFIG_USJ_NO_AUTO_LS_ON_CONNECTION

Don’t enter the automatic light sleep when USB Serial/JTAG port is connected

*Found in: Component config > Driver Configurations > USB Serial/JTAG Configuration*

If enabled, the chip will constantly monitor the connection status of the USB Serial/JTAG port. As long as the USB Serial/JTAG is connected, a ESP_PM_NO_LIGHT_SLEEP power management lock will be acquired to prevent the system from entering light sleep. This option can be useful if serial monitoring is needed via USB Serial/JTAG while power management is enabled, as the USB Serial/JTAG cannot work under light sleep and after waking up from light sleep. Note. This option can only control the automatic Light-Sleep behavior. If esp_light_sleep_start() is called manually from the program, enabling this option will not prevent light sleep entry even if the USB Serial/JTAG is in use.

Parallel IO Configuration  Contains:
- CONFIG_PARLIO_ENABLE_DEBUG_LOG
- CONFIG_PARLIO_ISR_IRAM_SAFE

CONFIG_PARLIO_ENABLE_DEBUG_LOG

Enable debug log

*Found in: Component config > Driver Configurations > Parallel IO Configuration*

Whether to enable the debug log message for parallel IO driver. Note that, this option only controls the parallel IO driver log, won’t affect other drivers.

**Default value:**
- No (disabled) if SOC_PARLIO_SUPPORTED

CONFIG_PARLIO_ISR_IRAM_SAFE

Parallel IO ISR IRAM-Safe

*Found in: Component config > Driver Configurations > Parallel IO Configuration*

Ensure the Parallel IO interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write).

**Default value:**
- No (disabled) if SOC_PARLIO_SUPPORTED
eFuse Bit Manager  Contains:

- **CONFIG_EFUSE_CODE_SCHEME_SELECTOR**
- **CONFIG_EFUSE_VIRTUAL**
- **CONFIG_EFUSE_CUSTOM_TABLE**

**CONFIG_EFUSE_CUSTOM_TABLE**

Use custom eFuse table

*Found in: Component config > eFuse Bit Manager*

Allows to generate a structure for eFuse from the CSV file.

**Default value:**
- No (disabled)

**CONFIG_EFUSE_CUSTOM_TABLE_FILENAME**

Custom eFuse CSV file

*Found in: Component config > eFuse Bit Manager > CONFIG_EFUSE_CUSTOM_TABLE*

Name of the custom eFuse CSV filename. This path is evaluated relative to the project root directory.

**Default value:**
- “main/esp_efuse_custom_table.csv” if CONFIG_EFUSE_CUSTOM_TABLE

**CONFIG_EFUSE_VIRTUAL**

Simulate eFuse operations in RAM

*Found in: Component config > eFuse Bit Manager*

If “n” - No virtual mode. All eFuse operations are real and use eFuse registers. If “y” - The virtual mode is enabled and all eFuse operations (read and write) are redirected to RAM instead of eFuse registers, all permanent changes (via eFuse) are disabled. Log output will state changes that would be applied, but they will not be.

If it is “y”, then SECURE_FLASH_ENCRYPTION_MODE_RELEASE cannot be used. Because the EFUSE VIRT mode is for testing only.

During startup, the eFuses are copied into RAM. This mode is useful for fast tests.

**Default value:**
- No (disabled)

**CONFIG_EFUSE_VIRTUAL_KEEP_IN_FLASH**

Keep eFuses in flash

*Found in: Component config > eFuse Bit Manager > CONFIG_EFUSE_VIRTUAL*

In addition to the “Simulate eFuse operations in RAM” option, this option just adds a feature to keep eFuses after reboots in flash memory. To use this mode the partition_table should have the efuse partition.

partition.csv: “efuse_em, data, efuse, , 0x2000,”

During startup, the eFuses are copied from flash or, in case if flash is empty, from real eFuse to RAM and then update flash. This mode is useful when need to keep changes after reboot (testing secure_boot and flash_encryption).
**CONFIG_EFUSE_VIRTUAL_LOG_ALL_WRITES**

Log all virtual writes

*Found in: Component config > eFuse Bit Manager > CONFIG_EFUSE_VIRTUAL*

If enabled, log efuse burns. This shows changes that would be made.

**CONFIG_EFUSE_CODE_SCHEME_SELECTOR**

Coding Scheme Compatibility

*Found in: Component config > eFuse Bit Manager*

Selector eFuse code scheme.

Available options:

- None Only (CONFIG_EFUSE_CODE_SCHEME_COMPAT_NONE)
- 3/4 and None (CONFIG_EFUSE_CODE_SCHEME_COMPAT_3_4)
- Repeat, 3/4 and None (common table does not support it) (CONFIG_EFUSE_CODE_SCHEME_COMPAT_REPEAT)

**ESP-TLS**

Contains:

- **CONFIG_ESP_TLS_INSECURE**
- **CONFIG_ESP_TLS_LIBRARY_CHOOSE**
- **CONFIG_ESP_TLS_CLIENT_SESSION_TICKETS**
- **CONFIG_ESP_DEBUG_WOLFSSL**
- **CONFIG_ESP_TLS_SERVER**
- **CONFIG_ESP_TLS_PSK_VERIFICATION**
- **CONFIG_WOLFSSL_SMALL_CERT_VERIFY**
- **CONFIG_ESP_TLS_USE_DS_PERIPHERAL**
- **CONFIG_ESP_TLS_USE_SECURE_ELEMENT**

**CONFIG_ESP_TLS_LIBRARY_CHOOSE**

Choose SSL/TLS library for ESP-TLS (See help for more Info)

*Found in: Component config > ESP-TLS*

The ESP-TLS APIs support multiple backend TLS libraries. Currently mbedTLS and WolfSSL are supported. Different TLS libraries may support different features and have different resource usage. Consult the ESP-TLS documentation in ESP-IDF Programming guide for more details.

Available options:

- mbedTLS (CONFIG_ESP_TLS_USING_MBEDTLS)
- wolfSSL (License info in wolfSSL directory README) (CONFIG_ESP_TLS_USING_WOLFSSL)

**CONFIG_ESP_TLS_USE_SECURE_ELEMENT**

Use Secure Element (ATECC608A) with ESP-TLS

*Found in: Component config > ESP-TLS*

Enable use of Secure Element for ESP-TLS, this enables internal support for ATECC608A peripheral on ESPWROOM32SE, which can be used for TLS connection.
**CONFIG_ESP_TLS_USE_DS_PERIPHERAL**

Use Digital Signature (DS) Peripheral with ESP-TLS

*Found in: Component config > ESP-TLS*

Enable use of the Digital Signature Peripheral for ESP-TLS. The DS peripheral can only be used when it is appropriately configured for TLS. Consult the ESP-TLS documentation in ESP-IDF Programming Guide for more details.

**Default value:**

- Yes (enabled) if `CONFIG_ESP_TLS_USING_MBEDTLS` && `SOC_DIG_SIGN_SUPPORTED`

**CONFIG_ESP_TLS_CLIENT_SESSION_TICKETS**

Enable client session tickets

*Found in: Component config > ESP-TLS*

Enable session ticket support as specified in RFC5077.

**CONFIG_ESP_TLS_SERVER**

Enable ESP-TLS Server

*Found in: Component config > ESP-TLS*

Enable support for creating server side SSL/TLS session, available for mbedTLS as well as wolfSSL TLS library.

**CONFIG_ESP_TLS_SERVER_SESSION_TICKETS**

Enable server session tickets

*Found in: Component config > ESP-TLS > CONFIG_ESP_TLS_SERVER*

Enable session ticket support as specified in RFC5077.

**CONFIG_ESP_TLS_SERVER_SESSION_TICKET_TIMEOUT**

Server session ticket timeout in seconds

*Found in: Component config > ESP-TLS > CONFIG_ESP_TLS_SERVER > CONFIG_ESP_TLS_SERVER_SESSION_TICKETS*

Sets the session ticket timeout used in the TLS server.

**Default value:**

- 86400 if `CONFIG_ESP_TLS_SERVER_SESSION_TICKETS`

**CONFIG_ESP_TLS_SERVER_CERT_SELECT_HOOK**

Certificate selection hook

*Found in: Component config > ESP-TLS > CONFIG_ESP_TLS_SERVER*

Ability to configure and use a certificate selection callback during server handshake, to select a certificate to present to the client based on the TLS extensions supplied in the client hello (alpn, sni, etc).
CONFIG_ESP_TLS_SERVER_MIN_AUTH_MODE_OPTIONAL

ESP-TLS Server: Set minimum Certificate Verification mode to Optional

*Found in: Component config > ESP-TLS > CONFIG_ESP_TLS_SERVER*

When this option is enabled, the peer (here, the client) certificate is checked by the server, however the handshake continues even if verification failed. By default, the peer certificate is not checked and ignored by the server.

`mbedtls_ssl_get_verify_result()` can be called after the handshake is complete to retrieve status of verification.

CONFIG_ESP_TLS_PSK_VERIFICATION

Enable PSK verification

*Found in: Component config > ESP-TLS*

Enable support for pre shared key ciphers, supported for both mbedTLS as well as wolfSSL TLS library.

CONFIG_ESP_TLS_INSECURE

Allow potentially insecure options

*Found in: Component config > ESP-TLS*

You can enable some potentially insecure options. These options should only be used for testing purposes. Only enable these options if you are very sure.

CONFIG_ESP_TLS_SKIP_SERVER_CERT_VERIFY

Skip server certificate verification by default (WARNING: ONLY FOR TESTING PURPOSE, READ HELP)

*Found in: Component config > ESP-TLS > CONFIG_ESP_TLS_INSECURE*

After enabling this option the esp-tls client will skip the server certificate verification by default. Note that this option will only modify the default behaviour of esp-tls client regarding server cert verification. The default behaviour should only be applicable when no other option regarding the server cert verification is opted in the esp-tls config (e.g. `crt_bundle_attach`, `use_global_ca_store` etc.). WARNING : Enabling this option comes with a potential risk of establishing a TLS connection with a server which has a fake identity, provided that the server certificate is not provided either through API or other mechanism like `ca_store` etc.

CONFIG_ESP_WOLFSSL_SMALL_CERT_VERIFY

Enable SMALL_CERT_VERIFY

*Found in: Component config > ESP-TLS*

Enables server verification with Intermediate CA cert, does not authenticate full chain of trust upto the root CA cert (After Enabling this option client only needs to have Intermediate CA certificate of the server to authenticate server, root CA cert is not necessary).

**Default value:**
- Yes (enabled) if `CONFIG_ESP_TLS_USING_WOLFSSL`

CONFIG_ESP_DEBUG_WOLFSSL

Enable debug logs for wolfSSL

*Found in: Component config > ESP-TLS*

Enable detailed debug prints for wolfSSL SSL library.
ADC and ADC Calibration

Contains:

- ADC Calibration Configurations
- CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE
- CONFIG_ADC_DISABLE_DAC_OUTPUT
- CONFIG_ADC_ONESHOT_CTRL_FUNC_IN_IRAM

CONFIG_ADC_ONESHOT_CTRL_FUNC_IN_IRAM

Place ISR version ADC oneshot mode read function into IRAM

*Found in: Component config > ADC and ADC Calibration*

Place ISR version ADC oneshot mode read function into IRAM.

**Default value:**
- No (disabled)

CONFIG_ADC_CONTINUOUS_ISR_IRAM_SAFE

ADC continuous mode driver ISR IRAM-Safe

*Found in: Component config > ADC and ADC Calibration*

Ensure the ADC continuous mode ISR is IRAM-Safe. When enabled, the ISR handler will be available when the cache is disabled.

**Default value:**
- No (disabled)

ADC Calibration Configurations

Contains:

- CONFIG_ADC_CALI_EFUSE_VREF_ENABLE
- CONFIG_ADC_CALI_LUT_ENABLE
- CONFIG_ADC_CALI_EFUSE_TP_ENABLE

CONFIG_ADC_CALI_EFUSE_TP_ENABLE

Use Two Point Values

*Found in: Component config > ADC and ADC Calibration > ADC Calibration Configurations*

Some ESP32s have Two Point calibration values burned into eFuse BLOCK3. This option will allow the ADC calibration component to characterize the ADC-Voltage curve using Two Point values if they are available.

**Default value:**
- Yes (enabled)

CONFIG_ADC_CALI_EFUSE_VREF_ENABLE

Use eFuse Vref

*Found in: Component config > ADC and ADC Calibration > ADC Calibration Configurations*

Some ESP32s have Vref burned into eFuse BLOCK0. This option will allow the ADC calibration component to characterize the ADC-Voltage curve using eFuse Vref if it is available.

**Default value:**
- Yes (enabled)
CONFIG_ADC_CALI_LUT_ENABLE

Use Lookup Tables

*Found in: Component config > ADC and ADC Calibration > ADC Calibration Configurations*

This option will allow the ADC calibration component to use Lookup Tables to correct for non-linear behavior in 11db attenuation. Other attenuations do not exhibit non-linear behavior hence will not be affected by this option.

**Default value:**
- Yes (enabled)

CONFIG_ADC_DISABLE_DAC_OUTPUT

Disable DAC when ADC2 is in use

*Found in: Component config > ADC and ADC Calibration*

By default, this is set. The ADC oneshot driver will disable the output of the corresponding DAC channels: ESP32: IO25 and IO26 ESP32S2: IO17 and IO18

Disable this option so as to measure the output of DAC by internal ADC, for test usage.

**Default value:**
- Yes (enabled)

Wireless Coexistence  Contains:

- CONFIG_ESP_COEX_SW_COEXIST_ENABLE

CONFIG_ESP_COEX_SW_COEXIST_ENABLE

Software controls WiFi/Bluetooth coexistence

*Found in: Component config > Wireless Coexistence*

If enabled, WiFi & Bluetooth coexistence is controlled by software rather than hardware. Recommended for heavy traffic scenarios. Both coexistence configuration options are automatically managed, no user intervention is required. If only Bluetooth is used, it is recommended to disable this option to reduce binary file size.

**Default value:**
- Yes (enabled) if CONFIG_BT_ENABLED

Common ESP-related  Contains:

- CONFIG_ESP_ERR_TO_NAME_LOOKUP

CONFIG_ESP_ERR_TO_NAME_LOOKUP

Enable lookup of error code strings

*Found in: Component config > Common ESP-related*

Functions esp_err_to_name() and esp_err_to_name_r() return string representations of error codes from a pre-generated lookup table. This option can be used to turn off the use of the look-up table in order to save memory but this comes at the price of sacrificing distinguishable (meaningful) output string representations.

**Default value:**
- Yes (enabled)
Ethernet  Contains:

- CONFIG_ETH_TRANSMIT_MUTEX
- CONFIG_ETH_USE_ESP32_EMAC
- CONFIG_ETH_USE_OPENETH
- CONFIG_ETH_USE_SPI_ETHERNET

**CONFIG_ETH_USE_ESP32_EMAC**

Support ESP32 internal EMAC controller

*Found in: Component config > Ethernet*

ESP32 integrates a 10/100M Ethernet MAC controller.

**Default value:**

- Yes (enabled)

Contains:

- CONFIG_ETH_DMA_RX_BUFFER_NUM
- CONFIG_ETH_DMA_TX_BUFFER_NUM
- CONFIG_ETH_IRAM_OPTIMIZATION
- CONFIG_ETH_SOFT_FLOW_CONTROL
- CONFIG_ETH_DMA_BUFFER_SIZE
- CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0
- CONFIG_ETH_PHY_INTERFACE
- CONFIG_ETH_RMII_CLK_OUTPUT_GPIO
- CONFIG_ETH_RMII_CLK_MODE

**CONFIG_ETH_PHY_INTERFACE**

PHY interface

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Select the communication interface between MAC and PHY chip.

Available options:

- Reduced Media Independent Interface (RMII) (CONFIG_ETH_PHY_INTERFACE_RMII)

**CONFIG_ETH_RMII_CLK_MODE**

RMII clock mode

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Select external or internal RMII clock.

Available options:

- Input RMII clock from external (CONFIG_ETH_RMII_CLK_INPUT)
  MAC will get RMII clock from outside. Note that ESP32 only supports GPIO0 to input the RMII clock.
- Output RMII clock from internal (CONFIG_ETH_RMII_CLK_OUTPUT)
  ESP32 can generate RMII clock by internal APLL. This clock can be routed to the external PHY device. ESP32 supports to route the RMII clock to GPIO0/16/17.
**CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0**

Output RMII clock from GPIO0 (Experimental!)

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

GPIO0 can be set to output a pre-divided PLL clock (test only!). Enabling this option will configure GPIO0 to output a 50MHz clock. In fact this clock doesn’t have directly relationship with EMAC peripheral. Sometimes this clock won’t work well with your PHY chip. You might need to add some extra devices after GPIO0 (e.g. inverter). Note that outputting RMII clock on GPIO0 is an experimental practice. If you want the Ethernet to work with WiFi, don’t select GPIO0 output mode for stability.

**Default value:**
- **No** (disabled) if `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0` and `CONFIG_ETH_USE_ESP32_EMAC`

**CONFIG_ETH_RMII_CLK_OUT_GPIO**

RMII clock GPIO number

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Set the GPIO number to output RMII Clock.

**Range:**
- **from 16 to 17** if `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0` and `CONFIG_ETH_USE_ESP32_EMAC`

**Default value:**
- **17** if `CONFIG_ETH_RMII_CLK_OUTPUT_GPIO0` and `CONFIG_ETH_USE_ESP32_EMAC`

**CONFIG_ETH_DMA_BUFFER_SIZE**

Ethernet DMA buffer size (Byte)

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Set the size of each buffer used by Ethernet MAC DMA.

**Range:**
- **from 256 to 1600**

**Default value:**
- **512**

**CONFIG_ETH_DMA_RX_BUFFER_NUM**

Amount of Ethernet DMA Rx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Number of DMA receive buffers. Each buffer’s size is ETH_DMA_BUFFER_SIZE. Larger number of buffers could increase throughput somehow.

**Range:**
- **from 3 to 30**

**Default value:**
- **10**

**CONFIG_ETH_DMA_TX_BUFFER_NUM**

Amount of Ethernet DMA Tx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*
Number of DMA transmit buffers. Each buffer’s size is ETH_DMA_BUFFER_SIZE. Larger number of buffers could increase throughput somehow.

**Range:**
- from 3 to 30

**Default value:**
- 10

---

**CONFIG_ETH_SOFT_FLOW_CONTROL**

Enable software flow control

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

Ethernet MAC engine on ESP32 doesn’t feature a flow control logic. The MAC driver can perform a software flow control if you enable this option. Note that, if the RX buffer number is small, enabling software flow control will cause obvious performance loss.

**Default value:**
- No (disabled) if `CONFIG_ETH_DMA_RX_BUFFER_NUM > 15` && `CONFIG_ETH_USE_ESP32_EMAC`

---

**CONFIG_ETH_IRAM_OPTIMIZATION**

Enable IRAM optimization

*Found in: Component config > Ethernet > CONFIG_ETH_USE_ESP32_EMAC*

If enabled, functions related to RX/TX are placed into IRAM. It can improve Ethernet throughput. If disabled, all functions are placed into FLASH.

**Default value:**
- No (disabled)

---

**CONFIG_ETH_USE_SPI_ETHERNET**

Support SPI to Ethernet Module

*Found in: Component config > Ethernet*

ESP-IDF can also support some SPI-Ethernet modules.

**Default value:**
- Yes (enabled)

Contains:
- `CONFIG_ETH_SPI_ETHERNET_DM9051`
- `CONFIG_ETH_SPI_ETHERNET_KSZ8851SNL`
- `CONFIG_ETH_SPI_ETHERNET_W5500`

---

**CONFIG_ETH_SPI_ETHERNET_DM9051**

Use DM9051

*Found in: Component config > Ethernet > CONFIG_ETH_USE_SPI_ETHERNET*

DM9051 is a fast Ethernet controller with an SPI interface. It’s also integrated with a 10/100M PHY and MAC. Select this to enable DM9051 driver.
CONFIG_ETH_SPI_ETHERNET_W5500

Use W5500 (MAC RAW)

*Found in: Component config > Ethernet > CONFIG_ETH_USE_SPI_ETHERNET*

W5500 is a HW TCP/IP embedded Ethernet controller. TCP/IP stack, 10/100 Ethernet MAC and PHY are embedded in a single chip. However the driver in ESP-IDF only enables the RAW MAC mode, making it compatible with the software TCP/IP stack. Say yes to enable W5500 driver.

CONFIG_ETH_SPI_ETHERNET_KSZ8851SNL

Use KSZ8851SNL

*Found in: Component config > Ethernet > CONFIG_ETH_USE_SPI_ETHERNET*

The KSZ8851SNL is a single-chip Fast Ethernet controller consisting of a 10/100 physical layer transceiver (PHY), a MAC, and a Serial Peripheral Interface (SPI). Select this to enable KSZ8851SNL driver.

CONFIG_ETH_USE_OPENETH

Support OpenCores Ethernet MAC (for use with QEMU)

*Found in: Component config > Ethernet*

OpenCores Ethernet MAC driver can be used when an ESP-IDF application is executed in QEMU. This driver is not supported when running on a real chip.

Default value:
- No (disabled)

Contains:
- CONFIG_ETH_OPENETH_DMA_RX_BUFFER_NUM
- CONFIG_ETH_OPENETH_DMA_TX_BUFFER_NUM

CONFIG_ETH_OPENETH_DMA_RX_BUFFER_NUM

Number of Ethernet DMA Rx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_OPENETH*

Number of DMA receive buffers, each buffer is 1600 bytes.

Range:
- from 1 to 64 if CONFIG_ETH_USE_OPENETH

Default value:
- 4 if CONFIG_ETH_USE_OPENETH

CONFIG_ETH_OPENETH_DMA_TX_BUFFER_NUM

Number of Ethernet DMA Tx buffers

*Found in: Component config > Ethernet > CONFIG_ETH_USE_OPENETH*

Number of DMA transmit buffers, each buffer is 1600 bytes.

Range:
- from 1 to 64 if CONFIG_ETH_USE_OPENETH

Default value:
- 1 if CONFIG_ETH_USE_OPENETH
**CONFIG_ETH_TRANSMIT_MUTEX**

Enable Transmit Mutex

*Found in: Component config > Ethernet*

Prevents multiple accesses when Ethernet interface is used as shared resource and multiple functionalities might try to access it at a time.

**Default value:**
- No (disabled)

**Event Loop Library**

Contains:

- `CONFIG_ESP_EVENT_LOOP_PROFILING`
- `CONFIG_ESP_EVENT_POST_FROM_ISR`

**CONFIG_ESP_EVENT_LOOP_PROFILING**

Enable event loop profiling

*Found in: Component config > Event Loop Library*

Enables collections of statistics in the event loop library such as the number of events posted to/recieved by an event loop, number of callbacks involved, number of events dropped to to a full event loop queue, run time of event handlers, and number of times/run time of each event handler.

**Default value:**
- No (disabled)

**CONFIG_ESP_EVENT_POST_FROM_ISR**

Support posting events from ISRs

*Found in: Component config > Event Loop Library*

Enable posting events from interrupt handlers.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR**

Support posting events from ISRs placed in IRAM

*Found in: Component config > Event Loop Library > CONFIG_ESP_EVENT_POST_FROM_ISR*

Enable posting events from interrupt handlers placed in IRAM. Enabling this option places API functions `esp_event_post` and `esp_event_post_to` in IRAM.

**Default value:**
- Yes (enabled)

**GDB Stub**

Contains:

- `CONFIG_ESP_GDBSTUB_SUPPORT_TASKS`
CONFIG_ESP_GDBSTUB_SUPPORT_TASKS
Enable listing FreeRTOS tasks through GDB Stub

*Found in: Component config > GDB Stub*

If enabled, GDBStub can supply the list of FreeRTOS tasks to GDB. Thread list can be queried from GDB using ‘info threads’ command. Note that if GDB task lists were corrupted, this feature may not work. If GDBStub fails, try disabling this feature.

CONFIG_ESP_GDBSTUB_MAX_TASKS
Maximum number of tasks supported by GDB Stub

*Found in: Component config > GDB Stub > CONFIG_ESP_GDBSTUB_SUPPORT_TASKS*

Set the number of tasks which GDB Stub will support.

*Default value:*
- 32 if CONFIG_ESP_GDBSTUB_SUPPORT_TASKS

ESP HTTP client Contains:
- CONFIG_ESP_HTTP_CLIENT_ENABLE_BASIC_AUTH
- CONFIG_ESP_HTTP_CLIENT_ENABLE_DIGEST_AUTH
- CONFIG_ESP_HTTP_CLIENT_ENABLE_HTTPS

CONFIG_ESP_HTTP_CLIENT_ENABLE_HTTPS
Enable https

*Found in: Component config > ESP HTTP client*

This option will enable https protocol by linking esp-tls library and initializing SSL transport

*Default value:*
- Yes (enabled)

CONFIG_ESP_HTTP_CLIENT_ENABLE_BASIC_AUTH
Enable HTTP Basic Authentication

*Found in: Component config > ESP HTTP client*

This option will enable HTTP Basic Authentication. It is disabled by default as Basic auth uses unencrypted encoding, so it introduces a vulnerability when not using TLS

*Default value:*
- No (disabled)

CONFIG_ESP_HTTP_CLIENT_ENABLE_DIGEST_AUTH
Enable HTTP Digest Authentication

*Found in: Component config > ESP HTTP client*

This option will enable HTTP Digest Authentication. It is enabled by default, but use of this configuration is not recommended as the password can be derived from the exchange, so it introduces a vulnerability when not using TLS

*Default value:*
- No (disabled)
HTTP Server  Contains:

- CONFIG_HTTPD_QUEUE_WORK_BLOCKING
- CONFIG_HTTPD_PURGE_BUF_LEN
- CONFIG_HTTPD_LOG_PURGE_DATA
- CONFIG_HTTPD_MAX_REQ_HDR_LEN
- CONFIG_HTTPD_MAX_URI_LEN
- CONFIG_HTTPD_ERR_RESP_NO_DELAY
- CONFIG_HTTPD_WS_SUPPORT

CONFIG_HTTPD_MAX_REQ_HDR_LEN

Max HTTP Request Header Length

*Found in: Component config > HTTP Server*

This sets the maximum supported size of headers section in HTTP request packet to be processed by the server

**Default value:**
- 512

CONFIG_HTTPD_MAX_URI_LEN

Max HTTP URI Length

*Found in: Component config > HTTP Server*

This sets the maximum supported size of HTTP request URI to be processed by the server

**Default value:**
- 512

CONFIG_HTTPD_ERR_RESP_NO_DELAY

Use TCP_NODELAY socket option when sending HTTP error responses

*Found in: Component config > HTTP Server*

Using TCP_NODEALY socket option ensures that HTTP error response reaches the client before the underlying socket is closed. Please note that turning this off may cause multiple test failures

**Default value:**
- Yes (enabled)

CONFIG_HTTPD_PURGE_BUF_LEN

Length of temporary buffer for purging data

*Found in: Component config > HTTP Server*

This sets the size of the temporary buffer used to receive and discard any remaining data that is received from the HTTP client in the request, but not processed as part of the server HTTP request handler.

If the remaining data is larger than the available buffer size, the buffer will be filled in multiple iterations. The buffer should be small enough to fit on the stack, but large enough to avoid excessive iterations.

**Default value:**
- 32
Chapter 2. API Reference

CONFIG_HTTPD_LOG_PURGE_DATA
Log purged content data at Debug level

*Found in: Component config > HTTP Server*

Enabling this will log discarded binary HTTP request data at Debug level. For large content data this may not be desirable as it will clutter the log.

**Default value:**
- No (disabled)

CONFIG_HTTPD_WS_SUPPORT
WebSocket server support

*Found in: Component config > HTTP Server*

This sets the WebSocket server support.

**Default value:**
- No (disabled)

CONFIG_HTTPD_QUEUE_WORK_BLOCKING
httpd_queue_work as blocking API

*Found in: Component config > HTTP Server*

This makes httpd_queue_work() API to wait until a message space is available on UDP control socket. It internally uses a counting semaphore with count set to LWIP_UDP_RECVMBOX_SIZE to achieve this. This config will slightly change API behavior to block until message gets delivered on control socket.

ESP HTTPS OTA  Contains:
- CONFIG_ESP_HTTPS_OTA_ALLOW_HTTP
- CONFIG_ESP_HTTPS_OTA_DECRYPT_CB

CONFIG_ESP_HTTPS_OTA_DECRYPT_CB
Provide decryption callback

*Found in: Component config > ESP HTTPS OTA*

Exposes an additional callback whereby firmware data could be decrypted before being processed by OTA update component. This can help to integrate external encryption related format and removal of such encapsulation layer from firmware image.

**Default value:**
- No (disabled)

CONFIG_ESP_HTTPS_OTA_ALLOW_HTTP
Allow HTTP for OTA (WARNING: ONLY FOR TESTING PURPOSE, READ HELP)

*Found in: Component config > ESP HTTPS OTA*

It is highly recommended to keep HTTPS (along with server certificate validation) enabled. Enabling this option comes with potential risk of:
- Non-encrypted communication channel with server
- Accepting firmware upgrade image from server with fake identity

**Default value:**
- No (disabled)
Chapter 2. API Reference

ESP HTTPS server  Contains:
  •  CONFIG_ESP_HTTPS_SERVER_ENABLE

CONFIG_ESP_HTTPS_SERVER_ENABLE
  Enable ESP_HTTPS_SERVER component
  Found in: Component config > ESP HTTPS server
  Enable ESP HTTPS server component

Hardware Settings  Contains:
  •  Chip revision
  •  Crypto DPA Protection
  •  ESP_SLEEP_WORKAROUND
  •  ETM Configuration
  •  GDMA Configuration
  •  MAC Config
  •  Main XTAL Config
  •  Peripheral Control
  •  RTC Clock Config
  •  Sleep Config

Chip revision  Contains:
  •  CONFIG_ESP_REV_NEW_CHIP_TEST
  •  CONFIG_ESP32_REV_MIN

CONFIG_ESP32_REV_MIN
  Minimum Supported ESP32 Revision
  Found in: Component config > Hardware Settings > Chip revision
  Required minimum chip revision. ESP-IDF will check for it and reject to boot if the chip revision fails
  the check. This ensures the chip used will have some modifications (features, or bugfixes).
  The complied binary will only support chips above this revision, this will also help to reduce binary size.
  Available options:
    •  Rev v0.0 (ECO0) (CONFIG_ESP32_REV_MIN_0)
    •  Rev v1.0 (ECO1) (CONFIG_ESP32_REV_MIN_1)
    •  Rev v1.1 (ECO1.1) (CONFIG_ESP32_REV_MIN_1_1)
    •  Rev v2.0 (ECO2) (CONFIG_ESP32_REV_MIN_2)
    •  Rev v3.0 (ECO3) (CONFIG_ESP32_REV_MIN_3)
    •  Rev v3.1 (ECO4) (CONFIG_ESP32_REV_MIN_3_1)

CONFIG_ESP_REV_NEW_CHIP_TEST
  Internal test mode
  Found in: Component config > Hardware Settings > Chip revision
  For internal chip testing, a small number of new versions chips didn’t update the version field in eFuse,
  you can enable this option to force the software recognize the chip version based on the rev selected in
  menuconfig.
  Default value:
Chapter 2. API Reference

MAC Config Contains:

- CONFIG_ESP_MAC_IGNORE_MAC_CRC_ERROR
- CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES

CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES

Number of universally administered (by IEEE) MAC address

Found in: Component config > Hardware Settings > MAC Config

Configure the number of universally administered (by IEEE) MAC addresses. During initialization, MAC addresses for each network interface are generated or derived from a single base MAC address. If the number of universal MAC addresses is four, all four interfaces (WiFi station, WiFi softap, Bluetooth and Ethernet) receive a universally administered MAC address. These are generated sequentially by adding 0, 1, 2 and 3 (respectively) to the final octet of the base MAC address. If the number of universal MAC addresses is two, only two interfaces (WiFi station and Bluetooth) receive a universally administered MAC address. These are generated sequentially by adding 0 and 1 (respectively) to the base MAC address. The remaining two interfaces (WiFi softap and Ethernet) receive local MAC addresses. These are derived from the universal WiFi station and Bluetooth MAC addresses, respectively. When using the default (Espressif-assigned) base MAC address, either setting can be used. When using a custom universal MAC address range, the correct setting will depend on the allocation of MAC addresses in this range (either 2 or 4 per device.)

Available options:

- Two (CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES_TWO)
- Four (CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES_FOUR)

CONFIG_ESP_MAC_IGNORE_MAC_CRC_ERROR

Ignore MAC CRC error (not recommended)

Found in: Component config > Hardware Settings > MAC Config

If you have an invalid MAC CRC (ESP_ERR_INVALID_CRC) problem and you still want to use this chip, you can enable this option to bypass such an error. This applies to both MAC_FACTORY and CUSTOM_MAC efuses.

Default value:

- No (disabled)

Sleep Config Contains:

- CONFIG_ESP_SLEEP_GPIO_ENABLE_INTERNAL_RESISTORS
- CONFIG_ESP_SLEEP_DEEP_SLEEP_WAKEUP_DELAY
- CONFIG_ESP_SLEEP_GPIO_RESET_WORKAROUND
- CONFIG_ESP_SLEEP_POWER_DOWN_FLASH
- CONFIG_ESP_SLEEP_MSPI_NEED_ALL_IO_PU
- CONFIG_ESP_SLEEP_FLASH_LEAKAGE_WORKAROUND
- CONFIG_ESP_SLEEP_PSRAM_LEAKAGE_WORKAROUND

CONFIG_ESP_SLEEP_POWER_DOWN_FLASH

Power down flash in light sleep when there is no SPIRAM

Found in: Component config > Hardware Settings > Sleep Config
If enabled, chip will try to power down flash as part of esp_light_sleep_start(), which costs more time when chip wakes up. Can only be enabled if there is no SPIRAM configured.

This option will power down flash under a strict but relatively safe condition. Also, it is possible to power down flash under a relaxed condition by using esp_sleep_pd_config() to set ESP_PD_DOMAIN_VDDSDIO to ESP_PD_OPTION_OFF. It should be noted that there is a risk in powering down flash, you can refer ESP-IDF Programming Guide/API Reference/System API/Sleep Modes/Power-down of Flash for more details.

**Default value:**
- No (disabled) if CONFIG_SPIRAM

**CONFIG_ESP_SLEEP_FLASH_LEAKAGE_WORKAROUND**

Pull-up Flash CS pin in light sleep

*Found in: Component config > Hardware Settings > Sleep Config*

All IOs will be set to isolate(floating) state by default during sleep. Since the power supply of SPI Flash is not lost during lightsleep, if its CS pin is recognized as low level(selected state) in the floating state, there will be a large current leakage, and the data in Flash may be corrupted by random signals on other SPI pins. Select this option will set the CS pin of Flash to PULL-UP state during sleep, but this will increase the sleep current about 10 uA. If you are developing with esp32xx modules, you must select this option, but if you are developing with chips, you can also pull up the CS pin of SPI Flash in the external circuit to save power consumption caused by internal pull-up during sleep. (!!! Don’t deselect this option if you don’t have external SPI Flash CS pin pullups.)

**Default value:**
- Yes (enabled) if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP && CONFIG_ESP_SLEEP_POWER_DOWN_FLASH

**CONFIG_ESP_SLEEP_PSRAM_LEAKAGE_WORKAROUND**

Pull-up PSRAM CS pin in light sleep

*Found in: Component config > Hardware Settings > Sleep Config*

All IOs will be set to isolate(floating) state by default during sleep. Since the power supply of PSRAM is not lost during lightsleep, if its CS pin is recognized as low level(selected state) in the floating state, there will be a large current leakage, and the data in PSRAM may be corrupted by random signals on other SPI pins. Select this option will set the CS pin of PSRAM to PULL-UP state during sleep, but this will increase the sleep current about 10 uA. If you are developing with esp32xx modules, you must select this option, but if you are developing with chips, you can also pull up the CS pin of PSRAM in the external circuit to save power consumption caused by internal pull-up during sleep. (!!! Don’t deselect this option if you don’t have external PSRAM CS pin pullups.)

**Default value:**
- Yes (enabled) if CONFIG_SPIRAM

**CONFIG_ESP_SLEEP_MSPI_NEED_ALL_IO_PU**

Pull-up all SPI pins in light sleep

*Found in: Component config > Hardware Settings > Sleep Config*

To reduce leakage current, some types of SPI Flash/RAM only need to pull up the CS pin during light sleep. But there are also some kinds of SPI Flash/RAM that need to pull up all pins. It depends on the SPI Flash/RAM chip used.
CONFIG_ESP_SLEEP_GPIO_RESET_WORKAROUND

light sleep GPIO reset workaround

*Found in: Component config > Hardware Settings > Sleep Config*

esp32c2, esp32c3, esp32s3, esp32c6 and esp32h2 will reset at wake-up if GPIO is received a small electrostatic pulse during light sleep, with specific condition

- GPIO needs to be configured as input-mode only
- The pin receives a small electrostatic pulse, and reset occurs when the pulse voltage is higher than 6 V

For GPIO set to input mode only, it is not a good practice to leave it open/floating. The hardware design needs to controlled it with determined supply or ground voltage is necessary.

This option provides a software workaround for this issue. Configure to isolate all GPIO pins in sleep state.

CONFIG_ESP_SLEEP_DEEP_SLEEP_WAKEUP_DELAY

Extra delay in deep sleep wake stub (in us)

*Found in: Component config > Hardware Settings > Sleep Config*

When the chip exits deep sleep, the CPU and the flash chip are powered on at the same time. CPU will run deep sleep stub first, and then proceed to load code from flash. Some flash chips need sufficient time to pass between power on and first read operation. By default, without any extra delay, this time is approximately 900us, although some flash chip types need more than that.

By default extra delay is set to 2000us. When optimizing startup time for applications which require it, this value may be reduced.

If you are seeing “flash read err, 1000” message printed to the console after deep sleep reset, try increasing this value.

*Range:*
- from 0 to 5000

*Default value:*
- 2000

CONFIG_ESP_SLEEP_GPIO_ENABLE_INTERNAL_RESISTORS

Allow to enable internal pull-up/downs for the Deep-Sleep wakeup IOs

*Found in: Component config > Hardware Settings > Sleep Config*

When using rtc gpio wakeup source during deepsleep without external pull-up/downs, you may want to make use of the internal ones.

*Default value:*
- Yes (enabled)

ESP_SLEEP_WORKAROUND

RTC Clock Config  Contains:

- CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT_METHOD
- CONFIG_RTC_XTAL_CAL_RETRY
- CONFIG_RTC_CLK_CAL_CYCLES
- CONFIG_RTC_CLK_SRC
CONFIG_RTC_CLK_SRC

RTC clock source

*Found in:* Component config > Hardware Settings > RTC Clock Config

Choose which clock is used as RTC clock source.

- **“Internal 150kHz oscillator” option provides lowest deep sleep current** consumption, and does not require extra external components. However frequency stability with respect to temperature is poor, so time may drift in deep/light sleep modes.

- **“External 32kHz crystal” provides better frequency stability, at the expense of slightly higher** (1uA) deep sleep current consumption.

- **“External 32kHz oscillator” allows using 32kHz clock generated by an external circuit. In this case, external clock signal must be connected to 32K_XN pin. Amplitude should be <1.2V in case of sine wave signal, and <1V in case of square wave signal. Common mode voltage should be 0.1 < Vcm < 0.5Vamp, where Vamp is the signal amplitude. Additionally, 1nF capacitor must be connected between 32K_XP pin and ground. 32K_XP pin cannot be used as a GPIO in this case.**

- **“Internal 8.5MHz oscillator divided by 256” option results in higher** deep sleep current (by 5uA) but has better frequency stability than the internal 150kHz oscillator. It does not require external components.

Available options:

- Internal 150kHz RC oscillator (CONFIG_RTC_CLK_SRC_INT_RC)
- External 32kHz crystal (CONFIG_RTC_CLK_SRC_EXT_CRYST)
- External 32kHz oscillator at 32K_XN pin (CONFIG_RTC_CLK_SRC_EXT_OSC)
- Internal 8.5MHz oscillator, divided by 256 (~33kHz) (CONFIG_RTC_CLK_SRC_INT_8MD256)

CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT_METHOD

Additional current for external 32kHz crystal

*Found in:* Component config > Hardware Settings > RTC Clock Config

With some 32kHz crystal configurations, the X32N and X32P pins may not have enough drive strength to keep the crystal oscillating. Choose the method to provide additional current from touchpad 9 to the external 32kHz crystal. Note that the deep sleep current is slightly high (4-5uA) and the touchpad and the wakeup sources of both touchpad and ULP are not available in method 1 and method 2.

This problem is fixed in ESP32 ECO 3, so this workaround is not needed. Setting the project configuration to minimum revision ECO3 will disable this option, all allow all wakeup sources, and save some code size.

- **“None” option will not provide additional current to external crystal**
- **“Method 1” option can’t ensure 100% to solve the external 32k crystal start failed issue, but the touchpad can work in this method.**
- **“Method 2” option can solve the external 32k issue, but the touchpad can’t work in this method.**

Available options:

- None (CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT_NONE)
- Method 1 (CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT)
- Method 2 (CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT_V2)
**CONFIG_RTC_CLK_CAL_CYCLES**

Number of cycles for RTC_SLOW_CLK calibration

*Found in: Component config > Hardware Settings > RTC Clock Config*

When the startup code initializes RTC_SLOW_CLK, it can perform calibration by comparing the RTC_SLOW_CLK frequency with main XTAL frequency. This option sets the number of RTC_SLOW_CLK cycles measured by the calibration routine. Higher numbers increase calibration precision, which may be important for applications which spend a lot of time in deep sleep. Lower numbers reduce startup time.

When this option is set to 0, clock calibration will not be performed at startup, and approximate clock frequencies will be assumed:

- **150000 Hz** if internal RC oscillator is used as clock source. For this use value 1024.
- **32768 Hz** if the 32k crystal oscillator is used. For this use value **3000 or more**. In case more value will help improve the definition of the launch of the crystal. If the crystal could not start, it will be switched to internal RC.

*Range:*
- from 0 to 27000 if **CONFIG_RTC_CLK_SRC_EXT_CRYS** || **CONFIG_RTC_CLK_SRC_EXT_OSC** || **CONFIG_RTC_CLK_SRC_INT_8MD256**
- from 0 to 32766

*Default value:*
- **3000** if **CONFIG_RTC_CLK_SRC_EXT_CRYS** || **CONFIG_RTC_CLK_SRC_EXT_OSC** || **CONFIG_RTC_CLK_SRC_INT_8MD256**
- **1024**

**CONFIG_RTC_XTAL_CAL_RETRY**

Number of attempts to repeat 32k XTAL calibration

*Found in: Component config > Hardware Settings > RTC Clock Config*

Number of attempts to repeat 32k XTAL calibration before giving up and switching to the internal RC. Increase this option if the 32k crystal oscillator does not start and switches to internal RC.

*Default value:*
- 1 if **CONFIG_RTC_CLK_SRC_EXT_CRYS**

**Peripheral Control**  
Contains:

- **CONFIG_PERIPH_CTRL_FUNC_IN_IRAM**

**CONFIG_PERIPH_CTRL_FUNC_IN_IRAM**

Place peripheral control functions into IRAM

*Found in: Component config > Hardware Settings > Peripheral Control*

Place peripheral control functions (e.g. periph_module_reset) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context.

*Default value:*
- No (disabled)

**ETM Configuration**  
Contains:

- **CONFIG_ETM_ENABLE_DEBUG_LOG**
CONFIG_ETM_ENABLE_DEBUG_LOG

Enable debug log

Found in: Component config > Hardware Settings > ETM Configuration

Whether to enable the debug log message for ETM core driver. Note that, this option only controls the ETM related driver log, won’t affect other drivers.

Default value:
- No (disabled) if SOC_ETM_SUPPORTED

GDMA Configuration  Contains:

- CONFIG_GDMA_ISR_IRAM_SAFE
- CONFIG_GDMA_CTRL_FUNC_IN_IRAM

CONFIG_GDMA_CTRL_FUNC_IN_IRAM

Place GDMA control functions into IRAM

Found in: Component config > Hardware Settings > GDMA Configuration

Place GDMA control functions (like start/stop/append/reset) into IRAM, so that these functions can be IRAM-safe and able to be called in the other IRAM interrupt context. Enabling this option can improve driver performance as well.

Default value:
- No (disabled) if SOC_GDMA_SUPPORTED

CONFIG_GDMA_ISR_IRAM_SAFE

GDMA ISR IRAM-Safe

Found in: Component config > Hardware Settings > GDMA Configuration

This will ensure the GDMA interrupt handler is IRAM-Safe, allow to avoid flash cache misses, and also be able to run whilst the cache is disabled. (e.g. SPI Flash write).

Default value:
- No (disabled) if SOC_GDMA_SUPPORTED

Main XTAL Config  Contains:

- CONFIG_XTAL_FREQ_SEL

CONFIG_XTAL_FREQ_SEL

Main XTAL frequency

Found in: Component config > Hardware Settings > Main XTAL Config

This option selects the operating frequency of the XTAL (crystal) clock used to drive the ESP target. The selected value MUST reflect the frequency of the given hardware.

Note: The XTAL_FREQ_AUTO option allows the ESP target to automatically estimating XTAL clock’s operating frequency. However, this feature is only supported on the ESP32. The ESP32 uses the internal 8MHZ as a reference when estimating. Due to the internal oscillator’s frequency being temperature dependent, usage of the XTAL_FREQ_AUTO is not recommended in applications that operate in high ambient temperatures or use high-temperature qualified chips and modules.

Available options:
Crypto DPA Protection Contains:

- CONFIG_ESP_CRYPTO_DPA_PROTECTION_AT_STARTUP

CONFIG_ESP_CRYPTO_DPA_PROTECTION_AT_STARTUP

Enable crypto DPA protection at startup

*Found in: Component config > Hardware Settings > Crypto DPA Protection*

This config controls the DPA (Differential Power Analysis) protection knob for the crypto peripherals. DPA protection dynamically adjusts the clock frequency of the crypto peripheral. DPA protection helps to make it difficult to perform SCA attacks on the crypto peripherals. However, there is also associated performance impact based on the security level set. Please refer to the TRM for more details.

*Default value:*

- Yes (enabled) if SOC_CRYPTO_DPA_PROTECTION_SUPPORTED

CONFIG_ESP_CRYPTO_DPA_PROTECTION_LEVEL

DPA protection level

*Found in: Component config > Hardware Settings > Crypto DPA Protection > CONFIG_ESP_CRYPTO_DPA_PROTECTION_AT_STARTUP*

Configure the DPA protection security level

*Available options:*

- Security level low (CONFIG_ESP_CRYPTO_DPA_PROTECTION_LEVEL_LOW)
- Security level medium (CONFIG_ESP_CRYPTO_DPA_PROTECTION_LEVEL_MEDIUM)
- Security level high (CONFIG_ESP_CRYPTO_DPA_PROTECTION_LEVEL_HIGH)

LCD and Touch Panel Contains:

- LCD Peripheral Configuration

LCD Peripheral Configuration Contains:

- CONFIG_LCD_ENABLE_DEBUG_LOG
- CONFIG_LCD_PANEL_IO_FORMAT_BUF_SIZE
- CONFIG_LCD_RGB_RESTART_IN_VSYNC
- CONFIG_LCD_RGB_ISR_ILR_IIR_I2C_SAFE

CONFIG_LCD_PANEL_IO_FORMAT_BUF_SIZE

LCD panel io format buffer size

*Found in: Component config > LCD and Touch Panel > LCD Peripheral Configuration*

LCD driver allocates an internal buffer to transform the data into a proper format, because of the endian order mismatch. This option is to set the size of the buffer, in bytes.

*Default value:*

- 32
CONFIG_LCD_ENABLE_DEBUG_LOG

Enable debug log

*Found in: Component config > LCD and Touch Panel > LCD Peripheral Configuration*

Whether to enable the debug log message for LCD driver. Note that, this option only controls the LCD driver log, won’t affect other drivers.

**Default value:**
- No (disabled)

CONFIG_LCD_RGB_ISR_IRAM_SAFE

RGB LCD ISR IRAM-Safe

*Found in: Component config > LCD and Touch Panel > LCD Peripheral Configuration*

Ensure the LCD interrupt is IRAM-Safe by allowing the interrupt handler to be executable when the cache is disabled (e.g. SPI Flash write). If you want the LCD driver to keep flushing the screen even when cache ops disabled, you can enable this option. Note, this will also increase the IRAM usage.

**Default value:**
- No (disabled) if SOC_LCD_RGB_SUPPORTED

CONFIG_LCD_RGB_RESTART_IN_VSYNC

Restart transmission in VSYNC

*Found in: Component config > LCD and Touch Panel > LCD Peripheral Configuration*

Reset the GDMA channel every VBlank to stop permanent desyncs from happening. Only need to enable it when in your application, the DMA can’t deliver data as fast as the LCD consumes it.

**Default value:**
- No (disabled) if SOC_LCD_RGB_SUPPORTED

ESP NETIF Adapter  
Contains:

- `CONFIG_ESP_NETIF_BRIDGE_EN`
- `CONFIG_ESP_NETIF_L2_TAP`
- `CONFIG_ESP_NETIF_IP_LOST_TIMER_INTERVAL`
- `CONFIG_ESP_NETIF_USE_TCP/IP_STACK_LIB`
- `CONFIG_ESP_NETIF_RECEIVE_REPORT_ERRORS`

CONFIG_ESP_NETIF_IP_LOST_TIMER_INTERVAL

IP Address lost timer interval (seconds)

*Found in: Component config > ESP NETIF Adapter*

The value of 0 indicates the IP lost timer is disabled, otherwise the timer is enabled.

The IP address may be lost because of some reasons, e.g. when the station disconnects from soft-AP, or when DHCP IP renew fails etc. If the IP lost timer is enabled, it will be started everytime the IP is lost. Event SYSTEM_EVENT_STA_LOST_IP will be raised if the timer expires. The IP lost timer is stopped if the station get the IP again before the timer expires.

**Range:**
- from 0 to 65535

**Default value:**
- 120
CONFIG_ESP_NETIF_USE_TCPIP_STACK_LIB

TCP/IP Stack Library

Found in: Component config > ESP NETIF Adapter

Choose the TCP/IP Stack to work, for example, LwIP, uIP, etc.

Available options:

- LwIP (CONFIG_ESP_NETIF_TCPIP_LWIP)
  lwIP is a small independent implementation of the TCP/IP protocol suite.
- Loopback (CONFIG_ESP_NETIF_LOOPBACK)
  Dummy implementation of esp-netif functionality which connects driver transmit to receive function. This option is for testing purpose only

CONFIG_ESP_NETIF_RECEIVE_REPORT_ERRORS

Use esp_err_t to report errors from esp_netif_receive

Found in: Component config > ESP NETIF Adapter

Enable if esp_netif_receive() should return error code. This is useful to inform upper layers that packet input to TCP/IP stack failed, so the upper layers could implement flow control. This option is disabled by default due to backward compatibility and will be enabled in v6.0 (IDF-7194)

Default value:
- No (disabled)

CONFIG_ESP_NETIF_L2_TAP

Enable netif L2 TAP support

Found in: Component config > ESP NETIF Adapter

A user program can read/write link layer (L2) frames from/to ESP TAP device. The ESP TAP device can be currently associated only with Ethernet physical interfaces.

CONFIG_ESP_NETIF_L2_TAP_MAX_FDS

Maximum number of opened L2 TAP File descriptors

Found in: Component config > ESP NETIF Adapter > CONFIG_ESP_NETIF_L2_TAP

Maximum number of opened File descriptors (FD’s) associated with ESP TAP device. ESP TAP FD’s take up a certain amount of memory, and allowing fewer FD’s to be opened at the same time conserves memory.

Range:
- from 1 to 10 if CONFIG_ESP_NETIF_L2_TAP

Default value:
- 5 if CONFIG_ESP_NETIF_L2_TAP

CONFIG_ESP_NETIF_L2_TAP_RX_QUEUE_SIZE

Size of L2 TAP Rx queue

Found in: Component config > ESP NETIF Adapter > CONFIG_ESP_NETIF_L2_TAP

Maximum number of frames queued in opened File descriptor. Once the queue is full, the newly arriving frames are dropped until the queue has enough room to accept incoming traffic (Tail Drop queue management).

Range:
• from 1 to 100 if `CONFIG_ESP_NETIF_L2_TAP`

**Default value:**
• 20 if `CONFIG_ESP_NETIF_L2_TAP`

---

**CONFIG_ESP_NETIF_BRIDGE_EN**

Enable LwIP IEEE 802.1D bridge

*Found in: Component config > ESP NETIF Adapter*

Enable LwIP IEEE 802.1D bridge support in ESP-NETIF. Note that "Number of clients store data in netif" (LWIP_NUM_NETIF_CLIENT_DATA) option needs to be properly configured to be LwIP bridge available!

*Default value:*
• No (disabled)

---

**Partition API Configuration**

---

**PHY**

Contains:

• `CONFIG_ESP_PHY_CALIBRATION_MODE`
• `CONFIG_ESP_PHY_ENABLE_USB`
• `CONFIG_ESP_PHYIMIZE_RX_11B`
• `CONFIG_ESP_PHY_MAX_WIFI_TX_POWER`
• `CONFIG_ESP_PHY_MAC_BB_PD`
• `CONFIG_ESP_PHY_REDUCE_TX_POWER`
• `CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE`
• `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION`

---

**CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE**

Store phy calibration data in NVS

*Found in: Component config > PHY*

If this option is enabled, NVS will be initialized and calibration data will be loaded from there. PHY calibration will be skipped on deep sleep wakeup. If calibration data is not found, full calibration will be performed and stored in NVS. Normally, only partial calibration will be performed. If this option is disabled, full calibration will be performed.

If it’s easy that your board calibrate bad data, choose ‘n’. Two cases for example, you should choose ‘n’: 1. If your board is easy to be booted up with antenna disconnected. 2. Because of your board design, each time when you do calibration, the result are too unstable. If unsure, choose ‘y’.

*Default value:*
• Yes (enabled)

---

**CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION**

Use a partition to store PHY init data

*Found in: Component config > PHY*

If enabled, PHY init data will be loaded from a partition. When using a custom partition table, make sure that PHY data partition is included (type: ‘data’, subtype: ‘phy’). With default partition tables, this is done automatically. If PHY init data is stored in a partition, it has to be flashed there, otherwise runtime error will occur.

If this option is not enabled, PHY init data will be embedded into the application binary.

If unsure, choose ‘n’.
Default value:
- No (disabled)

Contains:
- `CONFIG_ESP_PHY_DEFAULT_INIT_IF_INVALID`
- `CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN`

**CONFIG_ESP_PHY_DEFAULT_INIT_IF_INVALID**
Reset default PHY init data if invalid

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION*

If enabled, PHY init data will be restored to default if it cannot be verified successfully to avoid endless bootloops.

If unsure, choose ‘n’.

Default value:
- No (disabled) if `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION`

**CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN**
Support multiple PHY init data bin

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION*

If enabled, the corresponding PHY init data type can be automatically switched according to the country code. China’s PHY init data bin is used by default. Can be modified by country information in API `esp_wifi_set_country()`. The priority of switching the PHY init data type is: 1. Country configured by API `esp_wifi_set_country()` and the parameter policy is WIFI_COUNTRY_POLICY_MANUAL. 2. Country notified by the connected AP. 3. Country configured by API `esp_wifi_set_country()` and the parameter policy is WIFI_COUNTRY_POLICY_AUTO.

Default value:
- No (disabled) if `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION` && `CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN`

**CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN_EMBED**
Support embedded multiple phy init data bin to app bin

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION > CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN*

If enabled, multiple phy init data bin will be embedded into app bin If not enabled, multiple phy init data bin will still leave alone, and need to be flashed by users.

Default value:
- No (disabled) if `CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN` && `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION`

**CONFIG_ESP_PHY_INIT_DATA_ERROR**
Terminate operation when PHY init data error

*Found in: Component config > PHY > CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION > CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN*

If enabled, when an error occurs while the PHY init data is updated, the program will terminate and restart. If not enabled, the PHY init data will not be updated when an error occurs.

Default value:
CONFIG_ESP_PHY_MAX_WIFI_TX_POWER

Max WiFi TX power (dBm)

*Found in: Component config > PHY*

Set maximum transmit power for WiFi radio. Actual transmit power for high data rates may be lower than this setting.

*Range:*
- from 10 to 20

*Default value:*
- 20

CONFIG_ESP_PHY_MAC_BB_PD

Power down MAC and baseband of Wi-Fi and Bluetooth when PHY is disabled

*Found in: Component config > PHY*

If enabled, the MAC and baseband of Wi-Fi and Bluetooth will be powered down when PHY is disabled. Enabling this setting reduces power consumption by a small amount but increases RAM use by approximately 4 KB (Wi-Fi only), 2 KB (Bluetooth only) or 5.3 KB (Wi-Fi + Bluetooth).

*Default value:*
- No (disabled) if SOC_PM_SUPPORT_MAC_BB_PD && CONFIG_FREERTOS_USE_TICKLESS_IDLE

CONFIG_ESP_PHY_REDUCE_TX_POWER

Reduce PHY TX power when brownout reset

*Found in: Component config > PHY*

When brownout reset occurs, reduce PHY TX power to keep the code running.

*Default value:*
- No (disabled)

CONFIG_ESP_PHY_ENABLE_USB

Enable USB when phy init

*Found in: Component config > PHY*

When using USB Serial/JTAG/OTG/CDC, PHY should enable USB, otherwise USB module can not work properly. Notice: Enabling this configuration option will slightly impact WiFi performance.

*Default value:*
- No (disabled) if CONFIG_ESP_CONSOLE_USB_SERIAL_JTAG || CONFIG_ESP_CONSOLE_SECONDARY_USB_SERIAL_JTAG

CONFIG_ESP_PHY_CALIBRATION_MODE

Calibration mode

*Found in: Component config > PHY*

Select PHY calibration mode. During RF initialization, the partial calibration method is used by default for RF calibration. Full calibration takes about 100ms more than partial calibration. If boot duration is
not critical, it is suggested to use the full calibration method. No calibration method is only used when the device wakes up from deep sleep.

Available options:

- Calibration partial (CONFIG_ESP_PHY_RF_CAL_PARTIAL)
- Calibration none (CONFIG_ESP_PHY_RF_CAL_NONE)
- Calibration full (CONFIG_ESP_PHY_RF_CAL_FULL)

CONFIG_ESP_PHY_IMPROVE_RX_11B

Improve Wi-Fi receive 11b pkts

*Found in: Component config > PHY*

This is a workaround to improve Wi-Fi receive 11b pkts for some modules using AC-DC power supply with high interference, enable this option will sacrifice Wi-Fi OFDM receive performance. But to guarantee 11b receive performance serves as a bottom line in this case.

**Default value:**
- No (disabled) if SOC_PHY_IMPROVE_RX_11B

---

Power Management

Contains:

- CONFIG_PM_SLP_DISABLE_GPIO
- CONFIG_PM_POWER_DOWN_CPU_IN_LIGHT_SLEEP
- CONFIG_PM_POWER_DOWN_PERIPHERAL_IN_LIGHT_SLEEP
- CONFIG_PM_SLP_IRAM_OPT
- CONFIG_PM_RTOS_IDLE_OPT
- CONFIG_PM_ENABLE

---

CONFIG_PM_ENABLE

Support for power management

*Found in: Component config > Power Management*

If enabled, application is compiled with support for power management. This option has run-time overhead (increased interrupt latency, longer time to enter idle state), and it also reduces accuracy of RTOS ticks and timers used for timekeeping. Enable this option if application uses power management APIs.

**Default value:**
- No (disabled) if CONFIG_FREERTOS_SMP

---

CONFIG_PM_DFS_INIT_AUTO

Enable dynamic frequency scaling (DFS) at startup

*Found in: Component config > Power Management > CONFIG_PM_ENABLE*

If enabled, startup code configures dynamic frequency scaling. Max CPU frequency is set to DEFAULT_CPU_FREQ_MHZ setting, min frequency is set to XTAL frequency. If disabled, DFS will not be active until the application configures it using esp_pm_configure function.

**Default value:**
- No (disabled) if CONFIG_PM_ENABLE
CONFIG_PM_PROFILING

Enable profiling counters for PM locks

*Found in: Component config > Power Management > CONFIG_PM_ENABLE*

If enabled, esp_pm_* functions will keep track of the amount of time each of the power management locks has been held, and esp_pm_dump_locks function will print this information. This feature can be used to analyze which locks are preventing the chip from going into a lower power state, and see what time the chip spends in each power saving mode. This feature does incur some run-time overhead, so should typically be disabled in production builds.

**Default value:**
- No (disabled) if CONFIG_PM_ENABLE

CONFIG_PM_TRACE

Enable debug tracing of PM using GPIOs

*Found in: Component config > Power Management > CONFIG_PM_ENABLE*

If enabled, some GPIOs will be used to signal events such as RTOS ticks, frequency switching, entry/exit from idle state. Refer to pm_trace.c file for the list of GPIOs. This feature is intended to be used when analyzing/debugging behavior of power management implementation, and should be kept disabled in applications.

**Default value:**
- No (disabled) if CONFIG_PM_ENABLE

CONFIG_PM_SLP_IRAM_OPT

Put lightsleep related codes in internal RAM

*Found in: Component config > Power Management*

If enabled, about 1.8KB of lightsleep related source code would be in IRAM and chip would sleep longer for 760us at most each time. This feature is intended to be used when lower power consumption is needed while there is enough place in IRAM to place source code.

CONFIG_PM_RTOS_IDLE_OPT

Put RTOS IDLE related codes in internal RAM

*Found in: Component config > Power Management*

If enabled, about 260B of RTOS_IDLE related source code would be in IRAM and chip would sleep longer for 40us at most each time. This feature is intended to be used when lower power consumption is needed while there is enough place in IRAM to place source code.

CONFIG_PM_SLP_DISABLE_GPIO

Disable all GPIO when chip at sleep

*Found in: Component config > Power Management*

This feature is intended to disable all GPIO pins at automatic sleep to get a lower power mode. If enabled, chips will disable all GPIO pins at automatic sleep to reduce about 200–300 uA current. If you want to specifically use some pins normally as chip wakes when chip sleeps, you can call ‘gpio_sleep_set_dis’ to disable this feature on those pins. You can also keep this feature on and call ‘gpio_sleep_set_direction’ and ‘gpio_sleep_set_pull_mode’ to have a different GPIO configuration at sleep. Warning: If you want to enable this option on ESP32, you should enable GPIO_ESP32_SUPPORT_SWITCH_SLP_PULL at first, otherwise you will not be able to switch pullup/pulldown mode.
### CONFIG_PM_POWER_DOWN_CPU_IN_LIGHT_SLEEP

Power down CPU in light sleep

*Found in: Component config > Power Management*

If enabled, the CPU will be powered down in light sleep. On esp32c3 soc, enabling this option will consume 1.68 KB of internal RAM and will reduce sleep current consumption by about 100 uA. On esp32s3 soc, enabling this option will consume 8.58 KB of internal RAM and will reduce sleep current consumption by about 650 uA.

**Default value:**
- Yes (enabled) if SOC_PM_SUPPORT_CPU_PD

### CONFIG_PM_POWER_DOWN_PERIPHERAL_IN_LIGHT_SLEEP

Power down Digital Peripheral in light sleep (EXPERIMENTAL)

*Found in: Component config > Power Management*

If enabled, digital peripherals will be powered down in light sleep, it will reduce sleep current consumption by about 100 uA. Chip will save/restore register context at sleep/wake time to keep the system running. Enabling this option will increase static RAM and heap usage, the actual cost depends on the peripherals you have initialized. In order to save/restore the context of the necessary hardware for FreeRTOS to run, it will need at least 4.55 KB free heap at sleep time. Otherwise sleep will not power down the peripherals.

Note1: Please use this option with caution, the current IDF does not support the retention of all peripherals. When the digital peripherals are powered off and a sleep and wake-up is completed, the peripherals that have not saved the running context are equivalent to performing a reset. !!! Please confirm the peripherals used in your application and their sleep retention support status before enabling this option, peripherals sleep retention driver support status is tracked in power_management.rst

Note2: When this option is enabled simultaneously with FREERTOS_USE_TICKLESS_IDLE, since the UART will be powered down, the uart FIFO will be flushed before sleep to avoid data loss, however, this has the potential to block the sleep process and cause the wakeup time to be skipped, which will cause the tick of freertos to not be compensated correctly when returning from sleep and cause the system to crash. To avoid this, you can increase FREERTOS_IDLE_TIME_BEFORE_SLEEP threshold in menuconfig.

**Default value:**
- No (disabled) if SOC_PAU_SUPPORTED

### ESP PSRAM

Contains:

- `CONFIG_SPIRAM`

### CONFIG_SPIRAM

Support for external, SPI-connected RAM

*Found in: Component config > ESP PSRAM*

This enables support for an external SPI RAM chip, connected in parallel with the main SPI flash chip.

**Default value:**
- No (disabled) if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

### SPI RAM config

Contains:

- `CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY`
- `CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY`
- `CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY`
**Chapter 2. API Reference**

- `CONFIG_SPIRAM_SPIWP_SD3_PIN`
- `CONFIG_SPIRAM_BANKSWITCH_ENABLE`
- `CONFIG_SPIRAM_2T_MODE`
- `CONFIG_SPIRAM_CACHE_WORKAROUND`
- `CONFIG_SPIRAM_BOOT_INIT`
- `CONFIG_SPIRAM_MALLOCD_ALWAYSINTERNAL`
- `PSRAM clock and cs IO for ESP32-D2WD`
- `PSRAM clock and cs IO for ESP32-DOWD`
- `PSRAM clock and cs IO for ESP32-PICO-D4`
- `CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL`
- `SPIRAM cache workaround libraries placement`
- `SPIRAM workaround libraries placement`
- `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
- `CONFIG_SPIRAM_TYPE`
- `CONFIG_SPIRAM_CUSTOM_SPIWP_SD3_PIN`

**CONFIG_SPIRAM_TYPE**

Type of SPI RAM chip in use

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

Available options:

- Auto-detect (CONFIG_SPIRAM_TYPE_AUTO)
- ESP-PSRAM16 or APS1604 (CONFIG_SPIRAM_TYPE_ESPPSRAM16)
- ESP-PSRAM32 (CONFIG_SPIRAM_TYPE_ESPPSRAM32)
- ESP-PSRAM64 or LY68L6400 (CONFIG_SPIRAM_TYPE_ESPPSRAM64)

**CONFIG_SPIRAM_SPEED**

Set RAM clock speed

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

Select the speed for the SPI RAM chip. If SPI RAM is enabled, we only support three combinations of SPI speed mode we supported now:

1. Flash SPI running at 40Mhz and RAM SPI running at 40Mhz
2. Flash SPI running at 80Mhz and RAM SPI running at 40Mhz
3. Flash SPI running at 80Mhz and RAM SPI running at 80Mhz

Note: If the third mode(80Mhz+80Mhz) is enabled for SPI RAM of type 32MBit, one of the HSPI/VSPI host will be occupied by the system. Which SPI host to use can be selected by the config item SPIRAM_OCCUPY_SPI_HOST. Application code should never touch HSPI/VSPI hardware in this case. The option to select 80MHz will only be visible if the flash SPI speed is also 80MHz. (ESP-TOOLPY_FLASHFREQ_80M is true)

Available options:

- 40MHz clock speed (CONFIG_SPIRAM_SPEED_40M)
- 80MHz clock speed (CONFIG_SPIRAM_SPEED_80M)
**CONFIG_SPIRAM_BOOT_INIT**

Initialize SPI RAM during startup

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

If this is enabled, the SPI RAM will be enabled during initial boot. Unless you have specific requirements, you’ll want to leave this enabled so memory allocated during boot-up can also be placed in SPI RAM.

*Default value:*
- Yes (enabled) if `CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPEPURE_RAM_APP`

**CONFIG_SPIRAM_IGNORE_NOTFOUND**

Ignore PSRAM when not found

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > CONFIG_SPIRAM_BOOT_INIT*

Normally, if psram initialization is enabled during compile time but not found at runtime, it is seen as an error making the CPU panic. If this is enabled, booting will complete but no PSRAM will be available.

*Default value:*
- No (disabled) if `CONFIG_SPIRAM_BOOT_INIT && CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY && CONFIG_SPIRAM && CONFIG_APPBUILD_TYPEPURE_RAM_APP`

**CONFIG_SPIRAM_USE**

SPI RAM access method

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

The SPI RAM can be accessed in multiple methods: by just having it available as an unmanaged memory region in the CPU’s memory map, by integrating it in the heap as ‘special’ memory needing `heap_caps_malloc` to allocate, or by fully integrating it making `malloc()` also able to return SPI RAM pointers.

*Available options:*
- Integrate RAM into memory map (`CONFIG_SPIRAM_USE_MEMMAP`)
- Make RAM allocatable using `heap_caps_malloc` (CONFig_SPIRAM_USE_CAPS_ALLOC)
- Make RAM allocatable using malloc() as well (CONFIG_SPIRAM_USE_MALLOC)

**CONFIG_SPIRAM_MEMTEST**

Run memory test on SPI RAM initialization

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

Runs a rudimentary memory test on initialization. Aborts when memory test fails. Disable this for slightly faster startup.

*Default value:*
- Yes (enabled) if `CONFIG_SPIRAM_BOOT_INIT && CONFIG_SPIRAM && CONFIG_APPBUILD_TYPEPURE_RAM_APP`
CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL

Maximum malloc() size, in bytes, to always put in internal memory

Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config

If malloc() is capable of also allocating SPI-connected ram, its allocation strategy will prefer to allocate chunks less than this size in internal memory, while allocations larger than this will be done from external RAM. If allocation from the preferred region fails, an attempt is made to allocate from the non-preferred region instead, so malloc() will not suddenly fail when either internal or external memory is full.

Range:
• from 0 to 131072 if CONFIG_SPIRAM_USE_MALLOC && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

Default value:
• 16384 if CONFIG_SPIRAM_USE_MALLOC && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP

Try to allocate memories of WiFi and LWIP in SPIRAM firstly. If failed, allocate internal memory

Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config

Try to allocate memories of WiFi and LWIP in SPIRAM firstly. If failed, try to allocate internal memory then.

Default value:
• No (disabled) if (CONFIG_SPIRAM_USE_CAPS_ALLOC || CONFIG_SPIRAM_USE_MALLOC) && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL

Reserve this amount of bytes for data that specifically need to be in DMA or internal memory

Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config

Because the external/internal RAM allocation strategy is not always perfect, it sometimes may happen that the internal memory is entirely filled up. This causes allocations that are specifically done in internal memory, for example the stack for new tasks or memory to service DMA or have memory that’s also available when SPI cache is down, to fail. This option reserves a pool specifically for requests like that; the memory in this pool is not given out when a normal malloc() is called.

Set this to 0 to disable this feature.

Note that because FreeRTOS stacks are forced to internal memory, they will also use this memory pool; be sure to keep this in mind when adjusting this value.

Note also that the DMA reserved pool may not be one single contiguous memory region, depending on the configured size and the static memory usage of the app.

Range:
• from 0 to 262144 if CONFIG_SPIRAM_USE_MALLOC && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

Default value:
• 32768 if CONFIG_SPIRAM_USE_MALLOC && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY

Allow .bss segment placed in external memory

Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config
If enabled, variables with EXT_RAM_BSS_ATTR attribute will be placed in SPIRAM instead of internal DRAM. BSS section of lwip, net80211, pp, bt libraries will be automatically placed in SPIRAM. BSS sections from other object files and libraries can also be placed in SPIRAM through linker fragment scheme extram_bss.

Note that the variables placed in SPIRAM using EXT_RAM_BSS_ATTR will be zero initialized.

**Default value:**

- No (disabled) if `CONFIG_SPIRAM` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP` and `CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY`.

**CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY**

Allow .noinit segment placed in external memory

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

If enabled, noinit variables can be placed in PSRAM using EXT_RAM_NOINIT_ATTR.

Note the values placed into this section will not be initialized at startup and should keep its value after software restart.

**Default value:**

- No (disabled) if `CONFIG_SPIRAM` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP` and `CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY`.

**CONFIG_SPIRAM_CACHE_WORKAROUND**

Enable workaround for bug in SPI RAM cache for Rev1 ESP32s

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

Revision 1 of the ESP32 has a bug that can cause a write to PSRAM not to take place in some situations when the cache line needs to be fetched from external RAM and an interrupt occurs. This enables a fix in the compiler (-mfix-esp32-psram-cache-issue) that makes sure the specific code that is vulnerable to this will not be emitted.

This will also not use any bits of newlib that are located in ROM, opting for a version that is compiled with the workaround and located in flash instead.

The workaround is not required for ESP32 revision 3 and above.

**Default value:**

- Yes (enabled) if `(CONFIG_SPIRAM_USE_MEMMAP || CONFIG_SPIRAM_USE_CAPS_ALLOC || CONFIG_SPIRAM_USE_MALLOC) && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`.

**SPIRAM cache workaround debugging**

- Contains:

  * `CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY`

**CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY**

Workaround strategy

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM cache workaround debugging*

Select the workaround strategy. Note that the strategy for precompiled libraries (libgcc, newlib, bt, wifi) is not affected by this selection.

Unless you know you need a different strategy, it’s suggested you stay with the default MEMW strategy. Note that DUPLDST can interfere with hardware encryption and this will be automatically disabled if...
this workaround is selected. ‘Insert nops’ is the workaround that was used in older esp-idf versions. This workaround still can cause faulty data transfers from/to SPI RAM in some situation.

Available options:

- Insert memw after vulnerable instructions (default) (CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY_MEMW)
- Duplicate LD/ST for 32-bit, memw for 8/16 bit (CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST)
- Insert nops between vulnerable loads/stores (old strategy, obsolete) (CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY_NOPS)

**SPIRAM workaround libraries placement** Contains:

- CONFIG_SPIRAM_CACHE_LIBCHAR_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBENV_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBFILE_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBIO_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBJMP_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBMATH_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBMEM_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBMISC_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBNUMPARSER_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBRAND_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBSTR_IN_IRAM
- CONFIG_SPIRAM_CACHE_LIBTIME_IN_IRAM

**CONFIG_SPIRAM_CACHE_LIBJMP_IN_IRAM**

Put libc’s jump related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: longjmp and setjmp. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

*Default value:*

- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

**CONFIG_SPIRAM_CACHE_LIBMATH_IN_IRAM**

Put libc’s math related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: abs, div, labs, ldiv, quorem, fpclassify, and nan. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

*Default value:*

- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP
**CONFIG_SPIRAM_CACHE_LIBNUMPARSER_IN_IRAM**

Put libc’s number parsing related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: utoa, itoa, atoi, atol, strtol, and strtoul. Putting these functions in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**

- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_SPIRAM_CACHE_LIBIO_IN_IRAM**

Put libc’s I/O related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: wcrtomb, fwrite, wbuf, wsetup, fputwc, wctomb_r, ungetc, makebuf, fflush, refill, and sccl. Putting these functions in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**

- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_SPIRAM_CACHE_LIBTIME_IN_IRAM**

Put libc’s time related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: asctime, asctime_r, ctime, ctime_r, lcltime, lcltime_r, gmtime, gmtime_r, strftime, mktime, tzset_r, tzset, time, gettzinfo, systimes, month_lengths, timelocal, tzvars, tzlock, tzcalc_limits, and strptime. Putting these functions in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**

- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_SPIRAM_CACHE_LIBCHAR_IN_IRAM**

Put libc’s characters related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: ctype_, toupper, tolower, toascii, strupr, bzero, isalnum, isalpha, isascii, isblank, iscntrl, isdigit, isgraph, islower, isprint, ispunct, isspace, and isupper. Putting these functions in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**

- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
CONFIG_SPIRAM_CACHE_LIBMEM_IN_IRAM

Put libc’s memory related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: memccpy, memchr memmove, and memrchr. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPIRAM_CACHE_LIBSTR_IN_IRAM

Put libc’s string related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: strcasecmp, strcasestr, strchr, strcoll, strcpy, strcspn, strdup, strdup_r, strlcat, strlcpy, strlen, strlwr, strncasecmp, strncat, strn cmp, strncmp, strdup, strdup_r, strchr, strsep, strspn, strstr, strtok_r, and strupr. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPIRAM_CACHE_LIBRAND_IN_IRAM

Put libc’s random related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: srand, rand, and rand_r. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPIRAM_CACHE_LIBENV_IN_IRAM

Put libc’s environment related functions in IRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement*

The functions affected by this option are: environ, envlock, and getenv_r. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

**Default value:**
- Yes (enabled) if `CONFIG_SPIRAM_CACHE_WORKAROUND` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
CONFIG_SPIRAM_CACHE_LIBFILE_IN_IRAM

Put libc’s file related functions in IRAM

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement

The functions affected by this option are: lock, isatty, fclose, open, close, creat, read, rshift, sbrk, stdio, symlink, syslog, fsync, ftruncate, impure, fwrite, and ffindfp. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

*Default value:*
- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPIRAM_CACHE_LIBMISC_IN_IRAM

Put libc’s miscellaneous functions in IRAM, see help

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > SPIRAM workaround libraries placement

The functions affected by this option are: raise and system. Putting these function in IRAM will allow them to be called when flash cache is disabled but it will also reduce the available size of free IRAM for the user application.

*Default value:*
- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPIRAM_BANKSWITCH_ENABLE

Enable bank switching for >4MiB external RAM

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config

The ESP32 only supports 4MiB of external RAM in its address space. The hardware does support larger memories, but these have to be bank-switched in and out of this address space. Enabling this allows you to reserve some MMU pages for this, which allows the use of the esp_himem api to manage these banks.

#Note that this is limited to 62 banks, as esp_psram_extram_writeback_cache needs some kind of mapping of #some banks below that mark to work. We cannot at this moment guarantee this to exist when himem is #enabled.

If spiram 2T mode is enabled, the size of 64Mbit psram will be changed as 32Mbit, so himem will be unusable.

*Default value:*
- Yes (enabled) if (CONFIG_SPIRAM_USE_MEMMAP || CONFIG_SPIRAM_USE_CAPS_ALLOC || CONFIG_SPIRAM_USE_MALLOC) && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPIRAM_BANKSWITCH_RESERVE

Amount of 32K pages to reserve for bank switching

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > CONFIG_SPIRAM_BANKSWITCH_ENABLE

Select the amount of banks reserved for bank switching. Note that the amount of RAM allocatable with malloc/esp_heap_alloc_caps will decrease by 32K for each page reserved here.
Note that this reservation is only actually done if your program actually uses the himem API. Without any himem calls, the reservation is not done and the original amount of memory will be available to malloc/esp_heap_alloc_caps.

**Range:**
- from 1 to 62 if `CONFIG_SPIRAM_BANKSWITCH_ENABLE` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**Default value:**
- 8 if `CONFIG_SPIRAM_BANKSWITCH_ENABLE` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

---

**CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY**

Allow external memory as an argument to xTaskCreateStatic

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

Because some bits of the ESP32 code environment cannot be recompiled with the cache workaround, normally tasks cannot be safely run with their stack residing in external memory; for this reason xTaskCreate (and related task create functions) always allocate stack in internal memory and xTaskCreateStatic will check if the memory passed to it is in internal memory. If you have a task that needs a large amount of stack and does not call on ROM code in any way (no direct calls, but also no Bluetooth/WiFi), you can try enable this to cause xTaskCreateStatic to allow tasks stack in external memory.

**Default value:**
- No (disabled) if `CONFIG_SPIRAM_USE_MALLOC` && `CONFIG_SPIRAM` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

---

**CONFIG_SPIRAM_OCCUPY_SPI_HOST**

SPI host to use for 32MBit PSRAM

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

When both flash and PSRAM is working under 80MHz, and the PSRAM is of type 32MBit, one of the HSPI/VSPI host will be used to output the clock. Select which one to use here.

*Available options:*
- HSPI host (SPI2) (CONFIG_SPIRAM_OCCUPY_HSPI_HOST)
- VSPI host (SPI3) (CONFIG_SPIRAM_OCCUPY_VSPI_HOST)
- Will not try to use any host, will abort if not able to use the PSRAM (CONFIG_SPIRAM_OCCUPY_NO_HOST)

---

**PSRAM clock and cs IO for ESP32-DOWD**

Contains:

- `CONFIG_DOWD_PSRAM_CLK_IO`
- `CONFIG_DOWD_PSRAM_CS_IO`

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**CONFIG_DOWD_PSRAM_CLK_IO**

PSRAM CLK IO number

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > PSRAM clock and cs IO for ESP32-DOWD*

The PSRAM CLOCK IO can be any unused GPIO, user can config it based on hardware design. If user use 1.8V flash and 1.8V pfram, this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

If configured to the same pin as Flash, PSRAM shouldn’t be rev0. Contact Espressif for more information.
### CONFIG_D0WD_PSRAM_CS_IO

PSRAM CS IO number

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > PSRAM clock and cs IO for ESP32-D2WD

The PSRAM CS IO can be any unused GPIO, user can config it based on hardware design. If user use 1.8V flash and 1.8V psram, this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

*Range:*
- from 0 to 33 if \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_APP_BUILD_TYPE_PURE_RAM_APP}

*Default value:*
- 17 if \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_APP_BUILD_TYPE_PURE_RAM_APP}

### PSRAM clock and cs IO for ESP32-D2WD

Contains:

- \texttt{CONFIG_D2WD_PSRAM_CLK_IO}
- \texttt{CONFIG_D2WD_PSRAM_CS_IO}

### CONFIG_D2WD_PSRAM_CLK_IO

PSRAM CLK IO number

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > PSRAM clock and cs IO for ESP32-D2WD

User can config it based on hardware design. For ESP32-D2WD chip, the psram can only be 1.8V psram, so this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

If configured to the same pin (GPIO6) as Flash, PSRAM shouldn’t be rev0. Contact Espressif for more information.

*Range:*
- from 0 to 33 if \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_APP_BUILD_TYPE_PURE_RAM_APP}

*Default value:*
- 9 if \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_APP_BUILD_TYPE_PURE_RAM_APP}

### CONFIG_D2WD_PSRAM_CS_IO

PSRAM CS IO number

*Found in:* Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > PSRAM clock and cs IO for ESP32-D2WD

User can config it based on hardware design. For ESP32-D2WD chip, the psram can only be 1.8V psram, so this value can only be one of 6, 7, 8, 9, 10, 11, 16, 17.

*Range:*
- from 0 to 33 if \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_SPIRAM} \&\& \texttt{CONFIG_APP_BUILD_TYPE_PURE_RAM_APP}
**PSRAM clock and cs IO for ESP32-PICO-D4**

Contains:

- **CONFIG_PICO_PSRAM_CS_IO**

**CONFIG_PICO_PSRAM_CS_IO**

PSRAM CS IO number

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config > PSRAM clock and cs IO for ESP32-PICO-D4*

The PSRAM CS IO can be any unused GPIO, user can config it based on hardware design.

For ESP32-PICO chip, the psram share clock with flash, so user do not need to configure the clock IO. For the reference hardware design, please refer to https://www.espressif.com/sites/default/files/documentation/esp32-pico-d4_datasheet_en.pdf

*Range:*

- from 0 to 33 if CONFIG_SPIRAM && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

*Default value:*

- 10 if CONFIG_SPIRAM && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

**CONFIG_SPIRAM_CUSTOM_SPIWP_SD3_PIN**

Use custom SPI PSRAM WP(SD3) Pin when flash pins set in eFuse (read help)

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

This setting is only used if the SPI flash pins have been overridden by setting the eFuses SPI_PAD_CONFIG_xxx, and the SPI flash mode is DIO or DOUT.

When this is the case, the eFuse config only defines 3 of the 4 Quad I/O data pins. The WP pin (aka ESP32 pin “SD_DATA_3” or SPI flash pin “IO2”) is not specified in eFuse. The psram only has QPI mode, so a WP pin setting is necessary.

If this config item is set to N (default), the correct WP pin will be automatically used for any Espressif chip or module with integrated flash. If a custom setting is needed, set this config item to Y and specify the GPIO number connected to the WP pin.

When flash mode is set to QIO or QOUT, the PSRAM WP pin will be set the same as the SPI Flash WP pin configured in the bootloader.

*Default value:*

- No (disabled) if (CONFIG_ESPTOOLPY_FLASHMODE_DIO || CONFIG_ESPTOOLPY_FLASHMODE_DOUT) && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

**CONFIG_SPIRAM_SPIWP_SD3_PIN**

Custom SPI PSRAM WP(SD3) Pin

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

The option “Use custom SPI PSRAM WP(SD3) pin” must be set or this value is ignored

If burning a customized set of SPI flash pins in eFuse and using DIO or DOUT mode for flash, set this value to the GPIO number of the SPI RAM WP pin.
Range:
- from 0 to 33 if (CONFIG_ESPTOOLPY_FLASHMODE_DIO || CONFIG_ESPTOOLPY_FLASHMODE_DOUT) && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPEPURE_RAM_APP

Default value:
- 7 if (CONFIG_ESPTOOLPY_FLASHMODE_DIO || CONFIG_ESPTOOLPY_FLASHMODE_DOUT) && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPEPURE_RAM_APP

**CONFIG_SPIRAM_2T_MODE**

Enable SPI PSRAM 2T mode

*Found in: Component config > ESP PSRAM > CONFIG_SPIRAM > SPI RAM config*

Enable this option to fix single bit errors inside 64Mbit PSRAM.

Some 64Mbit PSRAM chips have a hardware issue in the RAM which causes bit errors at multiple fixed bit positions.

Note: If this option is enabled, the 64Mbit PSRAM chip will appear to be 32Mbit in size. Applications will not be affected unless the use the esp_himem APIs, which are not supported in 2T mode.

Default value:
- No (disabled) if CONFIG_SPIRAM && CONFIG_SPIRAM && CONFIG_APP_BUILD_TYPEPURE_RAM_APP

**ESP Ringbuf**

Contains:

- **CONFIG_RINGBUF_PLACE_FUNCTIONS_INTO_FLASH**

**CONFIG_RINGBUF_PLACE_FUNCTIONS_INTO_FLASH**

Place non-ISR ringbuf functions into flash

*Found in: Component config > ESP Ringbuf*

Place non-ISR ringbuf functions (like xRingbufferCreate/xRingbufferSend) into flash. This frees up IRAM, but the functions can no longer be called when the cache is disabled.

Default value:
- No (disabled)

**CONFIG_RINGBUF_PLACE_ISR_FUNCTIONS_INTO_FLASH**

Place ISR ringbuf functions into flash

*Found in: Component config > ESP Ringbuf > CONFIG_RINGBUF_PLACE_FUNCTIONS_INTO_FLASH*

Place ISR ringbuf functions (like xRingbufferSendFromISR/xRingbufferReceiveFromISR) into flash. This frees up IRAM, but the functions can no longer be called when the cache is disabled or from an IRAM interrupt context.

This option is not compatible with ESP-IDF drivers which are configured to run the ISR from an IRAM context, e.g. CONFIG_UART_ISR_IN_IRAM.

Default value:
- No (disabled) if CONFIG_RINGBUF_PLACE_FUNCTIONS_INTO_FLASH
**ESP System Settings**  Contains:

- `CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES`
- Brownout Detector
- `CONFIG_ESP_CONSOLE_UART`
- `CONFIG_ESP_CONSOLE_SECONDARY`
- `CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ`
- `CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP`
- `CONFIG_ESP_TASK_WDT_EN`
- `CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE`
- `CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL`
- `CONFIG_ESP_INT_WDT`
- `CONFIG_ESP_MAIN_TASK_AFFINITY`
- `CONFIG_ESP_MAIN_TASK_STACK_SIZE`
- `CONFIG_ESP_DEBUG_OCDAWARE`
- Memory
- Memory protection
- `CONFIG_ESP_MINIMAL_SHARED_STACK_SIZE`
- `CONFIG_ESP_DEBUG_STUBS_ENABLE`
- `CONFIG_ESP_SYSTEM_PANIC`
- `CONFIG_ESP_SYSTEM_PANIC_REBOOT_DELAY_SECONDS`
- `CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE`
- `CONFIG_ESP_PANIC_HANDLER_IRAM`
- `CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE`
- Trace memory
- `CONFIG_ESP_CONSOLE_UART_BAUDRATE`
- `CONFIG_ESP_CONSOLE_UART_NUM`
- `CONFIG_ESP_CONSOLE_UART_RX_GPIO`
- `CONFIG_ESP_CONSOLE_UART_TX_GPIO`

**CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ**

CPU frequency

*Found in: Component config > ESP System Settings*

CPU frequency to be set on application startup.

Available options:

- 40 MHz (CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ_40)
- 80 MHz (CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ_80)
- 160 MHz (CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ_160)
- 240 MHz (CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ_240)

**Memory**  Contains:

- `CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY`
- Non-backward compatible options
- `CONFIG_ESP32_RTCDATA_IN_FAST_MEM`
- `CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE`

**CONFIG_ESP32_RTCDATA_IN_FAST_MEM**

Place RTC_DATA_ATTR and RTC_RODATA_ATTR variables into RTC fast memory segment

*Found in: Component config > ESP System Settings > Memory*
This option allows to place .rtc_data and .rtc_rodata sections into RTC fast memory segment to free the slow memory region for ULP programs. This option depends on the CONFIG_FREERTOS_UNICORE option because RTC fast memory can be accessed only by PRO_CPU core.

**Default value:**
- No (disabled) if `CONFIG_FREERTOS_UNICORE`

**CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE**

Use fixed static RAM size

*Found in: Component config > ESP System Settings > Memory*

If this option is disabled, the DRAM part of the heap starts right after the .bss section, within the dram0_0 region. As a result, adding or removing some static variables will change the available heap size.

If this option is enabled, the DRAM part of the heap starts right after the dram0_0 region, where its length is set with ESP32_FIXED_STATIC_RAM_SIZE

**Default value:**
- No (disabled)

**CONFIG_ESP32_FIXED_STATIC_RAM_SIZE**

Fixed Static RAM size

*Found in: Component config > ESP System Settings > Memory > CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE*

RAM size dedicated for static variables (.data & .bss sections). Please note that the actual length will be reduced by BTDM_RESERVE_DRAM if Bluetooth controller is enabled.

**Range:**
- from 0 to 0x2c200 if `CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE`

**Default value:**
- “0x1E000” if `CONFIG_ESP32_USE_FIXED_STATIC_RAM_SIZE`

**CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY**

Enable IRAM as 8 bit accessible memory

*Found in: Component config > ESP System Settings > Memory*

If enabled, application can use IRAM as byte accessible region for storing data (Note: IRAM region cannot be used as task stack)

This is possible due to handling of exceptions LoadStoreError (3) and LoadStoreAlignmentError (9) Each unaligned read/write access will incur a penalty of maximum of 167 CPU cycles.

**Non-backward compatible options** Contains:
- `CONFIG_ESP_SYSTEM_ESP32_SRAM1_REGION_AS_IRAM`

**CONFIG_ESP_SYSTEM_ESP32_SRAM1_REGION_AS_IRAM**

Reserve parts of SRAM1 for app IRAM (WARNING, read help before enabling)

*Found in: Component config > ESP System Settings > Memory > Non-backward compatible options*

Reserve parts of SRAM1 for app IRAM which was previously reserved for bootloader DRAM. If booting an app on an older bootloader from before this option was introduced, the app will fail to boot due to not recognizing the new IRAM memory area.
If this is the case please test carefully before pushing out any OTA updates.

**Trace memory**  Contains:

- `CONFIG_ESP32_TRAX`

**CONFIG_ESP32_TRAX**

Use TRAX tracing feature

*Found in: Component config > ESP System Settings > Trace memory*

The ESP32 contains a feature which allows you to trace the execution path the processor has taken through the program. This is stored in a chunk of 32K (16K for single-processor) of memory that can’t be used for general purposes anymore. Disable this if you do not know what this is.

**Default value:**

- No (disabled)

**CONFIG_ESP32_TRAX_TWOBANKS**

Reserve memory for tracing both pro as well as app cpu execution

*Found in: Component config > ESP System Settings > Trace memory > CONFIG_ESP32_TRAX*

The ESP32 contains a feature which allows you to trace the execution path the processor has taken through the program. This is stored in a chunk of 32K (16K for single-processor) of memory that can’t be used for general purposes anymore. Disable this if you do not know what this is.

# Memory to reverse for trace, used in linker script

**Default value:**

- No (disabled) if `CONFIG_ESP32_TRAX` && `CONFIG_FREERTOS_UNICORE`

**CONFIG_ESP_SYSTEM_PANIC**

Panic handler behaviour

*Found in: Component config > ESP System Settings*

If FreeRTOS detects unexpected behaviour or an unhandled exception, the panic handler is invoked. Configure the panic handler’s action here.

**Available options:**

- Print registers and halt (CONFIG_ESP_SYSTEM_PANIC_PRINT_HALT)
  Outputs the relevant registers over the serial port and halt the processor. Needs a manual reset to restart.
- Print registers and reboot (CONFIG_ESP_SYSTEM_PANIC_PRINT_REBOOT)
  Outputs the relevant registers over the serial port and immediately reset the processor.
- Silent reboot (CONFIG_ESP_SYSTEM_PANIC_SILENT_REBOOT)
  Just resets the processor without outputting anything
- GDBStub on panic (CONFIG_ESP_SYSTEM_PANIC_GDBSTUB)
  Invoke gdbstub on the serial port, allowing for gdb to attach to it to do a postmortem of the crash.
- GDBStub at runtime (CONFIG_ESP_SYSTEM_GDBSTUB_RUNTIME)
  Invoke gdbstub on the serial port, allowing for gdb to attach to it and to do a debug on runtime.
CONFIG_ESP_SYSTEM_PANIC_REBOOT_DELAY_SECONDS
Panic reboot delay (Seconds)

Found in: Component config > ESP System Settings

After the panic handler executes, you can specify a number of seconds to wait before the device reboots.

Range:
- from 0 to 99

Default value:
- 0

CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES
Bootstrap cycles for external 32kHz crystal

Found in: Component config > ESP System Settings

To reduce the startup time of an external RTC crystal, we bootstrap it with a 32kHz square wave for a fixed number of cycles. Setting 0 will disable bootstrapping (if disabled, the crystal may take longer to start up or fail to oscillate under some conditions).

If this value is too high, a faulty crystal may initially start and then fail. If this value is too low, an otherwise good crystal may not start.

To accurately determine if the crystal has started, set a larger “Number of cycles for RTC_SLOW_CLK calibration” (about 3000).

CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP
Enable RTC fast memory for dynamic allocations

Found in: Component config > ESP System Settings

This config option allows to add RTC fast memory region to system heap with capability similar to that of DRAM region but without DMA. This memory will be consumed first per heap initialization order by early startup services and scheduler related code. Speed wise RTC fast memory operates on APB clock and hence does not have much performance impact.

Memory protection  Contains:
- CONFIG_ESP_SYSTEM_PMP_IDRAM_SPLIT
- CONFIG_ESP_SYSTEM_MEMPROT_FEATURE

CONFIG_ESP_SYSTEM_PMP_IDRAM_SPLIT
Enable IRAM/DRAM split protection

Found in: Component config > ESP System Settings > Memory protection

If enabled, the CPU watches all the memory access and raises an exception in case of any memory violation. This feature automatically splits the SRAM memory, using PMP, into data and instruction segments and sets Read/Execute permissions for the instruction part (below given splitting address) and Read/Write permissions for the data part (above the splitting address). The memory protection is effective on all access through the IRAM0 and DRAM0 buses.

Default value:
- Yes (enabled) if SOC_CPU_IDRAM_SPLIT_USING_PMP
CONFIG_ESP_SYSTEM_MEMPROT_FEATURE

Enable memory protection

*Found in:* Component config > ESP System Settings > Memory protection

If enabled, the permission control module watches all the memory access and fires the panic handler if a permission violation is detected. This feature automatically splits the SRAM memory into data and instruction segments and sets Read/Execute permissions for the instruction part (below given splitting address) and Read/Write permissions for the data part (above the splitting address). The memory protection is effective on all access through the IRAM0 and DRAM0 buses.

**Default value:**
- Yes (enabled) if SOC_MEMPROT_SUPPORTED

CONFIG_ESP_SYSTEM_MEMPROT_FEATURE_LOCK

Lock memory protection settings

*Found in:* Component config > ESP System Settings > Memory protection > CONFIG_ESP_SYSTEM_MEMPROT_FEATURE

Once locked, memory protection settings cannot be changed anymore. The lock is reset only on the chip startup.

**Default value:**
- Yes (enabled) if CONFIG_ESP_SYSTEM_MEMPROT_FEATURE

CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE

System event queue size

*Found in:* Component config > ESP System Settings

Config system event queue size in different application.

**Default value:**
- 32

CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE

Event loop task stack size

*Found in:* Component config > ESP System Settings

Config system event task stack size in different application.

**Default value:**
- 2304

CONFIG_ESP_MAIN_TASK_STACK_SIZE

Main task stack size

*Found in:* Component config > ESP System Settings

Configure the “main task” stack size. This is the stack of the task which calls app_main(). If app_main() returns then this task is deleted and its stack memory is freed.

**Default value:**
- 3584
CONFIG_ESP_MAIN_TASK_AFFINITY

Main task core affinity

*Found in: Component config > ESP System Settings*

Configure the “main task” core affinity. This is the used core of the task which calls app_main(). If app_main() returns then this task is deleted.

Available options:

- CPU0 (CONFIG_ESP_MAIN_TASK_AFFINITY_CPU0)
- CPU1 (CONFIG_ESP_MAIN_TASK_AFFINITY_CPU1)
- No affinity (CONFIG_ESP_MAIN_TASK_AFFINITY_NO_AFFINITY)

CONFIG_ESP_MINIMAL_SHARED_STACK_SIZE

Minimal allowed size for shared stack

*Found in: Component config > ESP System Settings*

Minimal value of size, in bytes, accepted to execute a expression with shared stack.

**Default value:**

- 2048

CONFIG_ESP_CONSOLE_UART

Channel for console output

*Found in: Component config > ESP System Settings*

Select where to send console output (through stdout and stderr).

- Default is to use UART0 on pre-defined GPIOs.
- If “Custom” is selected, UART0 or UART1 can be chosen, and any pins can be selected.
- If “None” is selected, there will be no console output on any UART, except for initial output from ROM bootloader. This ROM output can be suppressed by GPIO strapping or EFUSE, refer to chip datasheet for details.
- On chips with USB OTG peripheral, “USB CDC” option redirects output to the CDC port. This option uses the CDC driver in the chip ROM. This option is incompatible with TinyUSB stack.
- On chips with an USB serial/JTAG debug controller, selecting the option for that redirects output to the CDC/ACM (serial port emulation) component of that device.

Available options:

- Default: UART0 (CONFIG_ESP_CONSOLE_UART_DEFAULT)
- USB CDC (CONFIG_ESP_CONSOLE_USB_CDC)
- USB Serial/JTAG Controller (CONFIG_ESP_CONSOLE_USB_SERIAL_JTAG)
- Custom UART (CONFIG_ESP_CONSOLE_UART_CUSTOM)
- None (CONFIG_ESP_CONSOLE_NONE)

CONFIG_ESP_CONSOLE_SECONDARY

Channel for console secondary output

*Found in: Component config > ESP System Settings*

This secondary option supports output through other specific port like USB_SERIAL_JTAG when UART0 port as a primary is selected but not connected. This secondary output currently only supports non-blocking mode without using REPL. If you want to output in blocking mode with REPL or
input through this secondary port, please change the primary config to this port in Channel for console output menu.

Available options:

- No secondary console (CONFIG_ESP_CONSOLE_SECONDARY_NONE)
- USB_SERIAL_JTAG PORT (CONFIG_ESP_CONSOLE_SECONDARY_USB_SERIAL_JTAG)
  This option supports output through USB_SERIAL_JTAG port when the UART0 port is not connected. The output currently only supports non-blocking mode without using the console. If you want to output in blocking mode with REPL or input through USB_SERIAL_JTAG port, please change the primary config to ESP_CONSOLE_USB_SERIAL_JTAG above.

**CONFIG_ESP_CONSOLE_UART_NUM**

UART peripheral to use for console output (0-1)

*Found in: Component config > ESP System Settings*

This UART peripheral is used for console output from the ESP-IDF Bootloader and the app.

If the configuration is different in the Bootloader binary compared to the app binary, UART is reconfigured after the bootloader exits and the app starts.

Due to an ESP32 ROM bug, UART2 is not supported for console output via esp_rom_printf.

**CONFIG_ESP_CONSOLE_UART_RX_GPIO**

UART RX on GPIO#

*Found in: Component config > ESP System Settings*

This GPIO is used for UART RX input in the ESP-IDF Bootloader and the app (including boot log output and default standard output and standard error of the app).

If the configuration is different in the Bootloader binary compared to the app binary, UART is reconfigured after the bootloader exits and the app starts.

**Range:**
- from 0 to 46 if **CONFIG_ESP_CONSOLE_UART_CUSTOM**

**Default value:**
- 1 if **CONFIG_ESP_CONSOLE_UART_CUSTOM**
- 43 if **CONFIG_ESP_CONSOLE_UART_CUSTOM**

**CONFIG_ESP_CONSOLE_UART_TX_GPIO**

UART TX on GPIO#

*Found in: Component config > ESP System Settings*

This GPIO is used for console UART TX output in the ESP-IDF Bootloader and the app (including boot log output and default standard output and standard error of the app).

If the configuration is different in the Bootloader binary compared to the app binary, UART is reconfigured after the bootloader exits and the app starts.

**Range:**
- from 0 to 46 if **CONFIG_ESP_CONSOLE_UART_CUSTOM**

**Default value:**
- 1 if **CONFIG_ESP_CONSOLE_UART_CUSTOM**
- 43 if **CONFIG_ESP_CONSOLE_UART_CUSTOM**
Chapter 2. API Reference

**CONFIG_ESP_CONSOLE_UART_BAUDRATE**

UART console baud rate

*Found in: Component config > ESP System Settings*

This baud rate is used by both the ESP-IDF Bootloader and the app (including boot log output and default standard input/output/error of the app).

The app’s maximum baud rate depends on the UART clock source. If Power Management is disabled, the UART clock source is the APB clock and all baud rates in the available range will be sufficiently accurate. If Power Management is enabled, REF_TICK clock source is used so the baud rate is divided from 1MHz. Baud rates above 1Mbps are not possible and values between 500Kbps and 1Mbps may not be accurate.

If the configuration is different in the Bootloader binary compared to the app binary, UART is reconfigured after the bootloader exits and the app starts.

*Range:*
- from 1200 to 4000000 if `CONFIG_PM_ENABLE`
- from 1200 to 1000000 if `CONFIG_PM_ENABLE`

*Default value:*
- 115200

**CONFIG_ESP_INT_WDT**

Interrupt watchdog

*Found in: Component config > ESP System Settings*

This watchdog timer can detect if the FreeRTOS tick interrupt has not been called for a certain time, either because a task turned off interrupts and did not turn them on for a long time, or because an interrupt handler did not return. It will try to invoke the panic handler first and failing that reset the SoC.

*Default value:*
- Yes (enabled)

**CONFIG_ESP_INT_WDT_TIMEOUT_MS**

Interrupt watchdog timeout (ms)

*Found in: Component config > ESP System Settings > CONFIG_ESP_INT_WDT*

The timeout of the watchdog, in milliseconds. Make this higher than the FreeRTOS tick rate.

*Range:*
- from 10 to 10000

*Default value:*
- 300 if `CONFIG_SPIRAM` & `CONFIG_ESP_INT_WDT`
- 800 if `CONFIG_SPIRAM` & `CONFIG_ESP_INT_WDT`

**CONFIG_ESP_INT_WDT_CHECK_CPU1**

Also watch CPU1 tick interrupt

*Found in: Component config > ESP System Settings > CONFIG_ESP_INT_WDT*

Also detect if interrupts on CPU 1 are disabled for too long.
Chapter 2. API Reference

Default value:
- Yes (enabled) if `CONFIG_ESP_INT_WDT` && `CONFIG_FREERTOS_UNICORE`

**CONFIG_ESP_TASK_WDT_EN**
Enable Task Watchdog Timer

*Found in: Component config > ESP System Settings*

The Task Watchdog Timer can be used to make sure individual tasks are still running. Enabling this option will enable the Task Watchdog Timer. It can be either initialized automatically at startup or initialized after startup (see Task Watchdog Timer API Reference)

Default value:
- Yes (enabled)

**CONFIG_ESP_TASK_WDT_INIT**
Initialize Task Watchdog Timer on startup

*Found in: Component config > ESP System Settings > CONFIG_ESP_TASK_WDT_EN*

Enabling this option will cause the Task Watchdog Timer to be initialized automatically at startup.

Default value:
- Yes (enabled)

**CONFIG_ESP_TASK_WDT_PANIC**
Invoke panic handler on Task Watchdog timeout

*Found in: Component config > ESP System Settings > CONFIG_ESP_TASK_WDT_EN > CONFIG_ESP_TASK_WDT_INIT*

If this option is enabled, the Task Watchdog Timer will be configured to trigger the panic handler when it times out. This can also be configured at run time (see Task Watchdog Timer API Reference)

Default value:
- No (disabled)

**CONFIG_ESP_TASK_WDT_TIMEOUT_S**
Task Watchdog timeout period (seconds)

*Found in: Component config > ESP System Settings > CONFIG_ESP_TASK_WDT_EN > CONFIG_ESP_TASK_WDT_INIT*

Timeout period configuration for the Task Watchdog Timer in seconds. This is also configurable at run time (see Task Watchdog Timer API Reference)

Range:
- from 1 to 60

Default value:
- 5

**CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU0**
Watch CPU0 Idle Task

*Found in: Component config > ESP System Settings > CONFIG_ESP_TASK_WDT_EN > CONFIG_ESP_TASK_WDT_INIT*

If this option is enabled, the Task Watchdog Timer will watch the CPU0 Idle Task. Having the Task Watchdog watch the Idle Task allows for detection of CPU starvation as the Idle Task not being called is
usually a symptom of CPU starvation. Starvation of the Idle Task is detrimental as FreeRTOS household tasks depend on the Idle Task getting some runtime every now and then.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU1**

Watch CPU1 Idle Task

*Found in: Component config > ESP System Settings > CONFIG_ESP_TASK_WDT_EN > CONFIG_ESP_TASK_WDT_INIT*

If this option is enabled, the Task Watchdog Timer will wach the CPU1 Idle Task.

**Default value:**
- Yes (enabled) if CONFIG_ESP_TASK_WDT_INIT && CONFIG_FREERTOS_UNICORE

**CONFIG_ESP_PANIC_HANDLER_IRAM**

Place panic handler code in IRAM

*Found in: Component config > ESP System Settings*

If this option is disabled (default), the panic handler code is placed in flash not IRAM. This means that if ESP-IDF crashes while flash cache is disabled, the panic handler will automatically re-enable flash cache before running GDB Stub or Core Dump. This adds some minor risk, if the flash cache status is also corrupted during the crash.

If this option is enabled, the panic handler code (including required UART functions) is placed in IRAM. This may be necessary to debug some complex issues with crashes while flash cache is disabled (for example, when writing to SPI flash) or when flash cache is corrupted when an exception is triggered.

**Default value:**
- No (disabled)

**CONFIG_ESP_DEBUG_STUBS_ENABLE**

OpenOCD debug stubs

*Found in: Component config > ESP System Settings*

Debug stubs are used by OpenOCD to execute pre-compiled onboard code which does some useful debugging stuff, e.g. GCOV data dump.

**Default value:**
- “COMPILER_OPTIMIZATION_LEVEL_DEBUG” if CONFIG_ESP32_TRAX && ESP32S2_TRAX && ESP32S3_TRAX

**CONFIG_ESP_DEBUG_OCD_AWARE**

Make exception and panic handlers JTAG/OCD aware

*Found in: Component config > ESP System Settings*

The FreeRTOS panic and unhandled exception handlers can detect a JTAG OCD debugger and instead of panicking, have the debugger stop on the offending instruction.

**Default value:**
- Yes (enabled)
**CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL**

Interrupt level to use for Interrupt Watchdog and other system checks.

*Found in: Component config > ESP System Settings*

Interrupt level to use for Interrupt Watchdog and other system checks.

Available options:

- Level 5 interrupt (CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL_5)
  - Using level 5 interrupt for Interrupt Watchdog and other system checks.
- Level 4 interrupt (CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL_4)
  - Using level 4 interrupt for Interrupt Watchdog and other system checks.

**Brownout Detector**

Contains:

- `CONFIG_ESP_BROWNOUT_DET`

**CONFIG_ESP_BROWNOUT_DET**

Hardware brownout detect & reset.

*Found in: Component config > ESP System Settings > Brownout Detector*

The ESP has a built-in brownout detector which can detect if the voltage is lower than a specific value. If this happens, it will reset the chip in order to prevent unintended behaviour.

**Default value:**

- Yes (enabled)

**CONFIG_ESP_BROWNOUTDET_LVL_SEL**

Brownout voltage level

*Found in: Component config > ESP System Settings > Brownout Detector > CONFIG_ESP_BROWNOUT_DET*

The brownout detector will reset the chip when the supply voltage is approximately below this level. Note that there may be some variation of brownout voltage level between each ESP chip.

#The voltage levels here are estimates, more work needs to be done to figure out the exact voltages of the brownout threshold levels.

Available options:

- 2.43V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_0)
- 2.48V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_1)
- 2.58V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_2)
- 2.62V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_3)
- 2.67V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_4)
- 2.70V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_5)
- 2.77V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_6)
- 2.80V +/- 0.05 (CONFIG_ESP_BROWNOUTDET_LVL_SEL_7)

**CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE**

Permanently disable BASIC ROM Console

*Found in: Component config > ESP System Settings*
If set, the first time the app boots it will disable the BASIC ROM Console permanently (by burning an eFuse).

Otherwise, the BASIC ROM Console starts on reset if no valid bootloader is read from the flash.

(Enabling secure boot also disables the BASIC ROM Console by default.)

Default value:
• No (disabled)

IPC (Inter-Processor Call)  Contains:
• `CONFIG_ESP_IPC_TASK_STACK_SIZE`
• `CONFIG_ESP_IPC_USES_CALLERS_PRIORITY`

`CONFIG_ESP_IPC_TASK_STACK_SIZE`
Inter-Processor Call (IPC) task stack size

*Found in: Component config > IPC (Inter-Processor Call)*

Configure the IPC tasks stack size. An IPC task runs on each core (in dual core mode), and allows for cross-core function calls. See IPC documentation for more details. The default IPC stack size should be enough for most common simple use cases. However, users can increase/decrease the stack size to their needs.

Range:
• from 512 to 65536

Default value:
• 1024

`CONFIG_ESP_IPC_USES_CALLERS_PRIORITY`
IPC runs at caller’s priority

*Found in: Component config > IPC (Inter-Processor Call)*

If this option is not enabled then the IPC task will keep behavior same as prior to that of ESP-IDF v4.0, hence IPC task will run at (configMAX_PRIORITIES - 1) priority.

Default value:
• Yes (enabled) if `CONFIG_FREERTOS_UNICORE`

High resolution timer (esp_timer)  Contains:
• `CONFIG_ESP_TIMER_PROFILING`
• `CONFIG_ESP_TIMER_TASK_AFFINITY`
• `CONFIG_ESP_TIMER_TASK_STACK_SIZE`
• `CONFIG_ESP_TIMER_INTERRUPT_LEVEL`
• `CONFIG_ESP_TIMER_SHOW_EXPERIMENTAL`
• `CONFIG_ESP_TIMER_SUPPORTED_ISR_DISPATCH_METHOD`
• `CONFIG_ESP_TIMER_ISR_AFFINITY`

`CONFIG_ESP_TIMER_PROFILING`
Enable esp_timer profiling features

*Found in: Component config > High resolution timer (esp_timer)*

If enabled, esp_timer_dump will dump information such as number of times the timer was started, number of times the timer has triggered, and the total time it took for the callback to run. This option has some effect on timer performance and the amount of memory used for timer storage, and should only be used for debugging/testing purposes.
CONFIG_ESP_TIMER_TASK_STACK_SIZE

High-resolution timer task stack size

*Found in: Component config > High resolution timer (esp_timer)*

Configure the stack size of “timer_task” task. This task is used to dispatch callbacks of timers created using ets_timer and esp_timer APIs. If you are seeing stack overflow errors in timer task, increase this value.

Note that this is not the same as FreeRTOS timer task. To configure FreeRTOS timer task size, see “FreeRTOS timer task stack size” option in “FreeRTOS”.

*Range:*
- from 2048 to 65536

*Default value:*
- 3584

CONFIG_ESP_TIMER_INTERRUPT_LEVEL

Interrupt level

*Found in: Component config > High resolution timer (esp_timer)*

It sets the interrupt level for esp_timer ISR in range 1..3. A higher level (3) helps to decrease the ISR esp_timer latency.

*Range:*
- from 1 to 3
- from 1 to 1

*Default value:*
- 1

CONFIG_ESP_TIMER_SHOW_EXPERIMENTAL

show esp_timer’s experimental features

*Found in: Component config > High resolution timer (esp_timer)*

This shows some hidden features of esp_timer. Note that they may break other features, use them with care.

CONFIG_ESP_TIMER_TASK_AFFINITY

esp_timer task core affinity

*Found in: Component config > High resolution timer (esp_timer)*

The default settings: timer TASK on CPU0 and timer ISR on CPU0. Other settings may help in certain cases, but note that they may break other features, use them with care. - “CPU0” : (default) esp_timer task is processed by CPU0. - “CPU1” : esp_timer task is processed by CPU1. - “No affinity” : esp_timer task can be processed by any CPU.

*Available options:*

- CPU0 (CONFIG_ESP_TIMER_TASK_AFFINITY_CPU0)
- CPU1 (CONFIG_ESP_TIMER_TASK_AFFINITY_CPU1)
- No affinity (CONFIG_ESP_TIMER_TASK_AFFINITY_NO_AFFINITY)
**CONFIG_ESP_TIMER_ISR_AFFINITY**

Timer interrupt core affinity

*Found in: Component config > High resolution timer (esp_timer)*

The default settings: timer TASK on CPU0 and timer ISR on CPU0. Other settings may help in certain cases, but note that they may break other features, use them with care. - “CPU0” : (default) timer interrupt is processed by CPU0. - “CPU1” : timer interrupt is processed by CPU1. - “No affinity” : timer interrupt can be processed by any CPU. It helps to reduce latency but there is a disadvantage it leads to the timer ISR running on every core. It increases the CPU time usage for timer ISRs by N on an N-core system.

Available options:

- CPU0 (CONFIG_ESP_TIMER_ISR_AFFINITY_CPU0)
- CPU1 (CONFIG_ESP_TIMER_ISR_AFFINITY_CPU1)
- No affinity (CONFIG_ESP_TIMER_ISR_AFFINITY_NO_AFFINITY)

**CONFIG_ESP_TIMER_SUPPORTS_ISR_DISPATCH_METHOD**

Support ISR dispatch method

*Found in: Component config > High resolution timer (esp_timer)*

Allows using ESP_TIMER_ISR dispatch method (ESP_TIMER_TASK dispatch method is also available). - ESP_TIMER_TASK - Timer callbacks are dispatched from a high-priority esp_timer task. - ESP_TIMER_ISR - Timer callbacks are dispatched directly from the timer interrupt handler. The ISR dispatch can be used, in some cases, when a callback is very simple or need a lower-latency.

**Default value:**

- No (disabled)

**Wi-Fi** Contains:

- CONFIG_ESP_WIFI_TESTING_OPTIONS
- CONFIG_ESP_WIFI_WPS_SOFTAP_REGISTRAR
- CONFIG_ESP_WIFI_11KV_SUPPORT
- CONFIG_ESP_WIFI_11R_SUPPORT
- CONFIG_ESP_WIFI_DPP_SUPPORT
- CONFIG_ESP_WIFI_ENTERPRISE_SUPPORT
- CONFIG_ESP_WIFI_MBO_SUPPORT
- CONFIG_ESP_WIFI_SUITE_B_192
- CONFIG_ESP_WIFI_ENABLE_WPA3_OWE_STA
- CONFIG_ESP_WIFI_WAPI_PSK
- CONFIG_ESP_WIFI_ENABLE_WIFI_RX_STATS
- CONFIG_ESP_WIFI_ENABLE_WIFI_TX_STATS
- CONFIG_ESP_WIFI_ENABLE_WPA3_SAE
- CONFIG_ESP_WIFI_SOFTAP_BEACON_MAX_LEN
- CONFIG_ESP_WIFI_CACHE_TX_BUFFER_NUM
- CONFIG_ESP_WIFI_DYNAMIC_RX_BUFFER_NUM
- CONFIG_ESP_WIFI_DYNAMIC_TX_BUFFER_NUM
- CONFIG_ESP_WIFI_RX_MGMT_BUF_NUM_DEF
- CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM
- CONFIG_ESP_WIFI_STATIC_TX_BUFFER_NUM
- CONFIG_ESP_WIFI_ESPNOW_MAX_ENCRYPT_NUM
- CONFIG_ESP_WIFI_STA_DISCONNECTED_PM_ENABLE
- CONFIG_ESP_WIFI_DEBUG_PRINT
- CONFIG_ESP_WIFI_MGMT_RX_BUFFER
- CONFIG_ESP_WIFI_TX_BUFFER
**Chapter 2. API Reference**

- `CONFIG_ESP_WIFI_MBEDTLS_CRYPTO`
- `CONFIG_ESP_WIFI_AMPDU_RX_ENABLED`
- `CONFIG_ESP_WIFI_AMPDU_TX_ENABLED`
- `CONFIG_ESP_WIFI_AMSDU_TX_ENABLED`
- `CONFIG_ESP_WIFI_NAN_ENABLE`
- `CONFIG_ESP_WIFI_CSI_ENABLED`
- `CONFIG_ESP_WIFI_EXTRA_IRAM_OPT`
- `CONFIG_ESP_WIFI_FTM_ENABLE`
- `CONFIG_ESP_WIFI_GCMP_SUPPORT`
- `CONFIG_ESP_WIFI_GMAC_SUPPORT`
- `CONFIG_ESP_WIFI_IRAM_OPT`
- `CONFIG_ESP_WIFI_MGMT_SBUF_NUM`
- `CONFIG_ESP_WIFI_ENHANCED_LIGHT_SLEEP`
- `CONFIG_ESP_WIFI_NVS_ENABLED`
- `CONFIG_ESP_WIFI_RX_IRAM_OPT`
- `CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT`
- `CONFIG_ESP_WIFI_SLP_IRAM_OPT`
- `CONFIG_ESP_WIFI_SOFTAP_SUPPORT`
- `CONFIG_ESP_WIFI_TASK_CORE_ID`
- `WPS Configuration Options`

### `CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM`

Max number of WiFi static RX buffers

*Found in:* `Component config > Wi-Fi`

Set the number of WiFi static RX buffers. Each buffer takes approximately 1.6KB of RAM. The static rx buffers are allocated when `esp_wifi_init` is called, they are not freed until `esp_wifi_deinit` is called.

WiFi hardware use these buffers to receive all 802.11 frames. A higher number may allow higher throughput but increases memory use. If `ESP_WIFI_AMPDU_RX_ENABLE` is enabled, this value is recommended to set equal or bigger than `ESP_WIFI_RX_BA_WIN` in order to achieve better throughput and compatibility with both stations and APs.

**Range:**

- from 2 to 25 if `SOC_WIFI_HE_SUPPORT`
- from 2 to 128 if `SOC_WIFI_HE_SUPPORT`

**Default value:**

- 10 if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
- 16 if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`

### `CONFIG_ESP_WIFI_DYNAMIC_RX_BUFFER_NUM`

Max number of WiFi dynamic RX buffers

*Found in:* `Component config > Wi-Fi`

Set the number of WiFi dynamic RX buffers, 0 means unlimited RX buffers will be allocated (provided sufficient free RAM). The size of each dynamic RX buffer depends on the size of the received data frame.

For each received data frame, the WiFi driver makes a copy to an RX buffer and then delivers it to the high layer TCP/IP stack. The dynamic RX buffer is freed after the higher layer has successfully received the data frame.

For some applications, WiFi data frames may be received faster than the application can process them. In these cases we may run out of memory if RX buffer number is unlimited (0).

If a dynamic RX buffer limit is set, it should be at least the number of static RX buffers.

**Range:**

- from 0 to 128 if `CONFIG_LWIP_WND_SCALE`
• from 0 to 1024 if `CONFIG_LWIP_WND_SCALE`

Default value:
• 32

CONFIG_ESP_WIFI_TX_BUFFER

Type of WiFi TX buffers

*Found in: Component config > Wi-Fi*

Select type of WiFi TX buffers:

If “Static” is selected, WiFi TX buffers are allocated when WiFi is initialized and released when WiFi is de-initialized. The size of each static TX buffer is fixed to about 1.6KB.

If “Dynamic” is selected, each WiFi TX buffer is allocated as needed when a data frame is delivered to the WiFi driver from the TCP/IP stack. The buffer is freed after the data frame has been sent by the WiFi driver. The size of each dynamic TX buffer depends on the length of each data frame sent by the TCP/IP layer.

If PSRAM is enabled, “Static” should be selected to guarantee enough WiFi TX buffers. If PSRAM is disabled, “Dynamic” should be selected to improve the utilization of RAM.

Available options:

• Static (CONFIG_ESP_WIFI_STATIC_TX_BUFFER)
• Dynamic (CONFIG_ESP_WIFI_DYNAMIC_TX_BUFFER)

CONFIG_ESP_WIFI_STATIC_TX_BUFFER_NUM

Max number of WiFi static TX buffers

*Found in: Component config > Wi-Fi*

Set the number of WiFi static TX buffers. Each buffer takes approximately 1.6KB of RAM. The static RX buffers are allocated when esp_wifi_init() is called, they are not released until esp_wifi_deinit() is called.

For each transmitted data frame from the higher layer TCP/IP stack, the WiFi driver makes a copy of it in a TX buffer. For some applications especially UDP applications, the upper layer can deliver frames faster than WiFi layer can transmit. In these cases, we may run out of TX buffers.

Range:
• from 1 to 64 if `CONFIG_ESP_WIFI_STATIC_TX_BUFFER`

Default value:
• 16 if `CONFIG_ESP_WIFI_STATIC_TX_BUFFER`

CONFIG_ESP_WIFI_CACHE_TX_BUFFER_NUM

Max number of WiFi cache TX buffers

*Found in: Component config > Wi-Fi*

Set the number of WiFi cache TX buffer number.

For each TX packet from uplayer, such as LWIP etc, WiFi driver needs to allocate a static TX buffer and makes a copy of uplayer packet. If WiFi driver fails to allocate the static TX buffer, it caches the uplayer packets to a dedicated buffer queue, this option is used to configure the size of the cached TX queue.

Range:
• from 16 to 128 if `CONFIG_SPIRAM`

Default value:
• 32 if `CONFIG_SPIRAM`
**CONFIG_ESP_WIFI_DYNAMIC_TX_BUFFER_NUM**

Max number of WiFi dynamic TX buffers

*Found in: Component config > Wi-Fi*

Set the number of WiFi dynamic TX buffers. The size of each dynamic TX buffer is not fixed, it depends on the size of each transmitted data frame.

For each transmitted frame from the higher layer TCP/IP stack, the WiFi driver makes a copy of it in a TX buffer. For some applications, especially UDP applications, the upper layer can deliver frames faster than WiFi layer can transmit. In these cases, we may run out of TX buffers.

**Range:**
- from 1 to 128

**Default value:**
- 32

**CONFIG_ESP_WIFI_MGMT_RX_BUFFER**

Type of WiFi RX MGMT buffers

*Found in: Component config > Wi-Fi*

Select type of WiFi RX MGMT buffers:

If “Static” is selected, WiFi RX MGMT buffers are allocated when WiFi is initialized and released when WiFi is de-initialized. The size of each static RX MGMT buffer is fixed to about 500 Bytes.

If “Dynamic” is selected, each WiFi RX MGMT buffer is allocated as needed when a MGMT data frame is received. The MGMT buffer is freed after the MGMT data frame has been processed by the WiFi driver.

**Available options:**
- Static (CONFIG_ESP_WIFI_STATIC_RX_MGMT_BUFFER)
- Dynamic (CONFIG_ESP_WIFI_DYNAMIC_RX_MGMT_BUFFER)

**CONFIG_ESP_WIFI_RX_MGMT_BUF_NUM_DEF**

Max number of WiFi RX MGMT buffers

*Found in: Component config > Wi-Fi*

Set the number of WiFi RX_MGMT buffers.

For Management buffers, the number of dynamic and static management buffers is the same. In order to prevent memory fragmentation, the management buffer type should be set to static first.

**Range:**
- from 1 to 10

**Default value:**
- 5

**CONFIG_ESP_WIFI_CSI_ENABLED**

WiFi CSI(Channel State Information)

*Found in: Component config > Wi-Fi*

Select this option to enable CSI(Channel State Information) feature. CSI takes about CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM KB of RAM. If CSI is not used, it is better to disable this feature in order to save memory.

**Default value:**
• No (disabled)

**CONFIG_ESP_WIFI_AMPDU_TX_ENABLED**

WiFi AMPDU TX

*Found in: Component config > Wi-Fi*

Select this option to enable AMPDU TX feature

**Default value:**

• Yes (enabled)

**CONFIG_ESP_WIFI_TX_BA_WIN**

WiFi AMPDUTX BA windowsize

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_AMPDU_TX_ENABLED*

Set the size of WiFi Block Ack TX window. Generally a bigger value means higher throughput but more memory. Most of time we should NOT change the default value unless special reason, e.g. test the maximum UDP TX throughput with iperf etc. For iperf test in shieldbox, the recommended value is 9~12.

**Range:**

• from 2 to 32 if SOC_WIFI_HE_SUPPORT && CONFIG_ESP_WIFI_AMPDU_TX_ENABLED
• from 2 to 64 if SOC_WIFI_HE_SUPPORT && CONFIG_ESP_WIFI_AMPDU_TX_ENABLED

**Default value:**

• 6

**CONFIG_ESP_WIFI_AMPDU_RX_ENABLED**

WiFi AMPDU RX

*Found in: Component config > Wi-Fi*

Select this option to enable AMPDU RX feature

**Default value:**

• Yes (enabled)

**CONFIG_ESP_WIFI_RX_BA_WIN**

WiFi AMPDURX BA windowsize

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_AMPDU_RX_ENABLED*

Set the size of WiFi Block Ack RX window. Generally a bigger value means higher throughput and better compatibility but more memory. Most of time we should NOT change the default value unless special reason, e.g. test the maximum UDP RX throughput with iperf etc. For iperf test in shieldbox, the recommended value is 9~12. If PSRAM is used and WiFi memory is prefered to allocat in PSRAM first, the default and minimum value should be 16 to achieve better throughput and compatibility with both stations and APs.

**Range:**

• from 2 to 32 if SOC_WIFI_HE_SUPPORT && CONFIG_ESP_WIFI_AMPDU_RX_ENABLED
• from 2 to 64 if SOC_WIFI_HE_SUPPORT && CONFIG_ESP_WIFI_AMPDU_RX_ENABLED

**Default value:**
Chapter 2. API Reference

- 6 if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP` && `CONFIG_ESP_WIFI_AMSDU_RX_ENABLED`
- 16 if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP` && `CONFIG_ESP_WIFI_AMSDU_TX_ENABLED`

**CONFIG_ESP_WIFI_AMSDU_TX_ENABLED**

WiFi AMSDU TX

*Found in: Component config > Wi-Fi*

Select this option to enable AMSDU TX feature

**Default value:**
- No (disabled) if `CONFIG_SPIRAM`

**CONFIG_ESP_WIFI_NVS_ENABLED**

WiFi NVS flash

*Found in: Component config > Wi-Fi*

Select this option to enable WiFi NVS flash

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_TASK_CORE_ID**

WiFi Task Core ID

*Found in: Component config > Wi-Fi*

Pinned WiFi task to core 0 or core 1.

Available options:

- Core 0 (CONFIG_ESP_WIFI_TASK_PINNED_TO_CORE_0)
- Core 1 (CONFIG_ESP_WIFI_TASK_PINNED_TO_CORE_1)

**CONFIG_ESP_WIFI_SOFTAP_BEACON_MAX_LEN**

Max length of WiFi SoftAP Beacon

*Found in: Component config > Wi-Fi*

ESP-MESH utilizes beacon frames to detect and resolve root node conflicts (see documentation). However the default length of a beacon frame can simultaneously hold only five root node identifier structures, meaning that a root node conflict of up to five nodes can be detected at one time. In the occurrence of more root nodes conflict involving more than five root nodes, the conflict resolution process will detect five of the root nodes, resolve the conflict, and re-detect more root nodes. This process will repeat until all root node conflicts are resolved. However this process can generally take a very long time.

To counter this situation, the beacon frame length can be increased such that more root nodes can be detected simultaneously. Each additional root node will require 36 bytes and should be added on top of the default beacon frame length of 752 bytes. For example, if you want to detect 10 root nodes simultaneously, you need to set the beacon frame length as 932 (752+36*5).

Setting a longer beacon length also assists with debugging as the conflicting root nodes can be identified more quickly.

**Range:**
- from 752 to 1256
**CONFIG_ESP_WIFI_MGMT_SBUF_NUM**

WiFi mgmt short buffer number

*Found in: Component config > Wi-Fi*

Set the number of WiFi management short buffer.

**Range:**
- from 6 to 32

**Default value:**
- 32

**CONFIG_ESP_WIFI_IRAM_OPT**

WiFi IRAM speed optimization

*Found in: Component config > Wi-Fi*

Select this option to place frequently called Wi-Fi library functions in IRAM. When this option is disabled, more than 10Kbytes of IRAM memory will be saved but Wi-Fi throughput will be reduced.

**Default value:**
- No (disabled) if `CONFIG_BT_ENABLED` && `CONFIG_SPIRAM`
- Yes (enabled)

**CONFIG_ESP_WIFI_EXTRA_IRAM_OPT**

WiFi EXTRA IRAM speed optimization

*Found in: Component config > Wi-Fi*

Select this option to place additional frequently called Wi-Fi library functions in IRAM. When this option is disabled, more than 5Kbytes of IRAM memory will be saved but Wi-Fi throughput will be reduced.

**Default value:**
- No (disabled)

**CONFIG_ESP_WIFI_RX_IRAM_OPT**

WiFi RX IRAM speed optimization

*Found in: Component config > Wi-Fi*

Select this option to place frequently called Wi-Fi library RX functions in IRAM. When this option is disabled, more than 17Kbytes of IRAM memory will be saved but Wi-Fi performance will be reduced.

**Default value:**
- No (disabled) if `CONFIG_BT_ENABLED` && `CONFIG_SPIRAM`
- Yes (enabled)

**CONFIG_ESP_WIFI_ENABLE_WPA3_SAE**

Enable WPA3-Personal

*Found in: Component config > Wi-Fi*

Select this option to allow the device to establish a WPA3-Personal connection with eligible AP’s. PMF (Protected Management Frames) is a prerequisite feature for a WPA3 connection, it needs to be
explicitly configured before attempting connection. Please refer to the Wi-Fi Driver API Guide for details.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_ENABLE_SAE_PK**

Enable SAE-PK

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_ENABLE_WPA3_SAE*

Select this option to enable SAE-PK

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_SOFTAP_SAE_SUPPORT**

Enable WPA3 Personal(SAE) SoftAP

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_ENABLE_WPA3_SAE*

Select this option to enable SAE support in softAP mode.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_ENABLE_WPA3_OWE_STA**

Enable OWE STA

*Found in: Component config > Wi-Fi*

Select this option to allow the device to establish OWE connection with eligible AP’s. PMF (Protected Management Frames) is a prerequisite feature for a WPA3 connection, it needs to be explicitly configured before attempting connection. Please refer to the Wi-Fi Driver API Guide for details.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_SLP_IRAM_OPT**

WiFi SLP IRAM speed optimization

*Found in: Component config > Wi-Fi*

Select this option to place called Wi-Fi library TBTT process and receive beacon functions in IRAM. Some functions can be put in IRAM either by ESP_WIFI_IRAM_OPT and ESP_WIFI_RX_IRAM_OPT, or this one. If already enabled ESP_WIFI_IRAM_OPT, the other 7.3KB IRAM memory would be taken by this option. If already enabled ESP_WIFI_RX_IRAM_OPT, the other 1.3KB IRAM memory would be taken by this option. If neither of them are enabled, the other 7.4KB IRAM memory would be taken by this option. Wi-Fi power-save mode average current would be reduced if this option is enabled.

**CONFIG_ESP_WIFI_SLP_DEFAULT_MIN_ACTIVE_TIME**

Minimum active time

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_SLP_IRAM_OPT*

The minimum timeout for waiting to receive data, unit: milliseconds.

**Range:**
- from 8 to 60 if CONFIG_ESP_WIFI_SLP_IRAM_OPT
Default value:
  • 50 if \texttt{CONFIG\_ESP\_WIFI\_SLP\_IRAM\_OPT}

\textbf{CONFIG\_ESP\_WIFI\_SLP\_DEFAULT\_MAX\_ACTIVE\_TIME}

Maximum keep alive time

\textit{Found in: Component config > Wi-Fi > CONFIG\_ESP\_WIFI\_SLP\_IRAM\_OPT}

The maximum time that wifi keep alive, unit: seconds.

\textbf{Range:}
  • from 10 to 60 if \texttt{CONFIG\_ESP\_WIFI\_SLP\_IRAM\_OPT}

\textbf{Default value:}
  • 10 if \texttt{CONFIG\_ESP\_WIFI\_SLP\_IRAM\_OPT}

\textbf{CONFIG\_ESP\_WIFI\_FTM\_ENABLE}

WiFi FTM

\textit{Found in: Component config > Wi-Fi}

Enable feature Fine Timing Measurement for calculating WiFi Round-Trip-Time (RTT).

\textbf{Default value:}
  • No (disabled) if SOC\_WiFi\_FTM\_SUPPORT

\textbf{CONFIG\_ESP\_WIFI\_FTM\_INITIATOR\_SUPPORT}

FTM Initiator support

\textit{Found in: Component config > Wi-Fi > CONFIG\_ESP\_WIFI\_FTM\_ENABLE}

\textbf{Default value:}
  • Yes (enabled) if \texttt{CONFIG\_ESP\_WIFI\_FTM\_ENABLE}

\textbf{CONFIG\_ESP\_WIFI\_FTM\_RESPONDER\_SUPPORT}

FTM Responder support

\textit{Found in: Component config > Wi-Fi > CONFIG\_ESP\_WIFI\_FTM\_ENABLE}

\textbf{Default value:}
  • Yes (enabled) if \texttt{CONFIG\_ESP\_WIFI\_FTM\_ENABLE}

\textbf{CONFIG\_ESP\_WIFI\_STA\_DISCONNECTED\_PM\_ENABLE}

Power Management for station at disconnected

\textit{Found in: Component config > Wi-Fi}

Select this option to enable power_management for station when disconnected. Chip will do modem-sleep when rf module is not in use any more.

\textbf{Default value:}
  • Yes (enabled)

\textbf{CONFIG\_ESP\_WIFI\_GCMP\_SUPPORT}

WiFi GCMP Support(GCMP128 and GCMP256)

\textit{Found in: Component config > Wi-Fi}

Select this option to enable GCMP support. GCMP support is compulsory for WiFi Suite-B support.
**Default value:**
- No (disabled) if `SOC_WIFI_GCMP_SUPPORT`

**CONFIG_ESP_WIFI_GMAC_SUPPORT**

WiFi GMAC Support (GMAC128 and GMAC256)

*Found in: Component config > Wi-Fi*

Select this option to enable GMAC support. GMAC support is compulsory for WiFi 192 bit certification.

**Default value:**
- No (disabled)

**CONFIG_ESP_WIFI_SOFTAP_SUPPORT**

WiFi SoftAP Support

*Found in: Component config > Wi-Fi*

WiFi module can be compiled without SoftAP to save code size.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_ENHANCED_LIGHT_SLEEP**

WiFi modem automatically receives the beacon

*Found in: Component config > Wi-Fi*

The wifi modem automatically receives the beacon frame during light sleep.

**Default value:**
- No (disabled) if `CONFIG_ESP_PHY_MAC_BB_PD` && `SOC_PM_SUPPORT_BEACON_WAKEUP`

**CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT**

Wifi sleep optimize when beacon lost

*Found in: Component config > Wi-Fi*

Enable wifi sleep optimization when beacon loss occurs and immediately enter sleep mode when the WiFi module detects beacon loss.

**CONFIG_ESP_WIFI_SLP_BEACON_LOST_TIMEOUT**

Beacon loss timeout

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT*

Timeout time for close rf phy when beacon loss occurs, Unit: 1024 microsecond.

**Range:**
- from 5 to 100 if `CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT`

**Default value:**
- 10 if `CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT`
CONFIG_ESP_WIFI_SLP_BEACON_LOST_THRESHOLD

Maximum number of consecutive lost beacons allowed

Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

Maximum number of consecutive lost beacons allowed, WiFi keeps Rx state when the number of consecutive beacons lost is greater than the given threshold.

Range:
- from 0 to 8 if CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

Default value:
- 3 if CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

CONFIG_ESP_WIFI_SLP_PHY_ON_DELTA_EARLY_TIME

Delta early time for RF PHY on

Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

Delta early time for rf phy on. When the beacon is lost, the next rf phy on will be earlier the time specified by the configuration item. Unit: 32 microsecond.

Range:
- from 0 to 100 if CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

Default value:
- 2 if CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

CONFIG_ESP_WIFI_SLP_PHY_OFF_DELTA_TIMEOUT_TIME

Delta timeout time for RF PHY off

Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

Delta timeout time for rf phy off. When the beacon is lost, the next rf phy off will be delayed for the time specified by the configuration item. Unit: 1024 microsecond.

Range:
- from 0 to 8 if CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

Default value:
- 2 if CONFIG_ESP_WIFI_SLP_BEACON_LOST_OPT

CONFIG_ESP_WIFI_ESPNOW_MAX_ENCRYPT_NUM

Maximum espnow encrypt peers number

Found in: Component config > Wi-Fi

Maximum number of encrypted peers supported by espnow. The number of hardware keys for encryption is fixed. And the espnow and SoftAP share the same hardware keys. So this configuration will affect the maximum connection number of SoftAP. Maximum espnow encrypted peers number + maximum number of connections of SoftAP = Max hardware keys number. When using ESP mesh, this value should be set to a maximum of 6.

Range:
- from 0 to 17

Default value:
- 7

CONFIG_ESP_WIFI_NAN_ENABLE
WiFi Aware

*Found in: Component config > Wi-Fi*

Enable WiFi Aware (NAN) feature.

**Default value:**
- No (disabled)

**CONFIG_ESP_WIFI_ENABLE_WIFI_TX_STATS**

Enable Wi-Fi transmission statistics

*Found in: Component config > Wi-Fi*

Enable Wi-Fi transmission statistics. Total support 4 access category. Each access category will use 346 bytes memory.

**Default value:**
- Yes (enabled) if SOC_WIFI_HE_SUPPORT

**CONFIG_ESP_WIFI_MBEDTLS_CRYPTO**

Use MbedTLS crypto APIs

*Found in: Component config > Wi-Fi*

Select this option to enable the use of MbedTLS crypto APIs. The internal crypto support within the supplicant is limited and may not suffice for all new security features, including WPA3.

It is recommended to always keep this option enabled. Additionally, note that MbedTLS can leverage hardware acceleration if available, resulting in significantly faster cryptographic operations.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_MBEDTLS_TLS_CLIENT**

Use MbedTLS TLS client for WiFi Enterprise connection

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_MBEDTLS_CRYPTO*

Select this option to use MbedTLS TLS client for WPA2 enterprise connection. Please note that from MbedTLS-3.0 onwards, MbedTLS does not support SSL-3.0 TLS-v1.0, TLS-v1.1 versions. Incase your server is using one of these version, it is advisable to update your server. Please disable this option for compatibility with older TLS versions.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_WIFI_WAPI_PSK**

Enable WAPI PSK support

*Found in: Component config > Wi-Fi*

Select this option to enable WAPI-PSK which is a Chinese National Standard Encryption for Wireless LANs (GB 15629.11-2003).

**Default value:**
- No (disabled)
CONFIG_ESP_WIFI_SUITE_B_192
Enable NSA suite B support with 192 bit key
*Found in: Component config > Wi-Fi*
Select this option to enable 192 bit NSA suite-B. This is necessary to support WPA3 192 bit security.
**Default value:**
- No (disabled) if SOC_WIFI_GCMP_SUPPORT

CONFIG_ESP_WIFI_11KV_SUPPORT
Enable 802.11k, 802.11v APIs Support
*Found in: Component config > Wi-Fi*
Select this option to enable 802.11k 802.11v APIs (RRM and BTM support). Only APIs which are helpful for network assisted roaming are supported for now. Enable this option with BTM and RRM enabled in sta config to make device ready for network assisted roaming. BTM: BSS transition management enables an AP to request a station to transition to a specific AP, or to indicate to a station a set of preferred APs. RRM: Radio measurements enable STAs to understand the radio environment, it enables STAs to observe and gather data on radio link performance and on the radio environment. Current implementation adds beacon report, link measurement, neighbor report.
**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_SCAN_CACHE
Keep scan results in cache
*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_11KV_SUPPORT*
Keep scan results in cache, if not enabled, those will be flushed immediately.
**Default value:**
- No (disabled) if CONFIG_ESP_WIFI_11KV_SUPPORT

CONFIG_ESP_WIFI_MBO_SUPPORT
Enable Multi Band Operation Certification Support
*Found in: Component config > Wi-Fi*
Select this option to enable WiFi Multiband operation certification support.
**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_DPP_SUPPORT
Enable DPP support
*Found in: Component config > Wi-Fi*
Select this option to enable WiFi Easy Connect Support.
**Default value:**
- No (disabled)
CONFIG_ESP_WIFI_11R_SUPPORT
Enable 802.11R (Fast Transition) Support

*Found in: Component config > Wi-Fi*

Select this option to enable WiFi Fast Transition Support.

**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_WPS_SOFTAP_REGISTRAR
Add WPS Registrar support in SoftAP mode

*Found in: Component config > Wi-Fi*

Select this option to enable WPS registrar support in softAP mode.

**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_ENABLE_WIFI_RX_STATS
Enable Wi-Fi reception statistics

*Found in: Component config > Wi-Fi*

Enable Wi-Fi reception statistics. Total support 2 access category. Each access category will use 190 bytes memory.

**Default value:**
- Yes (enabled) if SOC_WIFI_HE_SUPPORT

CONFIG_ESP_WIFI_ENABLE_WIFI_RX_MU_STATS
Enable Wi-Fi DL MU-MIMO and DL OFDMA reception statistics

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_ENABLE_WIFI_RX_STATS*

Enable Wi-Fi DL MU-MIMO and DL OFDMA reception statistics. Will use 10932 bytes memory.

**Default value:**
- Yes (enabled) if CONFIG_ESP_WIFI_ENABLE_WIFI_RX_STATS

WPS Configuration Options Contains:

- CONFIG_ESP_WIFI_WPS_PASSPHRASE
- CONFIG_ESP_WIFI_WPS_STRICT

CONFIG_ESP_WIFI_WPS_STRICT
Strictly validate all WPS attributes

*Found in: Component config > Wi-Fi > WPS Configuration Options*

Select this option to enable validate each WPS attribute rigorously. Disabling this add the workarounds with various APs. Enabling this may cause inter operability issues with some APs.

**Default value:**
- No (disabled)
CONFIG_ESP_WIFI_WPS_PASSPHRASE

Get WPA2 passphrase in WPS config

*Found in: Component config > Wi-Fi > WPS Configuration Options*

Select this option to get passphrase during WPS configuration. This option fakes the virtual display capabilities to get the configuration in passphrase mode. Not recommended to be used since WPS credentials should not be shared to other devices, making it in readable format increases that risk, also passphrase requires pbkdf2 to convert in psk.

**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_DEBUG_PRINT

Print debug messages from WPASupplicant

*Found in: Component config > Wi-Fi*

Select this option to print logging information from WPASupplicant, this includes handshake information and key hex dumps depending on the project logging level. Enabling this could increase the build size ~60kb depending on the project logging level.

**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_TESTING_OPTIONS

Add DPP testing code

*Found in: Component config > Wi-Fi*

Select this to enable unity test for DPP.

**Default value:**
- No (disabled)

CONFIG_ESP_WIFI_ENTERPRISE_SUPPORT

Enable enterprise option

*Found in: Component config > Wi-Fi*

Select this to enable/disable enterprise connection support. Disabling this will reduce binary size. Disabling this will disable the use of any esp_wifi_sta_wpa2_ent_* (as APIs will be meaningless).

**Default value:**
- Yes (enabled)

Core dump Contains:
- CONFIG_ESP_COREDUMP_CHECK_BOOT
- CONFIG_ESP_COREDUMP_DATA_FORMAT
- CONFIG_ESP_COREDUMP_CHECKSUM
- CONFIG_ESP_COREDUMP_TO_FLASH_OR_UART
- CONFIG_ESP_COREDUMP_UART_DELAY
- CONFIG_ESP_COREDUMP_LOGS
- CONFIG_ESP_COREDUMP_DECODE
- CONFIG_ESP_COREDUMP_MAX_TASKS_NUM
- CONFIG_ESP_COREDUMP_STACK_SIZE
Chapter 2. API Reference

**CONFIG_ESP_COREDUMP_TO_FLASH_OR_UART**

Data destination

*Found in: Component config > Core dump*

Select place to store core dump: flash, uart or none (to disable core dumps generation).

Core dumps to Flash are not available if PSRAM is used for task stacks.

If core dump is configured to be stored in flash and custom partition table is used add corresponding entry to your CSV. For examples, please see predefined partition table CSV descriptions in the components/partition_table directory.

Available options:

- Flash (CONFIG_ESP_COREDUMP_ENABLE_TO_FLASH)
- UART (CONFIG_ESP_COREDUMP_ENABLE_TO_UART)
- None (CONFIG_ESP_COREDUMP_ENABLE_TO_NONE)

**CONFIG_ESP_COREDUMP_DATA_FORMAT**

Core dump data format

*Found in: Component config > Core dump*

Select the data format for core dump.

Available options:

- Binary format (CONFIG_ESP_COREDUMP_DATA_FORMAT_BIN)
- ELF format (CONFIG_ESP_COREDUMP_DATA_FORMAT_ELF)

**CONFIG_ESP_COREDUMP_CHECKSUM**

Core dump data integrity check

*Found in: Component config > Core dump*

Select the integrity check for the core dump.

Available options:

- Use CRC32 for integrity verification (CONFIG_ESP_COREDUMP_CHECKSUM_CRC32)
- Use SHA256 for integrity verification (CONFIG_ESP_COREDUMP_CHECKSUM_SHA256)

**CONFIG_ESP_COREDUMP_CHECK_BOOT**

Check core dump data integrity on boot

*Found in: Component config > Core dump*

When enabled, if any data are found on the flash core dump partition, they will be checked by calculating their checksum.

**Default value:**
- Yes (enabled) if CONFIG_ESP_COREDUMP_ENABLE_TO_FLASH
CONFIG_ESP_COREDUMP_LOGS
Enable coredump logs for debugging

*Found in: Component config > Core dump*

Enable/disable coredump logs. Logs strings from espcoredump component are placed in DRAM. Disabling these helps to save ~5KB of internal memory.

CONFIG_ESP_COREDUMP_MAX_TASKS_NUM
Maximum number of tasks

*Found in: Component config > Core dump*

Maximum number of tasks snapshots in core dump.

CONFIG_ESP_COREDUMP_UART_DELAY
Delay before print to UART

*Found in: Component config > Core dump*

Config delay (in ms) before printing core dump to UART. Delay can be interrupted by pressing Enter key.

**Default value:**

- 0 if `CONFIG_ESP_COREDUMP_ENABLE_TO_UART`

CONFIG_ESP_COREDUMP_STACK_SIZE
Reserved stack size

*Found in: Component config > Core dump*

Size of the memory to be reserved for core dump stack. If 0 core dump process will run on the stack of crashed task/ISR, otherwise special stack will be allocated. To ensure that core dump itself will not overflow task/ISR stack set this to the value above 800. NOTE: It eats DRAM.

CONFIG_ESP_COREDUMP_DECODE
Handling of UART core dumps in IDF Monitor

*Found in: Component config > Core dump*

Available options:

- Decode and show summary (info_corefile) (CONFIG_ESP_COREDUMP_DECODE_INFO)
- Don’t decode (CONFIG_ESP_COREDUMP_DECODE_DISABLE)

**FAT Filesystem support** Contains:

- `CONFIG_FATFS_API_ENCODING`
- `CONFIG_FATFS_VFS_FSTAT_BLKSIZE`
- `CONFIG_FATFS_USE_FASTSEEK`
- `CONFIG_FATFS_LONG_FILENAMES`
- `CONFIG_FATFS_MAX_LFN`
- `CONFIG_FATFS_FS_LOCK`
- `CONFIG_FATFS_VOLUME_COUNT`
- `CONFIG_FATFS_CHOOSE_CODEPAGE`
- `CONFIG_FATFS_ALLOC_PREFER_EXTRAM`


**CONFIG_FATFS_VOLUME_COUNT**

Number of volumes

*Found in: Component config > FAT Filesystem support*

Number of volumes (logical drives) to use.

**Range:**
- from 1 to 10

**Default value:**
- 2

**CONFIG_FATFS_LONG_FILENAMES**

Long filename support

*Found in: Component config > FAT Filesystem support*

Support long filenames in FAT. Long filename data increases memory usage. FATFS can be configured to store the buffer for long filename data in stack or heap.

Available options:

- No long filenames (CONFIG_FATFS_LFN_NONE)
- Long filename buffer in heap (CONFIG_FATFS_LFN_HEAP)
- Long filename buffer on stack (CONFIG_FATFS_LFN_STACK)

**CONFIG_FATFS_SECTOR_SIZE**

Sector size

*Found in: Component config > FAT Filesystem support*

Specify the size of the sector in bytes for FATFS partition generator.

Available options:

- 512 (CONFIG_FATFS_SECTOR_512)
- 4096 (CONFIG_FATFS_SECTOR_4096)

**CONFIG_FATFS_CHOOSE_CODEPAGE**

OEM Code Page

*Found in: Component config > FAT Filesystem support*

OEM code page used for file name encodings.

If “Dynamic” is selected, code page can be chosen at runtime using f_setcp function. Note that choosing this option will increase application size by ~480kB.

Available options:

- Dynamic (all code pages supported) (CONFIG_FATFS_CODEPAGE_DYNAMIC)
- US (CP437) (CONFIG_FATFS_CODEPAGE_437)
- Arabic (CP720) (CONFIG_FATFS_CODEPAGE_720)
Chapter 2. API Reference

• Greek (CP737) (CONFIG_FATFS_CODEPAGE_737)
• KBL (CP771) (CONFIG_FATFS_CODEPAGE_771)
• Baltic (CP775) (CONFIG_FATFS_CODEPAGE_775)
• Latin 1 (CP850) (CONFIG_FATFS_CODEPAGE_850)
• Latin 2 (CP852) (CONFIG_FATFS_CODEPAGE_852)
• Cyrillic (CP855) (CONFIG_FATFS_CODEPAGE_855)
• Turkish (CP857) (CONFIG_FATFS_CODEPAGE_857)
• Portuguese (CP860) (CONFIG_FATFS_CODEPAGE_860)
• Icelandic (CP861) (CONFIG_FATFS_CODEPAGE_861)
• Hebrew (CP862) (CONFIG_FATFS_CODEPAGE_862)
• Canadian French (CP863) (CONFIG_FATFS_CODEPAGE_863)
• Arabic (CP864) (CONFIG_FATFS_CODEPAGE_864)
• Nordic (CP865) (CONFIG_FATFS_CODEPAGE_865)
• Russian (CP866) (CONFIG_FATFS_CODEPAGE_866)
• Greek 2 (CP869) (CONFIG_FATFS_CODEPAGE_869)
• Japanese (DBCS) (CP932) (CONFIG_FATFS_CODEPAGE_932)
• Simplified Chinese (DBCS) (CP936) (CONFIG_FATFS_CODEPAGE_936)
• Korean (DBCS) (CP949) (CONFIG_FATFS_CODEPAGE_949)
• Traditional Chinese (DBCS) (CP950) (CONFIG_FATFS_CODEPAGE_950)

CONFIG_FATFS_MAX_LFN

Max long filename length

**Found in:** Component config > FAT Filesystem support

Maximum long filename length. Can be reduced to save RAM.

**Range:**
- from 12 to 255

**Default value:**
- 255

CONFIG_FATFS_API_ENCODING

API character encoding

**Found in:** Component config > FAT Filesystem support

Choose encoding for character and string arguments/returns when using FATFS APIs. The encoding of arguments will usually depend on text editor settings.

**Available options:**
- API uses ANSI/OEM encoding (CONFIG_FATFS_API_ENCODING_ANSI_OEM)
- API uses UTF-8 encoding (CONFIG_FATFS_API_ENCODING_UTF_8)

CONFIG_FATFS_FS_LOCK

Number of simultaneously open files protected by lock function

**Found in:** Component config > FAT Filesystem support

This option sets the FATFS configuration value _FS_LOCK. The option _FS_LOCK switches file lock function to control duplicated file open and illegal operation to open objects.

* 0: Disable file lock function. To avoid volume corruption, application should avoid illegal open, remove and rename to the open objects.

* >0: Enable file lock function. The value defines how many files/sub-directories can be opened simultaneously under file lock control.
Note that the file lock control is independent of re-entrancy.

**Range:**
- from 0 to 65535

**Default value:**
- 0

**CONFIG FATFS_TIMEOUT_MS**

Timeout for acquiring a file lock, ms

*Found in: Component config > FAT Filesystem support*

This option sets FATFS configuration value _FS_TIMEOUT, scaled to milliseconds. Sets the number of milliseconds FATFS will wait to acquire a mutex when operating on an open file. For example, if one task is performing a lengthy operation, another task will wait for the first task to release the lock, and time out after amount of time set by this option.

**Default value:**
- 10000

**CONFIG FATFS_PER_FILE_CACHE**

Use separate cache for each file

*Found in: Component config > FAT Filesystem support*

This option affects FATFS configuration value _FS_TINY.

If this option is set, _FS_TINY is 0, and each open file has its own cache, size of the cache is equal to the _MAX_SS variable (512 or 4096 bytes). This option uses more RAM if more than 1 file is open, but needs less reads and writes to the storage for some operations.

If this option is not set, _FS_TINY is 1, and single cache is used for all open files, size is also equal to _MAX_SS variable. This reduces the amount of heap used when multiple files are open, but increases the number of read and write operations which FATFS needs to make.

**Default value:**
- Yes (enabled)

**CONFIG FATFS_ALLOC_PREFER_EXTRAM**

Perfer external RAM when allocating FATFS buffers

*Found in: Component config > FAT Filesystem support*

When the option is enabled, internal buffers used by FATFS will be allocated from external RAM. If the allocation from external RAM fails, the buffer will be allocated from the internal RAM. Disable this option if optimizing for performance. Enable this option if optimizing for internal memory size.

**Default value:**
- Yes (enabled) if CONFIG_SPIRAM_USE_CAPS_ALLOC || CONFIG_SPIRAM_USE_MALLOC

**CONFIG FATFS_USE_FASTSEEK**

Enable fast seek algorithm when using lseek function through VFS FAT

*Found in: Component config > FAT Filesystem support*

The fast seek feature enables fast backward/long seek operations without FAT access by using an in-memory CLMT (cluster link map table). Please note, fast-seek is only allowed for read-mode files, if a file is opened in write-mode, the seek mechanism will automatically fallback to the default implementation.
Chapter 2. API Reference

**CONFIG_FATFS_FASTSEEK_BUFFER_SIZE**

Fast seek CLMT buffer size

*Found in: Component config > FAT Filesystem support > CONFIG_FATFS_USE_FASTSEEK*

If fast seek algorithm is enabled, this defines the size of CLMT buffer used by this algorithm in 32-bit word units. This value should be chosen based on prior knowledge of maximum elements of each file entry would store.

**Default value:**
- 64 if `CONFIG_FATFS_USE_FASTSEEK`

**CONFIG_FATFS_VFS_FSTAT_BLKSIZE**

Default block size

*Found in: Component config > FAT Filesystem support*

If set to 0, the ‘newlib’ library’s default size (BLKSIZ) is used (128 B). If set to a non-zero value, the value is used as the block size. Default file buffer size is set to this value and the buffer is allocated when first attempt of reading/writing to a file is made. Increasing this value improves fread() speed, however the heap usage is increased as well.

**NOTE:** The block size value is shared by all the filesystem functions accessing target media for given file descriptor! See ‘Improving I/O performance’ section of ‘Maximizing Execution Speed’ documentation page for more details.

**Default value:**
- 0

**FreeRTOS** Contains:
- **Kernel**
- **Port**

**Kernel** Contains:
- `CONFIG_FREERTOS_CHECK_STACKOVERFLOW`
- `CONFIG_FREERTOS_ENABLE_BACKWARD_COMPATIBILITY`
- `CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS`
- `CONFIG_FREERTOS_MAX_TASK_NAME_LEN`
- `CONFIG_FREERTOS_IDLE_TASK_STACKSIZE`
- `CONFIG_FREERTOS_THREAD_LOCAL_STORAGE_POINTERS`
- `CONFIG_FREERTOS_QUEUE_REGISTRY_SIZE`
- `CONFIG_FREERTOS_TASK_NOTIFICATION_ARRAY_ENTRIES`
- `CONFIG_FREERTOS_HZ`
- `CONFIG_FREERTOS_TIMER_QUEUE_LENGTH`
- `CONFIG_FREERTOS_TIMER_TASK_PRIORITY`
- `CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH`
- `CONFIG_FREERTOS_USE_IDLE_HOOK`
- `CONFIG_FREERTOS_OPTIMIZED_SCHEDULER`
- `CONFIG_FREERTOS_USE_TICK_HOOK`
- `CONFIG_FREERTOS_USE_TICKLESS_IDLE`
- `CONFIG_FREERTOS_USE_TRACE_FACILITY`
- `CONFIG_FREERTOS_UNICORE`
- `CONFIG_FREERTOS_SMP`
- `CONFIG_FREERTOS_USE_MINIMAL_IDLE_HOOK`
CONFIG_FREERTOS_SMP

Run the Amazon SMP FreeRTOS kernel instead (FEATURE UNDER DEVELOPMENT)

*Found in: Component config > FreeRTOS > Kernel*

Amazon has released an SMP version of the FreeRTOS Kernel which can be found via the following link: https://github.com/FreeRTOS/FreeRTOS-Kernel/tree/smp

IDF has added an experimental port of this SMP kernel located in components/freertos/FreeRTOS-Kernel-SMP. Enabling this option will cause IDF to use the Amazon SMP kernel. Note that THIS FEATURE IS UNDER ACTIVE DEVELOPMENT, users use this at their own risk.

Leaving this option disabled will mean the IDF FreeRTOS kernel is used instead, which is located in: components/freertos/FreeRTOS-Kernel. Both kernel versions are SMP capable, but differ in their implementation and features.

*Default value:*
  * No (disabled)

CONFIG_FREERTOS_UNICORE

Run FreeRTOS only on first core

*Found in: Component config > FreeRTOS > Kernel*

This version of FreeRTOS normally takes control of all cores of the CPU. Select this if you only want to start it on the first core. This is needed when e.g. another process needs complete control over the second core.

CONFIG_FREERTOS_HZ

`configTICK_RATE_HZ`

*Found in: Component config > FreeRTOS > Kernel*

Sets the FreeRTOS tick interrupt frequency in Hz (see `configTICK_RATE_HZ` documentation for more details).

*Range:*
  * from 1 to 1000

*Default value:*
  * 100

CONFIG_FREERTOS_OPTIMIZED_SCHEDULER

`configUSE_PORT_OPTIMISED_TASK_SELECTION`

*Found in: Component config > FreeRTOS > Kernel*

Enables port specific task selection method. This option can speed up the search of ready tasks when scheduling (see `configUSE_PORT_OPTIMISED_TASK_SELECTION` documentation for more details).

*Default value:*
  * Yes (enabled) if `CONFIG_FREERTOS_UNICORE` && `CONFIG_FREERTOS_SMP`

CONFIG_FREERTOS_CHECK_STACKOVERFLOW

`configCHECK_FOR_STACK_OVERFLOW`

*Found in: Component config > FreeRTOS > Kernel*

Enables FreeRTOS to check for stack overflows (see `configCHECK_FOR_STACK_OVERFLOW` documentation for more details).
Chapter 2. API Reference

Note: If users do not provide their own vApplicationStackOverflowHook() function, a default function will be provided by ESP-IDF.

Available options:

- No checking (CONFIG_FREERTOS_CHECK_STACKOVERFLOW_NONE)
  Do not check for stack overflows (configCHECK_FOR_STACK_OVERFLOW = 0)
- Check by stack pointer value (Method 1) (CONFIG_FREERTOS_CHECK_STACKOVERFLOW_PTRVAL)
  Check for stack overflows on each context switch by checking if the stack pointer is in a valid range. Quick but does not detect stack overflows that happened between context switches (configCHECK_FOR_STACK_OVERFLOW = 1)
- Check using canary bytes (Method 2) (CONFIG_FREERTOS_CHECK_STACKOVERFLOW_CANARY)
  Places some magic bytes at the end of the stack area and on each context switch, check if these bytes are still intact. More thorough than just checking the pointer, but also slightly slower. (configCHECK_FOR_STACK_OVERFLOW = 2)

CONFIG_FREERTOS_THREAD_LOCAL_STORAGE_POINTERS

configNUM_THREAD_LOCAL_STORAGE_POINTERS

*Found in: Component config > FreeRTOS > Kernel*

Set the number of thread local storage pointers in each task (see configNUM_THREAD_LOCAL_STORAGE_POINTERS documentation for more details).

Note: In ESP-IDF, this value must be at least 1. Index 0 is reserved for use by the pthreads API thread-local-storage. Other indexes can be used for any desired purpose.

**Range:**
- from 1 to 256

**Default value:**
- 1

CONFIG_FREERTOS_IDLE_TASK_STACKSIZE

configMINIMAL_STACK_SIZE (Idle task stack size)

*Found in: Component config > FreeRTOS > Kernel*

Sets the idle task stack size in bytes (see configMINIMAL_STACK_SIZE documentation for more details).

Note:
- ESP-IDF specifies stack sizes in bytes instead of words.
- The default size is enough for most use cases.
- The stack size may need to be increased above the default if the app installs idle or thread local storage cleanup hooks that use a lot of stack memory.
- Conversely, the stack size can be reduced to the minimum if none of the idle features are used.

**Range:**
- from 768 to 32768

**Default value:**
- 1536

CONFIG_FREERTOS_USE_IDLE_HOOK

configUSE_IDLE_HOOK

*Found in: Component config > FreeRTOS > Kernel*
Chapter 2. API Reference

Enables the idle task application hook (see configUSE_IDLE_HOOK documentation for more details).

Note:

• The application must provide the hook function `void vApplicationIdleHook( void );`
• `vApplicationIdleHook()` is called from FreeRTOS idle task(s)
• The FreeRTOS idle hook is NOT the same as the ESP-IDF Idle Hook, but both can be enabled simultaneously.

Default value:
• No (disabled)

CONFIG_FREERTOS_USE_MINIMAL_IDLE_HOOK

Use FreeRTOS minimal idle hook

Found in: Component config > FreeRTOS > Kernel

Enables the minimal idle task application hook (see configUSE_IDLE_HOOK documentation for more details).

Note:

• The application must provide the hook function `void vApplicationMinimalIdleHook( void );`
• `vApplicationMinimalIdleHook()` is called from FreeRTOS minimal idle task(s)

Default value:
• No (disabled) if CONFIG_FREERTOS_SMP

CONFIG_FREERTOS_USE_TICK_HOOK

configUSE_TICK_HOOK

Found in: Component config > FreeRTOS > Kernel

Enables the tick hook (see configUSE_TICK_HOOK documentation for more details).

Note:

• The application must provide the hook function `void vApplicationTickHook( void );`
• `vApplicationTickHook()` is called from FreeRTOS’ s tick handling function `xTaskIncrementTick()`
• The FreeRTOS tick hook is NOT the same as the ESP-IDF Tick Interrupt Hook, but both can be enabled simultaneously.

Default value:
• No (disabled)

CONFIG_FREERTOS_MAX_TASK_NAME_LEN

configMAX_TASK_NAME_LEN

Found in: Component config > FreeRTOS > Kernel

Sets the maximum number of characters for task names (see configMAX_TASK_NAME_LEN documentation for more details).

Note: For most uses, the default of 16 characters is sufficient.

Range:
• from 1 to 256

Default value:
• 16
Chapter 2. API Reference

**CONFIG_FREERTOS_ENABLE_BACKWARD_COMPATIBILITY**

configENABLE_BACKWARD_COMPATIBILITY

*Found in: Component config > FreeRTOS > Kernel*

Enable backward compatibility with APIs prior to FreeRTOS v8.0.0. (see configENABLE_BACKWARD_COMPATIBILITY documentation for more details).

*Default value:*
  - No (disabled)

**CONFIG_FREERTOS_TIMER_TASK_PRIORITY**

configTIMER_TASK_PRIORITY

*Found in: Component config > FreeRTOS > Kernel*

Sets the timer task’s priority (see configTIMER_TASK_PRIORITY documentation for more details).

*Range:*
  - from 1 to 25

*Default value:*
  - 1

**CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH**

configTIMER_TASK_STACK_DEPTH

*Found in: Component config > FreeRTOS > Kernel*

Set the timer task’s stack size (see configTIMER_TASK_STACK_DEPTH documentation for more details).

*Range:*
  - from 1536 to 32768

*Default value:*
  - 2048

**CONFIG_FREERTOS_TIMER_QUEUE_LENGTH**

configTIMER_QUEUE_LENGTH

*Found in: Component config > FreeRTOS > Kernel*

Set the timer task’s command queue length (see configTIMER_QUEUE_LENGTH documentation for more details).

*Range:*
  - from 5 to 20

*Default value:*
  - 10

**CONFIG_FREERTOS_QUEUE_REGISTRY_SIZE**

configQUEUE_REGISTRY_SIZE

*Found in: Component config > FreeRTOS > Kernel*

Set the size of the queue registry (see configQUEUE_REGISTRY_SIZE documentation for more details).

Note: A value of 0 will disable queue registry functionality

*Range:*
  - from 0 to 20
Default value:
  • 0

**CONFIG_FREERTOS_TASK_NOTIFICATION_ARRAY_ENTRIES**

`configTASK_NOTIFICATION_ARRAY_ENTRIES`

*Found in: Component config > FreeRTOS > Kernel*

Set the size of the task notification array of each task. When increasing this value, keep in mind that this means additional memory for each and every task on the system. However, task notifications in general are more lightweight compared to alternatives such as semaphores.

**Range:**
  • from 1 to 32

*Default value:*
  • 1

**CONFIG_FREERTOS_USE_TRACE_FACILITY**

`configUSE_TRACE_FACILITY`

*Found in: Component config > FreeRTOS > Kernel*

Enables additional structure members and functions to assist with execution visualization and tracing (see `configUSE_TRACE_FACILITY` documentation for more details).

*Default value:*
  • No (disabled)

**CONFIG_FREERTOS_USE_STATS_FORMATTING_FUNCTIONS**

`configUSE_STATS_FORMATTING_FUNCTIONS`

*Found in: Component config > FreeRTOS > Kernel > CONFIG_FREERTOS_USE_TRACE_FACILITY*

Set `configUSE_TRACE_FACILITY` and `configUSE_STATS_FORMATTING_FUNCTIONS` to 1 to include the `vTaskList()` and `vTaskGetRunTimeStats()` functions in the build (see `configUSE_STATS_FORMATTING_FUNCTIONS` documentation for more details).

*Default value:*
  • No (disabled) if `CONFIG_FREERTOS_USE_TRACE_FACILITY`

**CONFIG_FREERTOS_VTASKLIST_INCLUDE_COREID**

Enable display of xCoreID in `vTaskList`

*Found in: Component config > FreeRTOS > Kernel > CONFIG_FREERTOS_USE_TRACE_FACILITY > CONFIG_FREERTOS_USE_STATS_FORMATTING_FUNCTIONS*

If enabled, this will include an extra column when `vTaskList` is called to display the CoreID the task is pinned to (0,1) or -1 if not pinned.

*Default value:*
  • No (disabled) if `CONFIG_FREERTOS_SMP` && `CONFIG_FREERTOS_USE_STATS_FORMATTING_FUNCTIONS`

**CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS**

`configGENERATE_RUN_TIME_STATS`

*Found in: Component config > FreeRTOS > Kernel*
Enables collection of run time statistics for each task (see config\_GENERATE\_RUN\_TIME\_STATS documentation for more details).

Note: The clock used for run time statistics can be configured in FREERTOS\_RUN\_TIME\_STATS\_CLK.

**Default value:**
- No (disabled)

**CONFIG\_FREERTOS\_USE\_TICKLESS\_IDLE**

```c
configUSE\_TICKLESS\_IDLE
```

*Found in: Component config > FreeRTOS > Kernel*

If power management support is enabled, FreeRTOS will be able to put the system into light sleep mode when no tasks need to run for a number of ticks. This number can be set using FREERTOS\_IDLE\_TIME\_BEFORE\_SLEEP option. This feature is also known as “automatic light sleep”.

Note that timers created using esp\_timer APIs may prevent the system from entering sleep mode, even when no tasks need to run. To skip unnecessary wake-up initialize a timer with the “skip\_unhandled\_events” option as true.

If disabled, automatic light sleep support will be disabled.

**Default value:**
- No (disabled) if **CONFIG\_PM\_ENABLE**

**CONFIG\_FREERTOS\_IDLE\_TIME\_BEFORE\_SLEEP**

```c
configEXPECTED\_IDLE\_TIME\_BEFORE\_SLEEP
```

*Found in: Component config > FreeRTOS > Kernel > CONFIG\_FREERTOS\_USE\_TICKLESS\_IDLE*

FreeRTOS will enter light sleep mode if no tasks need to run for this number of ticks. You can enable PM\_PROFILING feature in esp\_pm components and dump the sleep status with esp\_pm\_dump\_locks, if the proportion of rejected sleeps is too high, please increase this value to improve scheduling efficiency.

**Range:**
- from 2 to 4294967295 if **CONFIG\_FREERTOS\_USE\_TICKLESS\_IDLE**

**Default value:**
- 3 if **CONFIG\_FREERTOS\_USE\_TICKLESS\_IDLE**

**Port**

Contains:
- CONFIG\_FREERTOS\_CHECK\_MUTEX\_GIVEN\_BY\_OWNER
- CONFIG\_FREERTOS\_RUN\_TIME\_STATS\_CLK
- CONFIG\_FREERTOS\_INTERRUPT\_BACKTRACE
- CONFIG\_FREERTOS\_WATCHPOINT\_END\_OF\_STACK
- CONFIG\_FREERTOS\_ENABLE\_STATIC\_TASK\_CLEAN\_UP
- CONFIG\_FREERTOS\_ENABLE\_TASK\_SNAPSHOT
- CONFIG\_FREERTOS\_TLS\_DELETION\_CALLBACKS
- CONFIG\_FREERTOS\_ISR\_STACKSIZE
- CONFIG\_FREERTOS\_PLACE\_FUNCTIONS\_INTO\_FLASH
- CONFIG\_FREERTOS\_PLACE\_SNAPSHOT\_FUNS\_INTO\_FLASH
- CONFIG\_FREERTOS\_CHECK\_PORT\_CRITICAL\_COMPLIANCE
- CONFIG\_FREERTOS\_CORE\_TIMER
- CONFIG\_FREERTOS\_FPU\_IN\_ISR
- CONFIG\_FREERTOS\_TASK\_FUNCTION\_WRAPPER
**CONFIG_FREERTOS_TASK_FUNCTION_WRAPPER**

Wrap task functions

*Found in: Component config > FreeRTOS > Port*

If enabled, all FreeRTOS task functions will be enclosed in a wrapper function. If a task function mistakenly returns (i.e. does not delete), the call flow will return to the wrapper function. The wrapper function will then log an error and abort the application. This option is also required for GDB backtraces and C++ exceptions to work correctly inside top-level task functions.

**Default value:**
- Yes (enabled)

**CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK**

Enable stack overflow debug watchpoint

*Found in: Component config > FreeRTOS > Port*

FreeRTOS can check if a stack has overflowed its bounds by checking either the value of the stack pointer or by checking the integrity of canary bytes. (See FREERTOS_CHECK_STACKOVERFLOW for more information.) These checks only happen on a context switch, and the situation that caused the stack overflow may already be long gone by then. This option will use the last debug memory watchpoint to allow breaking into the debugger (or panic) as soon as any of the last 32 bytes on the stack of a task are overwritten. The side effect is that using gdb, you effectively have one hardware watchpoint less because the last one is overwritten as soon as a task switch happens.

Another consequence is that due to alignment requirements of the watchpoint, the usable stack size decreases by up to 60 bytes. This is because the watchpoint region has to be aligned to its size and the size for the stack watchpoint in IDF is 32 bytes.

This check only triggers if the stack overflow writes within 32 bytes near the end of the stack, rather than overshooting further, so it is worth combining this approach with one of the other stack overflow check methods.

When this watchpoint is hit, gdb will stop with a SIGTRAP message. When no JTAG OCD is attached, esp-idf will panic on an unhandled debug exception.

**Default value:**
- No (disabled)

**CONFIG_FREERTOS_TLSP_DELETION_CALLBACKS**

Enable thread local storage pointers deletion callbacks

*Found in: Component config > FreeRTOS > Port*

ESP-IDF provides users with the ability to free TLSP memory by registering TLSP deletion callbacks. These callbacks are automatically called by FreeRTOS when a task is deleted. When this option is turned on, the memory reserved for TLSPs in the TCB is doubled to make space for storing the deletion callbacks. If the user does not wish to use TLSP deletion callbacks then this option could be turned off to save space in the TCB memory.

**Default value:**
- Yes (enabled)

**CONFIG_FREERTOS_ENABLE_STATIC_TASK_CLEAN_UP**

Enable static task clean up hook

*Found in: Component config > FreeRTOS > Port*

Enable this option to make FreeRTOS call the static task clean up hook when a task is deleted.

*Note: Users will need to provide a `void vPortCleanUpTCB ( void *pxTCB )` callback*
Default value:
- No (disabled)

**CONFIG_FREERTOS_CHECK_MUTEX_GIVEN_BY_OWNER**

Check that mutex semaphore is given by owner task

*Found in: Component config > FreeRTOS > Port*

If enabled, assert that when a mutex semaphore is given, the task giving the semaphore is the task which is currently holding the mutex.

Default value:
- Yes (enabled) if `CONFIG_FREERTOS_SMP`

**CONFIG_FREERTOS_ISR_STACKSIZE**

ISR stack size

*Found in: Component config > FreeRTOS > Port*

The interrupt handlers have their own stack. The size of the stack can be defined here. Each processor has its own stack, so the total size occupied will be twice this.

Range:
- from 2096 to 32768 if `CONFIG_ESP_COREDUMP_DATA_FORMAT_ELF`
- from 1536 to 32768

Default value:
- 2096 if `CONFIG_ESP_COREDUMP_DATA_FORMAT_ELF`
- 1536

**CONFIG_FREERTOS_INTERRUPT_BACKTRACE**

Enable backtrace from interrupt to task context

*Found in: Component config > FreeRTOS > Port*

If this option is enabled, interrupt stack frame will be modified to point to the code of the interrupted task as its return address. This helps the debugger (or the panic handler) show a backtrace from the interrupt to the task which was interrupted. This also works for nested interrupts: higher level interrupt stack can be traced back to the lower level interrupt. This option adds 4 instructions to the interrupt dispatching code.

Default value:
- Yes (enabled)

**CONFIG_FREERTOS_FPU_IN_ISR**

Use float in Level 1 ISR

*Found in: Component config > FreeRTOS > Port*

When enabled, the usage of float type is allowed inside Level 1 ISRs. Note that usage of float types in higher level interrupts is still not permitted.

Default value:
- No (disabled)
**CONFIG_FREERTOS_CORETIMER**

Tick timer source (Xtensa Only)

*Found in: Component config > FreeRTOS > Port*

FreeRTOS needs a timer with an associated interrupt to use as the main tick source to increase counters, run timers and do pre-emptive multitasking with. There are multiple timers available to do this, with different interrupt priorities.

Available options:

- Timer 0 (int 6, level 1) (CONFIG_FREERTOS_CORETIMER_0)
  
  Select this to use timer 0

- Timer 1 (int 15, level 3) (CONFIG_FREERTOS_CORETIMER_1)
  
  Select this to use timer 1

- SYSTIMER 0 (level 1) (CONFIG_FREERTOS_CORETIMER_SYSTIMER_LVL1)
  
  Select this to use systimer with the 1 interrupt priority.

- SYSTIMER 0 (level 3) (CONFIG_FREERTOS_CORETIMER_SYSTIMER_LVL3)
  
  Select this to use systimer with the 3 interrupt priority.

**CONFIG_FREERTOS_RUN_TIME_STATS_CLK**

Choose the clock source for run time stats

*Found in: Component config > FreeRTOS > Port*

Choose the clock source for FreeRTOS run time stats. Options are CPU0’s CPU Clock or the ESP Timer. Both clock sources are 32 bits. The CPU Clock can run at a higher frequency hence provide a finer resolution but will overflow much quicker. Note that run time stats are only valid until the clock source overflows.

Available options:

- Use ESP TIMER for run time stats (CONFIG_FREERTOS_RUN_TIME_STATS_USING_ESP_TIMER)
  
  ESP Timer will be used as the clock source for FreeRTOS run time stats. The ESP Timer runs at a frequency of 1MHz regardless of Dynamic Frequency Scaling. Therefore the ESP Timer will overflow in approximately 4290 seconds.

- Use CPU Clock for run time stats (CONFIG_FREERTOS_RUN_TIME_STATS_USING_CPU_CLK)
  
  CPU Clock will be used as the clock source for the generation of run time stats. The CPU Clock has a frequency dependent on ESP_DEFAULT_CPU_FREQ_MHZ and Dynamic Frequency Scaling (DFS). Therefore the CPU Clock frequency can fluctuate between 80 to 240MHz. Run time stats generated using the CPU Clock represents the number of CPU cycles each task is allocated and DOES NOT reflect the amount of time each task runs for (as CPU clock frequency can change). If the CPU clock consistently runs at the maximum frequency of 240MHz, it will overflow in approximately 17 seconds.

**CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH**

Place FreeRTOS functions into Flash

*Found in: Component config > FreeRTOS > Port*

When enabled the selected Non-ISR FreeRTOS functions will be placed into Flash memory instead of IRAM. This saves up to 8KB of IRAM depending on which functions are used.

**Default value:**

- No (disabled)
**CONFIG_FREERTOS_PLACE_SNAPSHOT_FUNS_INTO_FLASH**

Place task snapshot functions into flash

*Found in: Component config > FreeRTOS > Port*

When enabled, the functions related to snapshots, such as vTaskGetSnapshot or uxTaskGetSnapshotAll, will be placed in flash. Note that if enabled, these functions cannot be called when cache is disabled.

**Default value:**
- No (disabled) if `CONFIG_FREERTOS_ENABLE_TASK_SNAPSHOT` && `CONFIG_ESP_PANIC_HANDLER_IRAM`

**CONFIG_FREERTOS_CHECK_PORT_CRITICAL_COMPLIANCE**

Tests compliance with Vanilla FreeRTOS port*_CRITICAL calls

*Found in: Component config > FreeRTOS > Port*

If enabled, context of port*_CRITICAL calls (ISR or Non-ISR) would be checked to be in compliance with Vanilla FreeRTOS. e.g Calling port*_CRITICAL from ISR context would cause assert failure

**Default value:**
- No (disabled)

**CONFIG_FREERTOS_ENABLE_TASK_SNAPSHOT**

Enable task snapshot functions

*Found in: Component config > FreeRTOS > Port*

When enabled, the functions related to snapshots, such as vTaskGetSnapshot or uxTaskGetSnapshotAll, are compiled and linked. Task snapshots are used by Task Watchdog (TWDT), GDB Stub and Core dump.

**Default value:**
- Yes (enabled)

**Hardware Abstraction Layer (HAL) and Low Level (LL)** Contains:

- `CONFIG_HAL_DEFAULT_ASSERTION_LEVEL`
- `CONFIG_HAL_LOG_LEVEL`
- `CONFIG_HAL_SYSTIMER_USE_ROM_IMPL`
- `CONFIG_HAL_WDT_USE_ROM_IMPL`

**CONFIG_HAL_DEFAULT_ASSERTION_LEVEL**

Default HAL assertion level

*Found in: Component config > Hardware Abstraction Layer (HAL) and Low Level (LL)*

Set the assert behavior / level for HAL component. HAL component assert level can be set separately, but the level can’t exceed the system assertion level. e.g. If the system assertion is disabled, then the HAL assertion can’t be enabled either. If the system assertion is enable, then the HAL assertion can still be disabled by this Kconfig option.

Available options:

- Same as system assertion level (CONFIG_HAL_ASSERTION_EQUALS_SYSTEM)
- Disabled (CONFIG_HAL_ASSERTION_DISABLE)
- Silent (CONFIG_HAL_ASSERTION_SILENT)
- Enabled (CONFIG_HAL_ASSERTION_ENABLE)
**CONFIG_HAL_LOG_LEVEL**

HAL layer log verbosity

*Found in: Component config > Hardware Abstraction Layer (HAL) and Low Level (LL)*

Specify how much output to see in HAL logs.

Available options:

- No output (CONFIG_HAL_LOG_LEVEL_NONE)
- Error (CONFIG_HAL_LOG_LEVEL_ERROR)
- Warning (CONFIG_HAL_LOG_LEVEL_WARN)
- Info (CONFIG_HAL_LOG_LEVEL_INFO)
- Debug (CONFIG_HAL_LOG_LEVEL_DEBUG)
- Verbose (CONFIG_HAL_LOG_LEVEL_VERBOSE)

**CONFIG_HAL_SYSTIMER_USE_ROM_IMPL**

Use ROM implementation of SysTimer HAL driver

*Found in: Component config > Hardware Abstraction Layer (HAL) and Low Level (LL)*

Enable this flag to use HAL functions from ROM instead of ESP-IDF.

If keeping this as “n” in your project, you will have less free IRAM. If making this as “y” in your project, you will increase free IRAM, but you will lose the possibility to debug this module, and some new features will be added and bugs will be fixed in the IDF source but cannot be synced to ROM.

*Default value:*

- Yes (enabled) if ESP_ROM_HAS_HAL_SYSTIMER

**CONFIG_HAL_WDT_USE_ROM_IMPL**

Use ROM implementation of WDT HAL driver

*Found in: Component config > Hardware Abstraction Layer (HAL) and Low Level (LL)*

Enable this flag to use HAL functions from ROM instead of ESP-IDF.

If keeping this as “n” in your project, you will have less free IRAM. If making this as “y” in your project, you will increase free IRAM, but you will lose the possibility to debug this module, and some new features will be added and bugs will be fixed in the IDF source but cannot be synced to ROM.

*Default value:*

- Yes (enabled) if ESP_ROM_HAS_HAL_WDT

**Heap memory debugging**

Contains:

- CONFIG_HEAP_ABORT_WHEN_ALLOCATION_FAILS
- CONFIG_HEAP_TASK_TRACKING
- CONFIG_HEAP_PLACE_FUNCTION_INTO_FLASH
- CONFIG_HEAP_CORRUPTION_DETECTION
- CONFIG_HEAP_TRACING_DEST
- CONFIG_HEAP_TRACING_STACK_DEPTH
- CONFIG_HEAP_USE_HOOKS
- CONFIG_HEAP_TRACE_HASH_MAP
- CONFIG_HEAP_TLSF_USE_ROM_IMPL
CONFIG_HEAP_CORRUPTION_DETECTION
Heap corruption detection

*Found in: Component config > Heap memory debugging*

Enable heap poisoning features to detect heap corruption caused by out-of-bounds access to heap memory.

See the “Heap Memory Debugging” page of the IDF documentation for a description of each level of heap corruption detection.

Available options:

- Basic (no poisoning) (CONFIG_HEAP_POISONING_DISABLED)
- Light impact (CONFIG_HEAP_POISONING_LIGHT)
- Comprehensive (CONFIG_HEAP_POISONING_COMPREHENSIVE)

CONFIG_HEAP_TRACING_DEST
Heap tracing

*Found in: Component config > Heap memory debugging*

Enable the heap tracing API defined in esp_heap_trace.h.

This function causes a moderate increase in IRAM code side and a minor increase in heap function (malloc/free/realloc) CPU overhead, even when the tracing feature is not used. So it’s best to keep it disabled unless tracing is being used.

Available options:

- Disabled (CONFIG_HEAP_TRACING_OFF)
- Standalone (CONFIG_HEAP_TRACING_STANDALONE)
- Host-based (CONFIG_HEAP_TRACING_TOHOST)

CONFIG_HEAP_TRACING_STACK_DEPTH
Heap tracing stack depth

*Found in: Component config > Heap memory debugging*

Number of stack frames to save when tracing heap operation callers.

More stack frames uses more memory in the heap trace buffer (and slows down allocation), but can provide useful information.

CONFIG_HEAP_USE_HOOKS
Use allocation and free hooks

*Found in: Component config > Heap memory debugging*

Enable the user to implement function hooks triggered for each successful allocation and free.

CONFIG_HEAP_TASK_TRACKING
Enable heap task tracking

*Found in: Component config > Heap memory debugging*

Enables tracking the task responsible for each heap allocation.
This function depends on heap poisoning being enabled and adds four more bytes of overhead for each block allocated.

**CONFIG_HEAP_TRACE_HASH_MAP**

Use hash map mechanism to access heap trace records

*Found in: Component config > Heap memory debugging*

Enable this flag to use a hash map to increase performance in handling heap trace records.

Keeping this as “n” in your project will save RAM and heap memory but will lower the performance of the heap trace in adding, retrieving and removing trace records. Making this as “y” in your project, you will decrease free RAM and heap memory but, the heap trace performances in adding retrieving and removing trace records will be enhanced.

**Default value:**
- No (disabled) if `CONFIG_HEAP_TRACING_STANDALONE`

**CONFIG_HEAP_TRACE_HASH_MAP_SIZE**

The number of entries in the hash map

*Found in: Component config > Heap memory debugging > CONFIG_HEAP_TRACE_HASH_MAP*

Defines the number of entries in the heap trace hashmap. The bigger this number is, the bigger the hash map will be in the memory. In case the tracing mode is set to `HEAP_TRACE_ALL`, the bigger the hashmap is, the better the performances are.

**Range:**
- from 1 to 10000 if `CONFIG_HEAP_TRACE_HASH_MAP`

**Default value:**
- 10 if `CONFIG_HEAP_TRACE_HASH_MAP`

**CONFIG_HEAP_ABORT_WHEN_ALLOCATION_FAILS**

Abort if memory allocation fails

*Found in: Component config > Heap memory debugging*

When enabled, if a memory allocation operation fails it will cause a system abort.

**Default value:**
- No (disabled)

**CONFIG_HEAP_TLSF_USE_ROM_IMPL**

Use ROM implementation of heap tlsf library

*Found in: Component config > Heap memory debugging*

Enable this flag to use heap functions from ROM instead of ESP-IDF.

If keeping this as “n” in your project, you will have less free IRAM. If making this as “y” in your project, you will increase free IRAM, but you will lose the possibility to debug this module, and some new features will be added and bugs will be fixed in the IDF source but cannot be synced to ROM.

**Default value:**
- Yes (enabled) if `ESP_ROM_HAS_HEAP_TLSF`
**CONFIG_HEAP_PLACE_FUNCTION_INTO_FLASH**

Force the entire heap component to be placed in flash memory

*Found in: Component config > Heap memory debugging*

Enable this flag to save up RAM space by placing the heap component in the flash memory

Note that it is only safe to enable this configuration if no functions from esp_heap_caps.h or esp_heap_trace.h are called from ISR.

**Default value:**
- No (disabled) if `CONFIG_HEAP_TLSF_USE_ROM_IMPL`

**IEEE 802.15.4** Contains:

- `CONFIG_IEEE802154_CCA_THRESHOLD`
- `CONFIG_IEEE802154_CCA_MODE`
- `CONFIG_IEEE802154_DEBUG`
- `CONFIG_IEEE802154_SLEEP_ENABLE`
- `CONFIG_IEEE802154_MULTI_PAN_ENABLE`
- `CONFIG_IEEE802154_TIMING_OPTIMIZATION`
- `CONFIG_IEEE802154_PENDING_TABLE_SIZE`
- `CONFIG_IEEE802154_RX_BUFFER_SIZE`

**CONFIG_IEEE802154_RX_BUFFER_SIZE**

The number of 802.15.4 receive buffers

*Found in: Component config > IEEE 802.15.4*

The number of 802.15.4 receive buffers

**CONFIG_IEEE802154_CCA_MODE**

Clear Channel Assessment (CCA) mode

*Found in: Component config > IEEE 802.15.4*

configure the CCA mode

Available options:

- Carrier sense only (CONFIG_IEEE802154_CCA_CARRIER)
  - configure the CCA mode to Energy above threshold
- Energy above threshold (CONFIG_IEEE802154_CCA_ED)
  - configure the CCA mode to Energy above threshold
- Carrier sense OR energy above threshold (CONFIG_IEEE802154_CCA_CARRIER_OR_ED)
  - configure the CCA mode to Carrier sense OR Energy above threshold
- Carrier sense AND energy above threshold (CONFIG_IEEE802154_CCA_CARRIER_AND_ED)
  - configure the CCA mode to Carrier sense AND energy above threshold

**CONFIG_IEEE802154_CCA_THRESHOLD**

CCA detection threshold

*Found in: Component config > IEEE 802.15.4*

set the CCA threshold, in dB

**Range:**
from -120 to 0

**Default value:**
- 
- 

**CONFIG_IEEE802154_PENDING_TABLE_SIZE**

Pending table size

*Found in: Component config > IEEE 802.15.4*

set the pending table size

**Range:**
- from 1 to 100

**Default value:**
- 20

**CONFIG_IEEE802154_MULTI_PAN_ENABLE**

Enable multi-pan feature for frame filter

*Found in: Component config > IEEE 802.15.4*

Enable IEEE802154 multi-pan

**Default value:**
- No (disabled)

**CONFIG_IEEE802154_TIMING_OPTIMIZATION**

Enable throughput optimization

*Found in: Component config > IEEE 802.15.4*

Enabling this option increases throughput by ~5% at the expense of ~2.1k IRAM code size increase.

**Default value:**
- No (disabled)

**CONFIG_IEEE802154_SLEEP_ENABLE**

Enable IEEE802154 light sleep

*Found in: Component config > IEEE 802.15.4*

Enabling this option allows the IEEE802.15.4 module to be powered down during automatic light sleep, which reduces current consumption.

**Default value:**
- No (disabled) if `CONFIG_PM_ENABLE` & `CONFIG_PM_POWER_DOWN_PERIPHERAL_IN_LIGHT_SLEEP`

**CONFIG_IEEE802154_DEBUG**

Enable IEEE802154 Debug

*Found in: Component config > IEEE 802.15.4*

Enabling this option allows different kinds of IEEE802154 debug output. All IEEE802154 debug features increase the size of the final binary.

**Default value:**
- No (disabled)

Contains:
- `CONFIG_IEEE802154_RECORD_ABORT`
Chapter 2. API Reference

- CONFIG_IEEE802154_RECORD_CMD
- CONFIG_IEEE802154_RECORD_EVENT
- CONFIG_IEEE802154_RECORD_STATE
- CONFIG_IEEE802154_ASSERT

CONFIG_IEEE802154_ASSERT
Enrich the assert information with IEEE802154 state and event

**Found in:** Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG

Enabling this option to add some probe codes in the driver, and these informations will be printed when assert.

**Default value:**
- No (disabled) if `CONFIG_IEEE802154_DEBUG`

CONFIG_IEEE802154_RECORD_EVENT
Enable record event information for debugging

**Found in:** Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG

Enabling this option to record event, when assert, the recorded event will be printed.

**Default value:**
- No (disabled) if `CONFIG_IEEE802154_DEBUG`

CONFIG_IEEE802154_RECORD_EVENT_SIZE
Record event table size

**Found in:** Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG > CONFIG_IEEE802154_RECORD_Event

set the record event table size

**Range:**
- from 1 to 50 if `CONFIG_IEEE802154_RECORD_EVENT`

**Default value:**
- 30 if `CONFIG_IEEE802154_RECORD_EVENT`

CONFIG_IEEE802154_RECORD_STATE
Enable record state information for debugging

**Found in:** Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG

Enabling this option to record state, when assert, the recorded state will be printed.

**Default value:**
- No (disabled) if `CONFIG_IEEE802154_DEBUG`

CONFIG_IEEE802154_RECORD_STATE_SIZE
Record state table size

**Found in:** Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG > CONFIG_IEEE802154_RECORD_STATE

set the record state table size

**Range:**
- from 1 to 50 if `CONFIG_IEEE802154_RECORD_STATE`

**Default value:**
• 10 if `CONFIG_IEEE802154_RECORD_STATE`

**CONFIG_IEEE802154_RECORD_CMD**

Enable record command information for debugging  
*Found in: Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG*

Enabling this option to record the command, when assert, the recorded command will be printed.  

**Default value:**  
• No (disabled) if `CONFIG_IEEE802154_DEBUG`

**CONFIG_IEEE802154_RECORD_CMD_SIZE**

Record command table size  
*Found in: Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG > CONFIG_IEEE802154_RECORD_CMD*

set the record command table size  

**Range:**  
• from 1 to 50 if `CONFIG_IEEE802154_RECORD_CMD`

**Default value:**  
• 10 if `CONFIG_IEEE802154_RECORD_CMD`

**CONFIG_IEEE802154_RECORD_ABORT**

Enable record abort information for debugging  
*Found in: Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG*

Enabling this option to record the abort, when assert, the recorded abort will be printed.  

**Default value:**  
• No (disabled) if `CONFIG_IEEE802154_DEBUG`

**CONFIG_IEEE802154_RECORD_ABORT_SIZE**

Record abort table size  
*Found in: Component config > IEEE 802.15.4 > CONFIG_IEEE802154_DEBUG > CONFIG_IEEE802154_RECORD_ABORT*

set the record abort table size  

**Range:**  
• from 1 to 50 if `CONFIG_IEEE802154_RECORD_ABORT`

**Default value:**  
• 10 if `CONFIG_IEEE802154_RECORD_ABORT`

**Log output**  
Contains:  
• `CONFIG_LOG_DEFAULT_LEVEL`
• `CONFIG_LOG_TIMESTAMP_SOURCE`
• `CONFIG_LOG_MAXIMUM_LEVEL`
• `CONFIG_LOG_COLORS`
**CONFIG_LOG_DEFAULT_LEVEL**

Default log verbosity

*Found in: Component config > Log output*

Specify how much output to see in logs by default. You can set lower verbosity level at runtime using `esp_log_level_set()` function.

By default, this setting limits which log statements are compiled into the program. For example, selecting “Warning” would mean that changing log level to “Debug” at runtime will not be possible. To allow increasing log level above the default at runtime, see the next option.

Available options:

- No output (CONFIG_LOG_DEFAULT_LEVEL_NONE)
- Error (CONFIG_LOG_DEFAULT_LEVEL_ERROR)
- Warning (CONFIG_LOG_DEFAULT_LEVEL_WARN)
- Info (CONFIG_LOG_DEFAULT_LEVEL_INFO)
- Debug (CONFIG_LOG_DEFAULT_LEVEL_DEBUG)
- Verbose (CONFIG_LOG_DEFAULT_LEVEL_VERBOSE)

**CONFIG_LOG_MAXIMUM_LEVEL**

Maximum log verbosity

*Found in: Component config > Log output*

This config option sets the highest log verbosity that it’s possible to select at runtime by calling `esp_log_level_set()`. This level may be higher than the default verbosity level which is set when the app starts up.

This can be used to enable debugging output only at a critical point, for a particular tag, or to minimize startup time but then enable more logs once the firmware has loaded.

Note that increasing the maximum available log level will increase the firmware binary size.

This option only applies to logging from the app, the bootloader log level is fixed at compile time to the separate “Bootloader log verbosity” setting.

Available options:

- Same as default (CONFIG_LOG_MAXIMUM_EQUALS_DEFAULT)
- Error (CONFIG_LOG_MAXIMUM_LEVEL_ERROR)
- Warning (CONFIG_LOG_MAXIMUM_LEVEL_WARN)
- Info (CONFIG_LOG_MAXIMUM_LEVEL_INFO)
- Debug (CONFIG_LOG_MAXIMUM_LEVEL_DEBUG)
- Verbose (CONFIG_LOG_MAXIMUM_LEVEL_VERBOSE)

**CONFIG_LOG_COLORS**

Use ANSI terminal colors in log output

*Found in: Component config > Log output*

Enable ANSI terminal color codes in bootloader output.

In order to view these, your terminal program must support ANSI color codes.

**Default value:**

- Yes (enabled)
Chapter 2. API Reference

**CONFIG_LOG_TIMESTAMP_SOURCE**

Log Timestamps

*Found in: Component config > Log output*

Choose what sort of timestamp is displayed in the log output:

- Milliseconds since boot is calculated from the RTOS tick count multiplied by the tick period. This time will reset after a software reboot. e.g. (90000)
- System time is taken from POSIX time functions which use the chip’s RTC and high resolution timers to maintain an accurate time. The system time is initialized to 0 on startup, it can be set with an SNTP sync, or with POSIX time functions. This time will not reset after a software reboot. e.g. (00:01:30.000)
- NOTE: Currently this will not get used in logging from binary blobs (i.e WiFi & Bluetooth libraries), these will always print milliseconds since boot.

Available options:

- Milliseconds Since Boot (CONFIG_LOG_TIMESTAMP_SOURCE_RTOS)
- System Time (CONFIG_LOG_TIMESTAMP_SOURCE_SYSTEM)

**LWIP** Contains:

- `CONFIG_LWIP_CHECK_THREAD_SAFETY`
- `Checksums`
- `CONFIG_LWIP_DHCP_COARSE_TIMER_SECS`
- `DHCP server`
- `CONFIG_LWIP_DHCP_OPTIONS_LEN`
- `CONFIG_LWIP_DHCP_DISABLE_CLIENT_ID`
- `CONFIG_LWIP_DHCP_DISABLE_VENDOR_CLASS_ID`
- `CONFIG_LWIP_DHCP_DOES_ARP_CHECK`
- `CONFIG_LWIP_DHCP_RESTORE_LAST_IP`
- `CONFIG_LWIP_PPP_CHAP_SUPPORT`
- `CONFIG_LWIP_L2_TO_L3_COPY`
- `CONFIG_LWIP_IPV6_DHCP6`
- `CONFIG_LWIP_IP4_DHCP`
- `CONFIG_LWIP_IP6_DHCP`
- `CONFIG_LWIP_IP_FORWARD`
- `CONFIG_LWIP_NETBUF_RECVINFO`
- `CONFIG_LWIP_IPV4`
- `CONFIG_LWIP_AUTOIP`
- `CONFIG_LWIP_IPV6`
- `CONFIG_LWIP_ENABLE_LCP_ECHO`
- `CONFIG_LWIP_ESP_LWIP_ASSERT`
- `CONFIG_LWIP_DEBUG`
- `CONFIG_LWIP_IRAM_OPTIMIZATION`
- `CONFIG_LWIP_EXTRA_IRAM_OPTIMIZATION`
- `CONFIG_LWIP_STATS`
- `CONFIG_LWIP_TIMERS_ONDEMAND`
- `CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES`
- `CONFIG_LWIP_PPP_MPPP_SUPPORT`
- `CONFIG_LWIP_PPP_MSCHAP_SUPPORT`
- `CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT`
- `CONFIG_LWIP_PPP_PAP_SUPPORT`
- `CONFIG_LWIP_PPP_DEBUG_ON`
- `CONFIG_LWIP_PPP_SUPPORT`
- `CONFIG_LWIP_IP4_REASSEMBLY`
- `CONFIG_LWIP_IP6_REASSEMBLY`
- `CONFIG_LWIP_SLIP_SUPPORT`
- `CONFIG_LWIP_SO_LINGER`
- `CONFIG_LWIP_SO_RCVBUF`
- `CONFIG_LWIP_SO_REUSE`
- `CONFIG_LWIP_NETIF_STATUS_CALLBACK`
- `CONFIG_LWIP_TCPIP_CORE_LOCKING`
- `CONFIG_LWIP_NETIF_API`
- **Hooks**
  - `ICMP`
- `CONFIG_LWIP_LOCAL_HOSTNAME`
- `LWIP RAW API`
- `CONFIG_LWIP_TCPIP_TASK_PRIO`
- `CONFIG_LWIP_IPV6_NUM_OF_NEIGHBORS`
- `CONFIG_LWIP_IPV6_MEMP_NUM_OF_QUEUE`
- `CONFIG_LWIP_NETIF_API`
- **Hooks**
  - `ICMP`
- `CONFIG_LWIP_IPV6_NUM_OF_NEIGHBORS`
- `CONFIG_LWIP_IPV6_MEMP_NUM_OF_QUEUE`
- `SNTP`
- `CONFIG_LWIP_USE_ONLY_LWIP_SELECT`
- `TCP`
- `CONFIG_LWIP_TCPIP_TASK_PRIO`
- `CONFIG_LWIP_TCPIP_TASK_AFFINITY`
- `CONFIG_LWIP_TCPIP_TASK_STACK_SIZE`
- `CONFIG_LWIP_TCPIP_RECVMBX_SIZE`
- `UDP`
- `CONFIG_LWIP_IPV6_RDNSS_MAX_DNS_SERVERS`

### `CONFIG_LWIP_LOCAL_HOSTNAME`

Local netif hostname

*Found in: Component config > LWIP*

The default name this device will report to other devices on the network. Could be updated at runtime with `esp_netif_set_hostname()`

**Default value:**
- “espressif”

### `CONFIG_LWIP_NETIF_API`

Enable usage of standard POSIX APIs in LWIP

*Found in: Component config > LWIP*

If this feature is enabled, standard POSIX APIs: `if_indextoname()`, `if_nametoindex()` could be used to convert network interface index to name instead of IDF specific `esp_netif_get_netif_impl_name()`

**Default value:**
- No (disabled)

### `CONFIG_LWIP_TCPIP_TASK_PRIO`

LWIP TCP/IP task priority

*Found in: Component config > LWIP*
LWIP tcpip task priority. In case of high throughput, this parameter could be changed up to (config-
MAX_PRIORITIES-1).

**Range:**
- from 1 to 24

**Default value:**
- 18

**CONFIG_LWIP_TCPIP_CORE_LOCKING**

Enable tcpip core locking

*Found in: Component config > LWIP*

If Enable tcpip core locking, creates a global mutex that is held during TCPIP thread operations. Can be
locked by client code to perform lwIP operations without changing into TCPIP thread using callbacks.
See LOCK_TCPIP_CORE() and UNLOCK_TCPIP_CORE().

If disable tcpip core locking, TCPIP will perform tasks through context switching

**Default value:**
- No (disabled)

**CONFIG_LWIP_TCPIP_CORE_LOCKING_INPUT**

Enable tcpip core locking input

*Found in: Component config > LWIP > CONFIG_LWIP_TCPIP_CORE_LOCKING*

When LWIP_TCPIP_CORE_LOCKING is enabled, this lets tcpip_input() grab the mutex for input
packets as well, instead of allocating a message and passing it to tcpip_thread.

**Default value:**
- No (disabled) if CONFIG_LWIP_TCPIP_CORE_LOCKING

**CONFIG_LWIP_CHECK_THREAD_SAFETY**

Checks that lwip API runs in expected context

*Found in: Component config > LWIP*

Enable to check that the project does not violate lwip thread safety. If enabled, all lwip functions that
require thread awareness run an assertion to verify that the TCP/IP core functionality is either locked or
accessed from the correct thread.

**Default value:**
- No (disabled)

**CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES**

Enable mDNS queries in resolving hostname

*Found in: Component config > LWIP*

If this feature is enabled, standard API such as gethostbyname support .local addresses by sending one
shot multicast mDNS query

**Default value:**
- Yes (enabled)
CONFIG_LWIP_L2_TO_L3_COPY

Enable copy between Layer2 and Layer3 packets

*Found in: Component config > LWIP*

If this feature is enabled, all traffic from layer2 (WIFI Driver) will be copied to a new buffer before sending it to layer3 (LWIP stack), freeing the layer2 buffer. Please be notified that the total layer2 receiving buffer is fixed and ESP32 currently supports 25 layer2 receiving buffer, when layer2 buffer runs out of memory, then the incoming packets will be dropped in hardware. The layer3 buffer is allocated from the heap, so the total layer3 receiving buffer depends on the available heap size, when heap runs out of memory, no copy will be sent to layer3 and packet will be dropped in layer2. Please make sure you fully understand the impact of this feature before enabling it.

*Default value:*

- No (disabled)

CONFIG_LWIP_IRAM_OPTIMIZATION

Enable LWIP IRAM optimization

*Found in: Component config > LWIP*

If this feature is enabled, some functions relating to RX/TX in LWIP will be put into IRAM, it can improve UDP/TCP throughput by >10% for single core mode, it doesn’t help too much for dual core mode. On the other hand, it needs about 10KB IRAM for these optimizations.

If this feature is disabled, all lwip functions will be put into FLASH.

*Default value:*

- No (disabled)

CONFIG_LWIP_EXTRA_IRAM_OPTIMIZATION

Enable LWIP IRAM optimization for TCP part

*Found in: Component config > LWIP*

If this feature is enabled, some tcp part functions relating to RX/TX in LWIP will be put into IRAM, it can improve TCP throughput. On the other hand, it needs about 17KB IRAM for these optimizations.

*Default value:*

- No (disabled)

CONFIG_LWIP_TIMERS_ONDEMAND

Enable LWIP Timers on demand

*Found in: Component config > LWIP*

If this feature is enabled, IGMP and MLD6 timers will be activated only when joining groups or receiving QUERY packets.

This feature will reduce the power consumption for applications which do not use IGMP and MLD6.

*Default value:*

- Yes (enabled)

CONFIG_LWIP_ND6

LWIP NDP6 Enable/Disable

*Found in: Component config > LWIP*

This option is used to disable the Network Discovery Protocol (NDP) if it is not required. Please use this option with caution, as the NDP is essential for IPv6 functionality within a local network.
**Default value:**
- Yes (enabled)

**CONFIG_LWIP_MAX_SOCKETS**
Max number of open sockets

*Found in: Component config > LWIP*

Sockets take up a certain amount of memory, and allowing fewer sockets to be open at the same time conserves memory. Specify the maximum amount of sockets here. The valid value is from 1 to 16.

**Range:**
- from 1 to 16

**Default value:**
- 10

**CONFIG_LWIP_USE_ONLY_LWIP_SELECT**
Support LWIP socket select() only (DEPRECATED)

*Found in: Component config > LWIP*

This option is deprecated. Do not use this option, use VFS_SUPPORT_SELECT instead.

**Default value:**
- No (disabled)

**CONFIG_LWIP_SO_LINGER**
Enable SO_LINGER processing

*Found in: Component config > LWIP*

Enabling this option allows SO_LINGER processing. `l_onoff = 1, l_linger` can set the timeout.

If `l_linger`=0, When a connection is closed, TCP will terminate the connection. This means that TCP will discard any data packets stored in the socket send buffer and send an RST to the peer.

If `l_linger`!=0, Then closesocket() calls to block the process until the remaining data packets has been sent or timed out.

**Default value:**
- No (disabled)

**CONFIG_LWIP_SO_REUSE**
Enable SO_REUSEADDR option

*Found in: Component config > LWIP*

Enabling this option allows binding to a port which remains in TIME_WAIT.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_SO_REUSE_RXTOALL**

SO_REUSEADDR copies broadcast/multicast to all matches

*Found in: Component config > LWIP > CONFIG_LWIP_SO_REUSE*

Enabling this option means that any incoming broadcast or multicast packet will be copied to all of the local sockets that it matches (may be more than one if SO_REUSEADDR is set on the socket.)
This increases memory overhead as the packets need to be copied, however they are only copied per matching socket. You can safely disable it if you don’t plan to receive broadcast or multicast traffic on more than one socket at a time.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_SO_RCVBUF**

Enable SO_RCVBUF option

*Found in: Component config > LWIP*

Enabling this option allows checking for available data on a netconn.

**Default value:**
- No (disabled)

**CONFIG_LWIP_NETBUF_RECVINFO**

Enable IP_PKTINFO option

*Found in: Component config > LWIP*

Enabling this option allows checking for the destination address of a received IPv4 Packet.

**Default value:**
- No (disabled)

**CONFIG_LWIP_IP4_FRAG**

Enable fragment outgoing IP4 packets

*Found in: Component config > LWIP*

Enabling this option allows fragmenting outgoing IP4 packets if their size exceeds MTU.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_IP6_FRAG**

Enable fragment outgoing IP6 packets

*Found in: Component config > LWIP*

Enabling this option allows fragmenting outgoing IP6 packets if their size exceeds MTU.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_IP4_REASSEMBLY**

Enable reassembly incoming fragmented IP4 packets

*Found in: Component config > LWIP*

Enabling this option allows reassembling incoming fragmented IP4 packets.

**Default value:**
- No (disabled)
CONFIG_LWIP_IP6_REASSEMBLY
Enable reassembly incoming fragmented IP6 packets

*Found in: Component config > LWIP*

Enabling this option allows reassembling incoming fragmented IP6 packets.

**Default value:**
- No (disabled)

CONFIG_LWIP_IP_REASS_MAX_PBUFS
The maximum amount of pbufs waiting to be reassembled

*Found in: Component config > LWIP*

Set the maximum amount of pbufs waiting to be reassembled.

**Range:**
- from 10 to 100

**Default value:**
- 10

CONFIG_LWIP_IP_FORWARD
Enable IP forwarding

*Found in: Component config > LWIP*

Enabling this option allows packets forwarding across multiple interfaces.

**Default value:**
- No (disabled)

CONFIG_LWIP_IPV4_NAPT
Enable NAT (new/experimental)

*Found in: Component config > LWIP > CONFIG_LWIP_IP_FORWARD*

Enabling this option allows Network Address and Port Translation.

**Default value:**
- No (disabled) if CONFIG_LWIP_IP_FORWARD

CONFIG_LWIP_STATS
Enable LWIP statistics

*Found in: Component config > LWIP*

Enabling this option allows LWIP statistics

**Default value:**
- No (disabled)

CONFIG_LWIP_ESP_GRATUITOUS_ARP
Send gratuitous ARP periodically

*Found in: Component config > LWIP*

Enable this option allows to send gratuitous ARP periodically.
This option solve the compatibility issues. If the ARP table of the AP is old, and the AP doesn’t send ARP request to update it’s ARP table, this will lead to the STA sending IP packet fail. Thus we send gratuitous ARP periodically to let AP update it’s ARP table.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_GARP_TMR_INTERVAL**

GARP timer interval(seconds)

*Found in: Component config > LWIP > CONFIG_LWIP_ESP GRATUITOUS ARP*

Set the timer interval for gratuitous ARP. The default value is 60s

**Default value:**
- 60

**CONFIG_LWIP_ESP_MLDV6_REPORT**

Send mldv6 report periodically

*Found in: Component config > LWIP*

Enable this option allows to send mldv6 report periodically.

This option solve the issue that failed to receive multicast data. Some routers fail to forward multicast packets. To solve this problem, send multicast mldv6 report to routers regularly.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_MLDV6_TMR_INTERVAL**

mldv6 report timer interval(seconds)

*Found in: Component config > LWIP > CONFIG_LWIP_ESP_MLDV6_REPORT*

Set the timer interval for mldv6 report. The default value is 30s

**Default value:**
- 40

**CONFIG_LWIP_TCPIP_RECMBOX_SIZE**

TCP/IP task receive mailbox size

*Found in: Component config > LWIP*

Set TCP/IP task receive mailbox size. Generally bigger value means higher throughput but more memory. The value should be bigger than UDP/TCP mail box size.

**Range:**
- from 6 to 64 if CONFIG_LWIP_WND_SCALE
- from 6 to 1024 if CONFIG_LWIP_WND_SCALE

**Default value:**
- 32

**CONFIG_LWIP_DHCP_DOES_ARP_CHECK**

DHCP: Perform ARP check on any offered address

*Found in: Component config > LWIP*
Enabling this option performs a check (via ARP request) if the offered IP address is not already in use by another host on the network.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_DHCP_DISABLE_CLIENT_ID**
DHCP: Disable Use of HW address as client identification

*Found in: Component config > LWIP*

This option could be used to disable DHCP client identification with its MAC address. (Client id is used by DHCP servers to uniquely identify clients and are included in the DHCP packets as an option 61) Set this option to “y” in order to exclude option 61 from DHCP packets.

**Default value:**
- No (disabled)

**CONFIG_LWIP_DHCP_DISABLE_VENDOR_CLASS_ID**
DHCP: Disable Use of vendor class identification

*Found in: Component config > LWIP*

This option could be used to disable DHCP client vendor class identification. Set this option to “y” in order to exclude option 60 from DHCP packets.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_DHCP_RESTORE_LAST_IP**
DHCP: Restore last IP obtained from DHCP server

*Found in: Component config > LWIP*

When this option is enabled, DHCP client tries to re-obtain last valid IP address obtained from DHCP server. Last valid DHCP configuration is stored in nvs and restored after reset/power-up. If IP is still available, there is no need for sending discovery message to DHCP server and save some time.

**Default value:**
- No (disabled)

**CONFIG_LWIP_DHCP_OPTIONS_LEN**
DHCP total option length

*Found in: Component config > LWIP*

Set total length of outgoing DHCP option msg. Generally bigger value means it can carry more options and values. If your code meets LWIP_ASSERT due to option value is too long. Please increase the LWIP_DHCP_OPTIONS_LEN value.

**Range:**
- from 68 to 255

**Default value:**
- 68
- 108
**CONFIG_LWIP_NUM_NETIF_CLIENT_DATA**

Number of clients store data in netif

*Found in: Component config > LWIP*

Number of clients that may store data in client_data member array of struct netif.

**Range:**
- from 0 to 256

**Default value:**
- 0

**CONFIG_LWIP_DHCP_COARSE_TIMER_SECS**

DHCP coarse timer interval(s)

*Found in: Component config > LWIP*

Set DHCP coarse interval in seconds. A higher value will be less precise but cost less power consumption.

**Range:**
- from 1 to 10

**Default value:**
- 1

**DHCP server** Contains:

- **CONFIG_LWIP_DHCPS**

**CONFIG_LWIP_DHCPS**

DHCPs: Enable IPv4 Dynamic Host Configuration Protocol Server (DHCPs)

*Found in: Component config > LWIP > DHCP server*

Enabling this option allows the device to run the DHCP server (to dynamically assign IPv4 addresses to clients).

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_DHCPSLEASE_UNIT**

Multiplier for lease time, in seconds

*Found in: Component config > LWIP > DHCP server > CONFIG_LWIP_DHCPS*

The DHCP server is calculating lease time multiplying the sent and received times by this number of seconds per unit. The default is 60, that equals one minute.

**Range:**
- from 1 to 3600

**Default value:**
- 60

**CONFIG_LWIP_DHCPS_MAX_STATION_NUM**

Maximum number of stations

*Found in: Component config > LWIP > DHCP server > CONFIG_LWIP_DHCPS*

The maximum number of DHCP clients that are connected to the server. After this number is exceeded, DHCP server removes of the oldest device from it’s address pool, without notification.
CONFIG_LWIP_AUTOIP
Enable IPv4 Link-Local Addressing (AUTOIP)

*Found in: Component config > LWIP*

Enabling this option allows the device to self-assign an address in the 169.256/16 range if none is assigned statically or via DHCP.

See RFC 3927.

**Default value:**

- No (disabled)

Contains:

- `CONFIG_LWIP_AUTOIP_TRIES`
- `CONFIG_LWIP_AUTOIP_MAX_CONFLICTS`
- `CONFIG_LWIP_AUTOIP_RATE_LIMIT_INTERVAL`

CONFIG_LWIP_AUTOIP_TRIES
DHCP Probes before self-assigning IPv4 LL address

*Found in: Component config > LWIP > CONFIG_LWIP_AUTOIP*

DHCP client will send this many probes before self-assigning a link local address.

From LWIP help: “This can be set as low as 1 to get an AutoIP address very quickly, but you should be prepared to handle a changing IP address when DHCP overrides AutoIP.” (In the case of ESP-IDF, this means multiple SYSTEM_EVENT_STA_GOT_IP events.)

**Range:**

- from 1 to 100 if `CONFIG_LWIP_AUTOIP`

**Default value:**

- 2 if `CONFIG_LWIP_AUTOIP`

CONFIG_LWIP_AUTOIP_MAX_CONFLICTS
Max IP conflicts before rate limiting

*Found in: Component config > LWIP > CONFIG_LWIP_AUTOIP*

If the AUTOIP functionality detects this many IP conflicts while self-assigning an address, it will go into a rate limited mode.

**Range:**

- from 1 to 100 if `CONFIG_LWIP_AUTOIP`

**Default value:**

- 9 if `CONFIG_LWIP_AUTOIP`

CONFIG_LWIP_AUTOIP_RATE_LIMIT_INTERVAL
Rate limited interval (seconds)

*Found in: Component config > LWIP > CONFIG_LWIP_AUTOIP*

If rate limiting self-assignment requests, wait this long between each request.

**Range:**
• from 5 to 120 if `CONFIG_LWIP_AUTOIP`

**Default value:**
• 20 if `CONFIG_LWIP_AUTOIP`

###CONFIG_LWIP_IPV4

Enable IPv4

*Found in: Component config > LWIP*

Enable IPv4 stack. If you want to use IPv6 only TCP/IP stack, disable this.

**Default value:**
• Yes (enabled)

###CONFIG_LWIP_IPV6

Enable IPv6

*Found in: Component config > LWIP*

Enable IPv6 function. If not use IPv6 function, set this option to n. If disabling LWIP_IPV6 then some other components (coap and asio) will no longer be available.

**Default value:**
• Yes (enabled)

###CONFIG_LWIP_IPV6_AUTOCONFIG

Enable IPv6 stateless address autoconfiguration (SLAAC)

*Found in: Component config > LWIP > CONFIG_LWIP_IPV6*

Enabling this option allows the devices to IPV6 stateless address autoconfiguration (SLAAC).

See RFC 4862.

**Default value:**
• No (disabled)

###CONFIG_LWIP_IPV6_NUM_ADDRESSES

Number of IPv6 addresses on each network interface

*Found in: Component config > LWIP > CONFIG_LWIP_IPV6*

The maximum number of IPv6 addresses on each interface. Any additional addresses will be discarded.

**Default value:**
• 3

###CONFIG_LWIP_IPV6_FORWARD

Enable IPv6 forwarding between interfaces

*Found in: Component config > LWIP > CONFIG_LWIP_IPV6*

Forwarding IPv6 packets between interfaces is only required when acting as a router.

**Default value:**
• No (disabled)
**CONFIG_LWIP_IPV6_RDNSS_MAX_DNS_SERVERS**

Use IPv6 Router Advertisement Recursive DNS Server Option

*Found in: Component config > LWIP*

Use IPv6 Router Advertisement Recursive DNS Server Option (as per RFC 6106) to copy a defined maximum number of DNS servers to the DNS module. Set this option to a number of desired DNS servers advertised in the RA protocol. This feature is disabled when set to 0.

**Default value:**
- 0 if `CONFIG_LWIP_IPV6_AUTOCONFIG`

**CONFIG_LWIP_IPV6_DHCP6**

Enable DHCPv6 stateless address autoconfiguration

*Found in: Component config > LWIP*

Enable DHCPv6 for IPv6 stateless address autoconfiguration. Note that the dhcpv6 client has to be started using `dhcp6_enable_stateless(netif)`; Note that the stateful address autoconfiguration is not supported.

**Default value:**
- No (disabled) if `CONFIG_LWIP_IPV6_AUTOCONFIG`

**CONFIG_LWIP_NETIF_STATUS_CALLBACK**

Enable status callback for network interfaces

*Found in: Component config > LWIP*

Enable callbacks when the network interface is up/down and addresses are changed.

**Default value:**
- No (disabled)

**CONFIG_LWIP_NETIF_LOOPBACK**

Support per-interface loopback

*Found in: Component config > LWIP*

Enabling this option means that if a packet is sent with a destination address equal to the interface’s own IP address, it will “loop back” and be received by this interface. Disabling this option disables support of loopback interface in lwIP

**Default value:**
- Yes (enabled)

Contains:

- `CONFIG_LWIP_LOOPBACK_MAX_PBUFS`

**CONFIG_LWIP_LOOPBACK_MAX_PBUFS**

Max queued loopback packets per interface

*Found in: Component config > LWIP > CONFIG_LWIP_NETIF_LOOPBACK*

Configure the maximum number of packets which can be queued for loopback on a given interface. Reducing this number may cause packets to be dropped, but will avoid filling memory with queued packet data.

**Range:**
- from 0 to 16
**Default value:**
- 8

**TCP** Contains:
- `CONFIG_LWIP_TCP_WND_DEFAULT`
- `CONFIG_LWIP_TCP_SND_BUF_DEFAULT`
- `CONFIG_LWIP_TCP_RECVMBOX_SIZE`
- `CONFIG_LWIP_TCP_RTO_TIME`
- `CONFIG_LWIP_MAX_ACTIVE_TCP`
- `CONFIG_LWIP_TCP_FIN_WAIT_TIMEOUT`
- `CONFIG_LWIP_MAX_LISTENING_TCP`
- `CONFIG_LWIP_TCP_MAXRTX`
- `CONFIG_LWIP_TCP_SYNMAXRTX`
- `CONFIG_LWIP_TCP_MSL`
- `CONFIG_LWIP_TCP_MSS`
- `CONFIG_LWIP_TCP_OVERSIZE`
- `CONFIG_LWIP_TCP_QUEUE_OOSEQ`
- `CONFIG_LWIP_WND_SCALE`
- `CONFIG_LWIP_TCP_HIGH_SPEED_RETRANSMISSION`
- `CONFIG_LWIP_TCP_TMR_INTERVAL`

**CONFIG_LWIP_MAX_ACTIVE_TCP**

Maximum active TCP Connections

*Found in: Component config > LWIP > TCP*

The maximum number of simultaneously active TCP connections. The practical maximum limit is determined by available heap memory at runtime.

Changing this value by itself does not substantially change the memory usage of LWIP, except for preventing new TCP connections after the limit is reached.

**Range:**
- from 1 to 1024

*Default value:*
- 16

**CONFIG_LWIP_MAX_LISTENING_TCP**

Maximum listening TCP Connections

*Found in: Component config > LWIP > TCP*

The maximum number of simultaneously listening TCP connections. The practical maximum limit is determined by available heap memory at runtime.

Changing this value by itself does not substantially change the memory usage of LWIP, except for preventing new listening TCP connections after the limit is reached.

**Range:**
- from 1 to 1024

*Default value:*
- 16

**CONFIG_LWIP_TCP_HIGH_SPEED_RETRANSMISSION**

TCP high speed retransmissions

*Found in: Component config > LWIP > TCP*
Chapter 2. API Reference

Speed up the TCP retransmission interval. If disabled, it is recommended to change the number of SYN retransmissions to 6, and TCP initial rto time to 3000.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_TCP_MAXRTX**
Maximum number of retransmissions of data segments

*Found in: Component config > LWIP > TCP*

Set maximum number of retransmissions of data segments.

**Range:**
- from 3 to 12

**Default value:**
- 12

**CONFIG_LWIP_TCP_SYNMAXRTX**
Maximum number of retransmissions of SYN segments

*Found in: Component config > LWIP > TCP*

Set maximum number of retransmissions of SYN segments.

**Range:**
- from 3 to 12

**Default value:**
- 6
- 12

**CONFIG_LWIP_TCP_MSS**
Maximum Segment Size (MSS)

*Found in: Component config > LWIP > TCP*

Set maximum segment size for TCP transmission.

Can be set lower to save RAM, the default value 1460(ipv4)/1440(ipv6) will give best throughput. IPv4 TCP_MSS Range: 576 <= TCP_MSS <= 1460 IPv6 TCP_MSS Range: 1220 <= TCP_mSS <= 1440

**Range:**
- from 536 to 1460

**Default value:**
- 1440

**CONFIG_LWIP_TCP_TMR_INTERVAL**
TCP timer interval(ms)

*Found in: Component config > LWIP > TCP*

Set TCP timer interval in milliseconds.

Can be used to speed connections on bad networks. A lower value will redeliver unacked packets faster.

**Default value:**
- 250
Chapter 2. API Reference

CONFIG_LWIP_TCP_MSL

Maximum segment lifetime (MSL)

*Found in: Component config > LWIP > TCP*

Set maximum segment lifetime in milliseconds.

**Default value:**
- 60000

CONFIG_LWIP_TCP_FIN_WAIT_TIMEOUT

Maximum FIN segment lifetime

*Found in: Component config > LWIP > TCP*

Set maximum segment lifetime in milliseconds.

**Default value:**
- 20000

CONFIG_LWIP_TCP_SND_BUF_DEFAULT

Default send buffer size

*Found in: Component config > LWIP > TCP*

Set default send buffer size for new TCP sockets.

Per-socket send buffer size can be changed at runtime with lwip_setsockopt(s, TCP_SNDBUF, ...).

This value must be at least 2x the MSS size, and the default is 4x the default MSS size.

Setting a smaller default SNDBUF size can save some RAM, but will decrease performance.

**Range:**
- from 2440 to 65535 if `CONFIG_LWIP_WND_SCALE`
- from 2440 to 1024000 if `CONFIG_LWIP_WND_SCALE`

**Default value:**
- 5744

CONFIG_LWIP_TCP_WND_DEFAULT

Default receive window size

*Found in: Component config > LWIP > TCP*

Set default TCP receive window size for new TCP sockets.

Per-socket receive window size can be changed at runtime with lwip_setsockopt(s, TCP_WINDOW, ...).

Setting a smaller default receive window size can save some RAM, but will significantly decrease performance.

**Range:**
- from 2440 to 65535 if `CONFIG_LWIP_WND_SCALE`
- from 2440 to 1024000 if `CONFIG_LWIP_WND_SCALE`

**Default value:**
- 5744
**CONFIG_LWIP_TCP_RECVMBOX_SIZE**

Default TCP receive mail box size

*Found in: Component config > LWIP > TCP*

Set TCP receive mail box size. Generally bigger value means higher throughput but more memory. The recommended value is: LWIP_TCP_WND_DEFAULT/TCP_MSS + 2. e.g. if LWIP_TCP_WND_DEFAULT=14360, TCP_MSS=1436, then the recommended receive mail box size is \((14360/1436 + 2) = 12\).

TCP receive mail box is a per socket mail box, when the application receives packets from TCP socket, LWIP core firstly posts the packets to TCP receive mail box and the application then fetches the packets from mail box. It means LWIP can caches maximum LWIP_TCP_RECCVMBOX_SIZE packets for each TCP socket, so the maximum possible cached TCP packets for all TCP sockets is LWIP_TCP_RECCVMBOX_SIZE multiples the maximum TCP socket number. In other words, the bigger LWIP_TCP_RECCVMBOX_SIZE means more memory. On the other hand, if the receive mail box is too small, the mail box may be full. If the mail box is full, the LWIP drops the packets. So generally we need to make sure the TCP receive mail box is big enough to avoid packet drop between LWIP core and application.

**Range:**
- from 6 to 64 if CONFIG_LWIP_WND_SCALE
- from 6 to 1024 if CONFIG_LWIP_WND_SCALE

**Default value:**
- 6

**CONFIG_LWIP_TCP_QUEUE_OOSEQ**

Queue incoming out-of-order segments

*Found in: Component config > LWIP > TCP*

Queue incoming out-of-order segments for later use.

Disable this option to save some RAM during TCP sessions, at the expense of increased retransmissions if segments arrive out of order.

**Default value:**
- Yes (enabled)

**CONFIG_LWIP_TCP_SACK_OUT**

Support sending selective acknowledgements

*Found in: Component config > LWIP > TCP > CONFIG_LWIP_TCP_QUEUE_OOSEQ*

TCP will support sending selective acknowledgements (SACKs).

**Default value:**
- No (disabled)

**CONFIG_LWIP_TCP_OVERSIZE**

Pre-allocate transmit PBUF size

*Found in: Component config > LWIP > TCP*

Allows enabling “oversize” allocation of TCP transmission pbufs ahead of time, which can reduce the length of pbuf chains used for transmission.

This will not make a difference to sockets where Nagle’s algorithm is disabled.

Default value of MSS is fine for most applications, 25% MSS may save some RAM when only transmitting small amounts of data. Disabled will have worst performance and fragmentation characteristics, but uses least RAM overall.
Available options:

- MSS (CONFIG_LWIP_TCP_OVERSIZE_MSS)
- 25% MSS (CONFIG_LWIP_TCP_OVERSIZE_QUARTER_MSS)
- Disabled (CONFIG_LWIP_TCP_OVERSIZE_DISABLE)

**CONFIG_LWIP_WND_SCALE**

Support TCP window scale

*Found in: Component config > LWIP > TCP*

Enable this feature to support TCP window scaling.

**Default value:**

- No (disabled) if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`

**CONFIG_LWIP_TCP_RCV_SCALE**

Set TCP receiving window scaling factor

*Found in: Component config > LWIP > TCP > CONFIG_LWIP_WND_SCALE*

Enable this feature to support TCP window scaling.

**Range:**

- from 0 to 14 if `CONFIG_LWIP_WND_SCALE`

**Default value:**

- 0 if `CONFIG_LWIP_WND_SCALE`

**CONFIG_LWIP_TCP_RTO_TIME**

Default TCP rto time

*Found in: Component config > LWIP > TCP*

Set default TCP rto time for a reasonable initial rto. In bad network environment, recommend set value of rto time to 1500.

**Default value:**

- 3000
- 1500

**UDP** Contains:

- `CONFIG_LWIP_UDP_RECVMBOX_SIZE`
- `CONFIG_LWIP_MAX_UDP_PCBS`

**CONFIG_LWIP_MAX_UDP_PCBS**

Maximum active UDP control blocks

*Found in: Component config > LWIP > UDP*

The maximum number of active UDP “connections” (ie UDP sockets sending/receiving data). The practical maximum limit is determined by available heap memory at runtime.

**Range:**

- from 1 to 1024

**Default value:**

- 16
CONFIG_LWIP_UDP_RECVBOX_SIZE
Default UDP receive mail box size

*Found in: Component config > LWIP > UDP*

Set UDP receive mail box size. The recommended value is 6.

UDP receive mail box is a per socket mail box, when the application receives packets from UDP socket, LWIP core firstly posts the packets to UDP receive mail box and the application then fetches the packets from mail box. It means LWIP can caches maximum UDP_RECVBOX_SIZE packets for each UDP socket, so the maximum possible cached UDP packets for all UDP sockets is UDP_RECVBOX_SIZE multiples the maximum UDP socket number. In other words, the bigger UDP_RECVBOX_SIZE means more memory. On the other hand, if the receive mail box is too small, the mail box may be full. If the mail box is full, the LWIP drops the packets. So generally we need to make sure the UDP receive mail box is big enough to avoid packet drop between LWIP core and application.

*Range:*
  * from 6 to 64

*Default value:*
  * 6

Checksums Contains:

- CONFIG_LWIP_CHECKSUM_CHECK_ICMP
- CONFIG_LWIP_CHECKSUM_CHECK_IP
- CONFIG_LWIP_CHECKSUM_CHECK_UDP

CONFIG_LWIP_CHECKSUM_CHECK_IP
Enable LWIP IP checksums

*Found in: Component config > LWIP > Checksums*

Enable checksum checking for received IP messages

*Default value:*
  * No (disabled)

CONFIG_LWIP_CHECKSUM_CHECK_UDP
Enable LWIP UDP checksums

*Found in: Component config > LWIP > Checksums*

Enable checksum checking for received UDP messages

*Default value:*
  * No (disabled)

CONFIG_LWIP_CHECKSUM_CHECK_ICMP
Enable LWIP ICMP checksums

*Found in: Component config > LWIP > Checksums*

Enable checksum checking for received ICMP messages

*Default value:*
  * Yes (enabled)*
CONFIG_LWIP_TCPIP_TASK_STACK_SIZE

TCP/IP Task Stack Size

*Found in: Component config > LWIP*

Configure TCP/IP task stack size, used by LWIP to process multi-threaded TCP/IP operations. Setting this stack too small will result in stack overflow crashes.

**Range:**
- from 2048 to 65536

**Default value:**
- 3072

CONFIG_LWIP_TCPIP_TASK_AFFINITY

TCP/IP task affinity

*Found in: Component config > LWIP*

Allows setting LwIP tasks affinity, i.e. whether the task is pinned to CPU0, pinned to CPU1, or allowed to run on any CPU. Currently this applies to “TCP/IP” task and “Ping” task.

**Available options:**
- No affinity (CONFIG_LWIP_TCPIP_TASK_AFFINITY_NO_AFFINITY)
- CPU0 (CONFIG_LWIP_TCPIP_TASK_AFFINITY_CPU0)
- CPU1 (CONFIG_LWIP_TCPIP_TASK_AFFINITY_CPU1)

CONFIG_LWIP_PPP_SUPPORT

Enable PPP support

*Found in: Component config > LWIP*

Enable PPP stack. Now only PPP over serial is possible.

**Default value:**
- No (disabled)

**Contains:**
- CONFIG_LWIP_PPP_ENABLE_IPV6

CONFIG_LWIP_PPP_ENABLE_IPV6

Enable IPv6 support for PPP connections (IPV6CP)

*Found in: Component config > LWIP > CONFIG_LWIP_PPP_SUPPORT*

Enable IPv6 support in PPP for the local link between the DTE (processor) and DCE (modem). There are some modems which do not support the IPv6 addressing in the local link. If they are requested for IPv6CP negotiation, they may time out. This would in turn fail the configuration for the whole link. If your modem is not responding correctly to PPP Phase Network, try to disable IPv6 support.

**Default value:**
- Yes (enabled) if CONFIG_LWIP_PPP_SUPPORT && CONFIG_LWIP_IPV6

CONFIG_LWIP_IPV6_MEMP_NUM_ND6_QUEUE

Max number of IPv6 packets to queue during MAC resolution

*Found in: Component config > LWIP*

Config max number of IPv6 packets to queue during MAC resolution.
CONFIG_LWIP_IPV6 ND6_NUM_NEIGHBORS
Max number of entries in IPv6 neighbor cache
Found in: Component config > LWIP
Config max number of entries in IPv6 neighbor cache
Range:
• from 3 to 10
Default value:
• 3

CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT
Enable Notify Phase Callback
Found in: Component config > LWIP
Enable to set a callback which is called on change of the internal PPP state machine.
Default value:
• No (disabled) if CONFIG_LWIP_PPP_SUPPORT

CONFIG_LWIP_PPP_PAP_SUPPORT
Enable PAP support
Found in: Component config > LWIP
Enable Password Authentication Protocol (PAP) support
Default value:
• No (disabled) if CONFIG_LWIP_PPP_SUPPORT

CONFIG_LWIP_PPP_CHAP_SUPPORT
Enable CHAP support
Found in: Component config > LWIP
Enable Challenge Handshake Authentication Protocol (CHAP) support
Default value:
• No (disabled) if CONFIG_LWIP_PPP_SUPPORT

CONFIG_LWIP_PPP_MSCHAP_SUPPORT
Enable MSCHAP support
Found in: Component config > LWIP
Enable Microsoft version of the Challenge-Handshake Authentication Protocol (MSCHAP) support
Default value:
• No (disabled) if CONFIG_LWIP_PPP_SUPPORT
**CONFIG_LWIP_PPP_MPPE_SUPPORT**
Enable MPPE support

*Found in: Component config > LWIP*
Enable Microsoft Point-to-Point Encryption (MPPE) support

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

**CONFIG_LWIP_ENABLE_LCP_ECHO**
Enable LCP ECHO

*Found in: Component config > LWIP*
Enable LCP echo keepalive requests

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`

**CONFIG_LWIP_LCP_ECHOINTERVAL**
Echo interval (s)

*Found in: Component config > LWIP > CONFIG_LWIP_ENABLE_LCP_ECHO*
Interval in seconds between keepalive LCP echo requests, 0 to disable.

**Range:**
- from 0 to 1000000 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

**Default value:**
- 3 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

**CONFIG_LWIP_LCP_MAXECHOFAILS**
Maximum echo failures

*Found in: Component config > LWIP > CONFIG_LWIP_ENABLE_LCP_ECHO*
Number of consecutive unanswered echo requests before failure is indicated.

**Range:**
- from 0 to 100000 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

**Default value:**
- 3 if `CONFIG_LWIP_ENABLE_LCP_ECHO`

**CONFIG_LWIP_PPP_DEBUG_ON**
Enable PPP debug log output

*Found in: Component config > LWIP*
Enable PPP debug log output

**Default value:**
- No (disabled) if `CONFIG_LWIP_PPP_SUPPORT`
CONFIG_LWIP_SLIP_SUPPORT
Enable SLIP support (new/experimental)

*Found in: Component config > LWIP*
Enable SLIP stack. Now only SLIP over serial is possible.
SLIP over serial support is experimental and unsupported.

**Default value:**
- No (disabled)

Contains:
- `CONFIG_LWIP_SLIP_DEBUG_ON`

CONFIG_LWIP_SLIP_DEBUG_ON
Enable SLIP debug log output

*Found in: Component config > LWIP > CONFIG_LWIP_SLIP_SUPPORT*
Enable SLIP debug log output

**Default value:**
- No (disabled) if `CONFIG_LWIP_SLIP_SUPPORT`

ICMP
Contains:
- `CONFIG_LWIP_ICMP`
- `CONFIG_LWIP_BROADCAST_PING`
- `CONFIG_LWIP_MULTICAST_PING`

CONFIG_LWIP_ICMP
ICMP: Enable ICMP

*Found in: Component config > LWIP > ICMP*
Enable ICMP module for check network stability

**Default value:**
- Yes (enabled)

CONFIG_LWIP_MULTICAST_PING
Respond to multicast pings

*Found in: Component config > LWIP > ICMP*

**Default value:**
- No (disabled)

CONFIG_LWIP_BROADCAST_PING
Respond to broadcast pings

*Found in: Component config > LWIP > ICMP*

**Default value:**
- No (disabled)
LWIP RAW API Contains:
  • CONFIG_LWIP_MAX_RAW_PCBS

CONFIG_LWIP_MAX_RAW_PCBS
Maximum LWIP RAW PCBs

*Found in: Component config > LWIP > LWIP RAW API*

The maximum number of simultaneously active LWIP RAW protocol control blocks. The practical maximum limit is determined by available heap memory at runtime.

*Range:*
  • from 1 to 1024

*Default value:*
  • 16

SNTP Contains:
  • CONFIG_LWIP_SNTP_MAX_SERVERS
  • CONFIG_LWIP_SNTP_UPDATE_DELAY
  • CONFIG_LWIP_DHCP_GET_NTP_SRV

CONFIG_LWIP_SNTP_MAX_SERVERS
Maximum number of NTP servers

*Found in: Component config > LWIP > SNTP*

Set maximum number of NTP servers used by LwIP SNTP module. First argument of sntp_setserver/sntp_setservername functions is limited to this value.

*Range:*
  • from 1 to 16

*Default value:*
  • 1

CONFIG_LWIP_DHCP_GET_NTP_SRV
Request NTP servers from DHCP

*Found in: Component config > LWIP > SNTP*

If enabled, LWIP will add ‘NTP’ to Parameter-Request Option sent via DHCP-request. DHCP server might reply with an NTP server address in option 42. SNTP callback for such replies should be set accordingly (see sntp_servermode_dhcp() func.)

*Default value:*
  • No (disabled)

CONFIG_LWIP_DHCP_MAX_NTP_SERVERS
Maximum number of NTP servers acquired via DHCP

*Found in: Component config > LWIP > SNTP > CONFIG_LWIP_DHCP_GET_NTP_SRV*

Set maximum number of NTP servers acquired via DHCP-offer. Should be less or equal to “Maximum number of NTP servers”, any extra servers would be just ignored.

*Range:*
  • from 1 to 16 if CONFIG_LWIP_DHCP_GET_NTP_SRV

*Default value:*
  • 1 if CONFIG_LWIP_DHCP_GET_NTP_SRV
**CONFIG_LWIP_SNTP_UPDATE_DELAY**

Request interval to update time (ms)

*Found in: Component config > LWIP > SNTP*

This option allows you to set the time update period via SNTP. Default is 1 hour. Must not be below 15 seconds by specification. (SNTPv4 RFC 4330 enforces a minimum update time of 15 seconds).

*Range:*
- from 15000 to 4294967295

*Default value:*
- 3600000

**CONFIG_LWIP_BRIDGEIF_MAX_PORTS**

Maximum number of bridge ports

*Found in: Component config > LWIP*

Set maximum number of ports a bridge can consists of.

*Range:*
- from 1 to 63

*Default value:*
- 7

**CONFIG_LWIP_ESP_LWIP_ASSERT**

Enable LWIP ASSERT checks

*Found in: Component config > LWIP*

Enable this option keeps LWIP assertion checks enabled. It is recommended to keep this option enabled. If asserts are disabled for the entire project, they are also disabled for LWIP and this option is ignored.

*Default value:*
- Yes (enabled) if `CONFIG_COMPILER_OPTIMIZATION_ASSERTIONS_DISABLE`

**Hooks**

Contains:
- `CONFIG_LWIP_HOOK_ND6_GET_GW`
- `CONFIG_LWIP_HOOK_IP6_INPUT`
- `CONFIG_LWIP_HOOK_IP6_ROUTE`
- `CONFIG_LWIP_HOOK_IP6_SELECT_SRC_ADDR`
- `CONFIG_LWIP_HOOK_NETCONN_EXTERNAL_RESOLVE`
- `CONFIG_LWIP_HOOK_TCP_ISN`

**CONFIG_LWIP_HOOK_TCP_ISN**

TCP ISN Hook

*Found in: Component config > LWIP > Hooks*

Enables to define a TCP ISN hook to randomize initial sequence number in TCP connection. The default TCP ISN algorithm used in IDF (standardized in RFC 6528) produces ISN by combining an MD5 of the new TCP id and a stable secret with the current time. This is because the lwIP implementation (`tcp_next_iss`) is not very strong, as it does not take into consideration any platform specific entropy source.

Set to `LWIP_HOOK_TCP_ISN_CUSTOM` to provide custom implementation. Set to `LWIP_HOOK_TCP_ISN_NONE` to use lwIP implementation.

Available options:
• No hook declared (CONFIG_LWIP_HOOK_TCP_ISN_NONE)
• Default implementation (CONFIG_LWIP_HOOK_TCP_ISN_DEFAULT)
• Custom implementation (CONFIG_LWIP_HOOK_TCP_ISN_CUSTOM)

**CONFIG_LWIP_HOOK_IP6_ROUTE**

IPv6 route Hook

*Found in: Component config > LWIP > Hooks*

Enables custom IPv6 route hook. Setting this to “default” provides weak implementation stub that could be overwritten in application code. Setting this to “custom” provides hook’s declaration only and expects the application to implement it.

Available options:

• No hook declared (CONFIG_LWIP_HOOK_IP6_ROUTE_NONE)
• Default (weak) implementation (CONFIG_LWIP_HOOK_IP6_ROUTE_DEFAULT)
• Custom implementation (CONFIG_LWIP_HOOK_IP6_ROUTE_CUSTOM)

**CONFIG_LWIP_HOOK_ND6_GET_GW**

IPv6 get gateway Hook

*Found in: Component config > LWIP > Hooks*

Enables custom IPv6 route hook. Setting this to “default” provides weak implementation stub that could be overwritten in application code. Setting this to “custom” provides hook’s declaration only and expects the application to implement it.

Available options:

• No hook declared (CONFIG_LWIP_HOOK_ND6_GET_GW_NONE)
• Default (weak) implementation (CONFIG_LWIP_HOOK_ND6_GET_GW_DEFAULT)
• Custom implementation (CONFIG_LWIP_HOOK_ND6_GET_GW_CUSTOM)

**CONFIG_LWIP_HOOK_IP6_SELECT_SRC_ADDR**

IPv6 source address selection Hook

*Found in: Component config > LWIP > Hooks*

Enables custom IPv6 source address selection. Setting this to “default” provides weak implementation stub that could be overwritten in application code. Setting this to “custom” provides hook’s declaration only and expects the application to implement it.

Available options:

• No hook declared (CONFIG_LWIP_HOOK_IP6_SELECT_SRC_ADDR_NONE)
• Default (weak) implementation (CONFIG_LWIP_HOOK_IP6_SELECT_SRC_ADDR_DEFAULT)
• Custom implementation (CONFIG_LWIP_HOOK_IP6_SELECT_SRC_ADDR_CUSTOM)
**CONFIG_LWIP_HOOK_NETCONN_EXTERNAL_RESOLVE**

Netconn external resolve Hook

*Found in: Component config > LWIP > Hooks*

Enables custom DNS resolve hook. Setting this to “default” provides weak implementation stub that could be overwitten in application code. Setting this to “custom” provides hook’s declaration only and expects the application to implement it.

Available options:

- No hook declared (CONFIG_LWIP_HOOK_NETCONN_EXT_RESOLVE_NONE)
- Default (weak) implementation (CONFIG_LWIP_HOOK_NETCONN_EXT_RESOLVE_DEFAULT)
- Custom implementation (CONFIG_LWIP_HOOK_NETCONN_EXT_RESOLVE_CUSTOM)

**CONFIG_LWIP_HOOK_IP6_INPUT**

IPv6 packet input

*Found in: Component config > LWIP > Hooks*

Enables custom IPv6 packet input. Setting this to “default” provides weak implementation stub that could be overwritten in application code. Setting this to “custom” provides hook’s declaration only and expects the application to implement it.

Available options:

- No hook declared (CONFIG_LWIP_HOOK_IP6_INPUT_NONE)
- Default (weak) implementation (CONFIG_LWIP_HOOK_IP6_INPUT_DEFAULT)
- Custom implementation (CONFIG_LWIP_HOOK_IP6_INPUT_CUSTOM)

**CONFIG_LWIP_DEBUG**

Enable LWIP Debug

*Found in: Component config > LWIP*

Enabling this option allows different kinds of lwIP debug output.

All lwIP debug features increase the size of the final binary.

**Default value:**

- No (disabled)

Contains:

- CONFIG_LWIP_API_LIB_DEBUG
- CONFIG_LWIP_BRIDGEIF_FDB_DEBUG
- CONFIG_LWIP_BRIDGEIF_FW_DEBUG
- CONFIG_LWIP_BRIDGEIF_DEBUG
- CONFIG_LWIP_DHCP_DEBUG
- CONFIG_LWIP_DHCP_STATE_DEBUG
- CONFIG_LWIP_DNS_DEBUG
- CONFIG_LWIP_ETHARP_DEBUG
- CONFIG_LWIP_ICMP_DEBUG
- CONFIG_LWIP_ICMP6_DEBUG
- CONFIG_LWIP_IP_DEBUG
- CONFIG_LWIP_IP6_DEBUG
- CONFIG_LWIP_NAPT_DEBUG
- CONFIG_LWIP_NETIF_DEBUG
- CONFIG_LWIP_PBUF_DEBUG
• `CONFIG_LWIP_SNTP_DEBUG`
• `CONFIG_LWIP_SOCKETS_DEBUG`
• `CONFIG_LWIP_TCP_DEBUG`
• `CONFIG_LWIP_UDP_DEBUG`
• `CONFIG_LWIP_DEBUG_ESP_LOG`

`CONFIG_LWIP_DEBUG_ESP_LOG`

Route LWIP debugs through ESP_LOG interface

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

Enabling this option routes all enabled LWIP debugs through ESP_LOGD.

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

`CONFIG_LWIP_NETIF_DEBUG`

Enable netif debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

`CONFIG_LWIP_PBUF_DEBUG`

Enable pbuf debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

`CONFIG_LWIP_ETHARP_DEBUG`

Enable etharp debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

`CONFIG_LWIP_API_LIB_DEBUG`

Enable api lib debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

`CONFIG_LWIP_SOCKETS_DEBUG`

Enable socket debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`
Chapter 2. API Reference

**CONFIG_LWIP_IP_DEBUG**
Enable IP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

**CONFIG_LWIP_ICMP_DEBUG**
Enable ICMP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG` and `CONFIG_LWIP_ICMP`

**CONFIG_LWIP_DHCP_STATE_DEBUG**
Enable DHCP state tracking

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

**CONFIG_LWIP_DHCP_DEBUG**
Enable DHCP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

**CONFIG_LWIP_IP6_DEBUG**
Enable IP6 debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

**CONFIG_LWIP_ICMP6_DEBUG**
Enable ICMP6 debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

**CONFIG_LWIP_TCP_DEBUG**
Enable TCP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`
CONFIG_LWIP_UDP_DEBUG
Enable UDP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

CONFIG_LWIP_Sntp_Debug
Enable SNTP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

CONFIG_LWIP_Dns_Debug
Enable DNS debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

CONFIG_LWIP_NAPT_Debug
Enable NAPT debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG` && `CONFIG_LWIP_IPV4_NAPT`

CONFIG_LWIP_BridgeIf_Debug
Enable bridge generic debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

CONFIG_LWIP_BridgeIf_Fdb_Debug
Enable bridge FDB debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`

CONFIG_LWIP_BridgeIf_Fw_Debug
Enable bridge forwarding debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

**Default value:**
- No (disabled) if `CONFIG_LWIP_DEBUG`
**mbedTLS** Contains:

- `CONFIG_MBEDTLSASYMMETRICCONTENTLEN`
- Certificate Bundle
- Certificates
- `CONFIG_MBEDTLSCHACHA20_C`
- `CONFIG_MBEDTLSDHM_C`
- `CONFIG_MBEDTLECP_C`
- `CONFIG_MBEDTLSECDH_C`
- `CONFIG_MBEDTLSJPAKE_C`
- `CONFIG_MBEDTLS_ECP_DP_BP256R1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_BP384R1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_BP512R1_ENABLED`
- `CONFIG_MBEDTLS_CMCC_C`
- `CONFIG_MBEDTLS_ECP_DP_CURVE25519_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC192K1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC192R1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC224K1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC224R1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC256K1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC256R1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC384R1_ENABLED`
- `CONFIG_MBEDTLS_ECP_DP_SEC512R1_ENABLED`
- `CONFIG_MBEDTLS_SHA512_C`
- `CONFIG_MBEDTLS_THREADING_C`
- `CONFIG_MBEDTLS_LARGE_KEYSOFTWARE_MPI`
- `CONFIG_MBEDTLS_HKDF_C`

**mbedTLS v3.x related**

- `CONFIG_MBEDTLS_MEM_ALLOC_MODE`
- `CONFIG_MBEDTLS_NIST_OPTIM`
- `CONFIG_MBEDTLS_POLY1305_C`
- `CONFIG_MBEDTLS_SSL_ALPN`
- `CONFIG_MBEDTLS_SSL_PROTO_DTLS`
- `CONFIG_MBEDTLS_SSL_PROTO_GMTSSL1_1`
- `CONFIG_MBEDTLS_SSL_PROTO_TLS1_2`
- `CONFIG_MBEDTLS_SSL_RENEGOTIATION`
- Symmetric Ciphers
- TLS Key Exchange Methods
- `CONFIG_MBEDTLS_SSL_MAXCONTENTLEN`
- `CONFIG_MBEDTLS_TLS_MODE`
- `CONFIG_MBEDTLS_CLIENT_SSL_SESSION_TICKETS`
- `CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS`
- `CONFIG_MBEDTLS_ROM_MD5`
- `CONFIG_MBEDTLS_DYNAMIC_BUFFER`
**CONFIG_MBEDTLS_MEM_ALLOC_MODE**

Memory allocation strategy

*Found in: Component config > mbedTLS*

Allocation strategy for mbedTLS, essentially provides ability to allocate all required dynamic allocations from,

- Internal DRAM memory only
- External SPIRAM memory only
- Either internal or external memory based on default malloc() behavior in ESP-IDF
- Custom allocation mode, by overwriting calloc()/free() using mbedtls_platform_set_calloc_free() function
- Internal IRAM memory wherever applicable else internal DRAM

Recommended mode here is always internal (*), since that is most preferred from security perspective. But if application requirement does not allow sufficient free internal memory then alternate mode can be selected.

(*) In case of ESP32-S2/ESP32-S3, hardware allows encryption of external SPIRAM contents provided hardware flash encryption feature is enabled. In that case, using external SPIRAM allocation strategy is also safe choice from security perspective.

**Available options:**

- Internal memory (CONFIG_MBEDTLS_INTERNAL_MEM_ALLOC)
- External SPIRAM (CONFIG_MBEDTLS_EXTERNAL_MEM_ALLOC)
- Default alloc mode (CONFIG_MBEDTLS_DEFAULT_MEM_ALLOC)
- Custom alloc mode (CONFIG_MBEDTLS_CUSTOM_MEM_ALLOC)
- Internal IRAM (CONFIG_MBEDTLS_IRAM_8BIT_MEM_ALLOC)

**CONFIG_MBEDTLS_SSL_MAX_CONTENT_LEN**

TLS maximum message content length

*Found in: Component config > mbedTLS*

Maximum TLS message length (in bytes) supported by mbedTLS.

16384 is the default and this value is required to comply fully with TLS standards.

However you can set a lower value in order to save RAM. This is safe if the other end of the connection supports Maximum Fragment Length Negotiation Extension (max_fragment_length, see RFC6066) or you know for certain that it will never send a message longer than a certain number of bytes.

If the value is set too low, symptoms are a failed TLS handshake or a return value of MBEDTLS_ERR_SSL_INVALID_RECORD (-0x7200).

**Range:**

- from 512 to 16384

**Default value:**

- 16384

**CONFIG_MBEDTLS_SYMMETRIC_CONTENT_LEN**

Asymmetric in/out fragment length

*Found in: Component config > mbedTLS*
If enabled, this option allows customizing TLS in/out fragment length in asymmetric way. Please note that enabling this with default values saves 12KB of dynamic memory per TLS connection.

**Default value:**
- Yes (enabled)

**CONFIG_MBEDTLS_SSL_IN_CONTENT_LEN**

TLS maximum incoming fragment length

*Found in: Component config > mbedTLS > CONFIG_MBEDTLSASYMMETRICCONTENT_LEN*

This defines maximum incoming fragment length, overriding default maximum content length (MBEDTLS_SSL_MAXCONTENT_LEN).

**Range:**
- from 512 to 16384

**Default value:**
- 16384

**CONFIG_MBEDTLS_SSL_OUT_CONTENT_LEN**

TLS maximum outgoing fragment length

*Found in: Component config > mbedTLS > CONFIG_MBEDTLSASYMMETRICCONTENT_LEN*

This defines maximum outgoing fragment length, overriding default maximum content length (MBEDTLS_SSL_MAXCONTENT_LEN).

**Range:**
- from 512 to 16384

**Default value:**
- 4096

**CONFIG_MBEDTLS_DYNAMIC_BUFFER**

Using dynamic TX/RX buffer

*Found in: Component config > mbedTLS*

Using dynamic TX/RX buffer. After enabling this option, mbedTLS will allocate TX buffer when need to send data and then free it if all data is sent, allocate RX buffer when need to receive data and then free it when all data is used or read by upper layer.

By default, when SSL is initialized, mbedTLS also allocate TX and RX buffer with the default value of “MBEDTLS_SSL_OUT_CONTENT_LEN” or “MBEDTLS_SSL_IN_CONTENT_LEN”, so to save more heap, users can set the options to be an appropriate value.

**Default value:**
- No (disabled) if CONFIG_MBEDTLS_SSLPROTOCOLTLS && CONFIG_MBEDTLS_SSLVARIABLEBUFFER_LENGTH

**CONFIG_MBEDTLS_DYNAMIC_FREE_CONFIG_DATA**

Free private key and DHM data after its usage

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_DYNAMICBUFFER*

Free private key and DHM data after its usage in handshake process.

The option will decrease heap cost when handshake, but also lead to problem:

Because all certificate, private key and DHM data are freed so users should register certificate and private key to ssl config object again.
Default value:
- No (disabled) if CONFIG_MBEDTLS_DYNAMIC_BUFFER

**CONFIG_MBEDTLS_DYNAMIC_FREE_CA_CERT**
Free SSL CA certificate after its usage

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_DYNAMIC_BUFFER > CONFIG_MBEDTLS_DYNAMIC_FREE_CONFIG_DATA*

Free CA certificate after its usage in the handshake process. This option will decrease the heap footprint for the TLS handshake, but may lead to a problem: If the respective ssl object needs to perform the TLS handshake again, the CA certificate should once again be registered to the ssl object.

Default value:
- Yes (enabled) if CONFIG_MBEDTLS_DYNAMIC_FREE_CONFIG_DATA

**CONFIG_MBEDTLS_DEBUG**
Enable mbedTLS debugging

*Found in: Component config > mbedTLS*

Enable mbedTLS debugging functions at compile time.

If this option is enabled, you can include "mbedtls/esp_debug.h" and call mbedtls_esp_enable_debug_log() at runtime in order to enable mbedTLS debug output via the ESP log mechanism.

Default value:
- No (disabled)

**CONFIG_MBEDTLS_DEBUG_LEVEL**
Set mbedTLS debugging level

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_DEBUG*

Set mbedTLS debugging level

Available options:

- Warning (CONFIG_MBEDTLS_DEBUG_LEVEL_WARN)
- Info (CONFIG_MBEDTLS_DEBUG_LEVEL_INFO)
- Debug (CONFIG_MBEDTLS_DEBUG_LEVEL_DEBUG)
- Verbose (CONFIG_MBEDTLS_DEBUG_LEVEL_VERBOSE)

**mbedTLS v3.x related**
Contains:

- DTLS-based configurations
- CONFIG_MBEDTLS_PKCS7_C
- CONFIG_MBEDTLS_SSL_CONTEXT_SERIALIZATION
- CONFIG_MBEDTLS_X509_TRUSTED_CERT_CALLBACK
- CONFIG_MBEDTLS_SSL_KEEP_PEER_CERTIFICATE
- CONFIG_MBEDTLS_SSL_PROTO_TLS1_3
- CONFIG_MBEDTLS_ECDH_LEGACY_CONTEXT
- CONFIG_MBEDTLS_SSL_VARIABLE_BUFFER_LENGTH
CONFIG_MBEDTLS_SSL_PROTO_TLS1_3

Support TLS 1.3 protocol

*Found in:* Component config > mbedTLS > mbedTLS v3.x related

**Default value:**
- No (disabled) if `CONFIG_MBEDTLS_SSL_KEEP_PEER_CERTIFICATE` && `CONFIG_MBEDTLS_DYNAMIC_BUFFER`

**TLS 1.3 related configurations**

Contains:
- `CONFIG_MBEDTLS_SSL_TLS1_3_KEXM_EPHEMERAL`
- `CONFIG_MBEDTLS_SSL_TLS1_3_COMPATIBILITY_MODE`
- `CONFIG_MBEDTLS_SSL_TLS1_3_KEXM_PSK_EPHEMERAL`
- `CONFIG_MBEDTLS_SSL_TLS1_3_KEXM_PSK`

**CONFIG_MBEDTLS_SSL_TLS1_3_COMPATIBILITY_MODE**

TLS 1.3 middlebox compatibility mode

*Found in:* Component config > mbedTLS > mbedTLS v3.x related > `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3` > TLS 1.3 related configurations

**Default value:**
- Yes (enabled) if `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3`

**CONFIG_MBEDTLS_SSL_TLS1_3_KEXM_PSK**

TLS 1.3 PSK key exchange mode

*Found in:* Component config > mbedTLS > mbedTLS v3.x related > `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3` > TLS 1.3 related configurations

**Default value:**
- Yes (enabled) if `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3`

**CONFIG_MBEDTLS_SSL_TLS1_3_KEXM_EPHEMERAL**

TLS 1.3 ephemeral key exchange mode

*Found in:* Component config > mbedTLS > mbedTLS v3.x related > `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3` > TLS 1.3 related configurations

**Default value:**
- Yes (enabled) if `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3`

**CONFIG_MBEDTLS_SSL_TLS1_3_KEXM_PSK_EPHEMERAL**

TLS 1.3 PSK ephemeral key exchange mode

*Found in:* Component config > mbedTLS > mbedTLS v3.x related > `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3` > TLS 1.3 related configurations

**Default value:**
- Yes (enabled) if `CONFIG_MBEDTLS_SSL_PROTO_TLS1_3`
CONFIG_MBEDTLS_SSL_VARIABLE_BUFFER_LENGTH
Variable SSL buffer length

*Found in: Component config > mbedTLS > mbedTLS v3.x related*

This enables the SSL buffer to be resized automatically based on the negotiated maximum fragment length in each direction.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_ECDH_LEGACY_CONTEXT
Use a backward compatible ECDH context (Experimental)

*Found in: Component config > mbedTLS > mbedTLS v3.x related*

Use the legacy ECDH context format. Define this option only if you enable MBEDTLS_ECP_RESTARTABLE or if you want to access ECDH context fields directly.

**Default value:**
- No (disabled) if CONFIG_MBEDTLS_ECDH_C && CONFIG_MBEDTLS_ECP_RESTARTABLE

CONFIG_MBEDTLS_X509_TRUSTED_CERT_CALLBACK
Enable trusted certificate callbacks

*Found in: Component config > mbedTLS > mbedTLS v3.x related*

Enables users to configure the set of trusted certificates through a callback instead of a linked list.

See mbedTLS documentation for required API and more details.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_SSL_CONTEXT_SERIALIZATION
Enable serialization of the TLS context structures

*Found in: Component config > mbedTLS > mbedTLS v3.x related*

Enable serialization of the TLS context structures. This is a local optimization in handling a single, potentially long-lived connection.

See mbedTLS documentation for required API and more details. Disabling this option will save some code size.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_SSL_KEEP_PEER_CERTIFICATE
Keep peer certificate after handshake completion

*Found in: Component config > mbedTLS > mbedTLS v3.x related*

Keep the peer’s certificate after completion of the handshake. Disabling this option will save about 4kB of heap and some code size.

See mbedTLS documentation for required API and more details.

**Default value:**
- Yes (enabled) if MBEDTLS_DYNAMIC_FREE_PEER_CERT
CONFIG_MBEDTLS_PKCS7_C

Enable PKCS #7

*Found in: Component config > mbedTLS > mbedTLS v3.x related*

Enable PKCS #7 core for using PKCS #7-formatted signatures.

**Default value:**
- Yes (enabled)

**DTLS-based configurations** Contains:
- `CONFIG_MBEDTLS_SSL_DTLS_SRTP`
- `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID`

CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID

Support for the DTLS Connection ID extension

*Found in: Component config > mbedTLS > mbedTLS v3.x related > DTLS-based configurations*

Enable support for the DTLS Connection ID extension which allows to identify DTLS connections across changes in the underlying transport.

**Default value:**
- No (disabled) if `CONFIG_MBEDTLS_SSL_PROTO_DTLS`

CONFIG_MBEDTLS_SSL_CID_IN_LEN_MAX

Maximum length of CIDs used for incoming DTLS messages

*Found in: Component config > mbedTLS > mbedTLS v3.x related > DTLS-based configurations > CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID*

Maximum length of CIDs used for incoming DTLS messages

**Range:**
- from 0 to 32 if `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID` && `CONFIG_MBEDTLS_SSL_PROTO_DTLS`

**Default value:**
- 32 if `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID` && `CONFIG_MBEDTLS_SSL_PROTO_DTLS`

CONFIG_MBEDTLS_SSL_CID_OUT_LEN_MAX

Maximum length of CIDs used for outgoing DTLS messages

*Found in: Component config > mbedTLS > mbedTLS v3.x related > DTLS-based configurations > CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID*

Maximum length of CIDs used for outgoing DTLS messages

**Range:**
- from 0 to 32 if `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID` && `CONFIG_MBEDTLS_SSL_PROTO_DTLS`

**Default value:**
- 32 if `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID` && `CONFIG_MBEDTLS_SSL_PROTO_DTLS`
Chapter 2. API Reference

**CONFIG_MBEDTLS_SSL_CID_PADDING_GRANULARITY**

Record plaintext padding (for DTLS 1.2)

*Found in: Component config > mbedTLS > mbedTLS v3.x related > DTLS-based configurations > CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID*

Controls the use of record plaintext padding when using the Connection ID extension in DTLS 1.2.

The padding will always be chosen so that the length of the padded plaintext is a multiple of the value of this option.

**Notes:** A value of 1 means that no padding will be used for outgoing records. On systems lacking division instructions, a power of two should be preferred.

**Range:**
* from 0 to 32 if CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID && CONFIG_MBEDTLS_SSL_PROTO_DTLS

**Default value:**
* 16 if CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID && CONFIG_MBEDTLS_SSL_PROTO_DTLS

**CONFIG_MBEDTLS_SSL_DTLS_SRTP**

Enable support for negotiation of DTLS-SRTP (RFC 5764)

*Found in: Component config > mbedTLS > mbedTLS v3.x related > DTLS-based configurations*

Enable support for negotiation of DTLS-SRTP (RFC 5764) through the use_srtp extension.

See mbedTLS documentation for required API and more details. Disabling this option will save some code size.

**Default value:**
* No (disabled) if CONFIG_MBEDTLS_SSL_PROTO_DTLS

**Certificate Bundle**  Contains:

* CONFIG_MBEDTLS_CERTIFICATE_BUNDLE

**CONFIG_MBEDTLS_CERTIFICATE_BUNDLE**

Enable trusted root certificate bundle

*Found in: Component config > mbedTLS > Certificate Bundle*

Enable support for large number of default root certificates

When enabled this option allows user to store default as well as customer specific root certificates in compressed format rather than storing full certificate. For the root certificates the public key and the subject name will be stored.

**Default value:**
* Yes (enabled)

**CONFIG_MBEDTLS_DEFAULT_CERTIFICATE_BUNDLE**

Default certificate bundle options

*Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE*

Available options:

* Use the full default certificate bundle (CONFIG_MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_FULL)
• Use only the most common certificates from the default bundles (CONFIG_MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_CMN)
  Use only the most common certificates from the default bundles, reducing the size with 50%, while still having around 99% coverage.
• Do not use the default certificate bundle (CONFIG_MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_NONE)

CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE
Add custom certificates to the default bundle

Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE

Default value:
  • No (disabled)

CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE_PATH
Custom certificate bundle path

Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE > CONFIG_MBEDTLS_CUSTOM_CERTIFICATE_BUNDLE

Name of the custom certificate directory or file. This path is evaluated relative to the project root directory.

CONFIG_MBEDTLS_CERTIFICATE_BUNDLE_MAX_CERTS
Maximum no of certificates allowed in certificate bundle

Found in: Component config > mbedTLS > Certificate Bundle > CONFIG_MBEDTLS_CERTIFICATE_BUNDLE

Default value:
  • 200

CONFIG_MBEDTLS_ECP_RESTARTABLE
Enable mbedTLS ecp restartable

Found in: Component config > mbedTLS

Enable “non-blocking” ECC operations that can return early and be resumed.

Default value:
  • No (disabled)

CONFIG_MBEDTLS_CMAC_C
Enable CMAC mode for block ciphers

Found in: Component config > mbedTLS

Enable the CMAC (Cipher-based Message Authentication Code) mode for block ciphers.

Default value:
  • No (disabled)
**CONFIG_MBEDTLS_HARDWARE_AES**

Enable hardware AES acceleration

*Found in: Component config > mbedTLS*

Enable hardware accelerated AES encryption & decryption.

Note that if the ESP32 CPU is running at 240MHz, hardware AES does not offer any speed boost over software AES.

**Default value:**
- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST

**CONFIG_MBEDTLS_HARDWARE_GCM**

Enable partially hardware accelerated GCM

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_HARDWARE_AES*

Enable partially hardware accelerated GCM. GHASH calculation is still done in software.

If MBEDTLS_HARDWARE_GCM is disabled and MBEDTLS_HARDWARE_AES is enabled then mbedTLS will still use the hardware accelerated AES block operation, but on a single block at a time.

**Default value:**
- Yes (enabled) if SOC_AES_SUPPORT_GCM && CONFIG_MBEDTLS_HARDWARE_AES

**CONFIG_MBEDTLS_HARDWARE_MPI**

Enable hardware MPI (bignum) acceleration

*Found in: Component config > mbedTLS*

Enable hardware accelerated multiple precision integer operations.

Hardware accelerated multiplication, modulo multiplication, and modular exponentiation for up to SOC_RSA_MAX_BIT_LEN bit results.

These operations are used by RSA.

**Default value:**
- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST

**CONFIG_MBEDTLS_HARDWARE_SHA**

Enable hardware SHA acceleration

*Found in: Component config > mbedTLS*

Enable hardware accelerated SHA1, SHA256, SHA384 & SHA512 in mbedTLS.

Due to a hardware limitation, on the ESP32 hardware acceleration is only guaranteed if SHA digests are calculated one at a time. If more than one SHA digest is calculated at the same time, one will be calculated fully in hardware and the rest will be calculated (at least partially calculated) in software. This happens automatically.

SHA hardware acceleration is faster than software in some situations but slower in others. You should benchmark to find the best setting for you.

**Default value:**
- Yes (enabled) if CONFIG_SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST
CONFIG_MBEDTLS_HARDWARE_ECC
Enable hardware ECC acceleration

*Found in: Component config > mbedTLS*
Enable hardware accelerated ECC point multiplication and point verification for points on curve SECP192R1 and SECP256R1 in mbedTLS

**Default value:**
- Yes (enabled) if SOC_ECC_SUPPORTED

CONFIG_MBEDTLS_ECC_OTHER_CURVES_SOFT_FALLBACK
Fallback to software implementation for curves not supported in hardware

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_HARDWARE_ECC*
Fallback to software implementation of ECC point multiplication and point verification for curves not supported in hardware.

**Default value:**
- Yes (enabled) if CONFIG_MBEDTLS_HARDWARE_ECC

CONFIG_MBEDTLS_ROM_MD5
Use MD5 implementation in ROM

*Found in: Component config > mbedTLS*
Use ROM MD5 in mbedTLS.

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_HARDWARE_ECDSA_SIGN
Enable ECDSA signing using on-chip ECDSA peripheral

*Found in: Component config > mbedTLS*
Enable hardware accelerated ECDSA peripheral to sign data on curve SECP192R1 and SECP256R1 in mbedTLS.

Note that for signing, the private key has to be burnt in an efuse key block with key purpose set to ECDSA_KEY. If no key is burnt, it will report an error.

The key should be burnt in little endian format. espfuse.py utility handles it internally but care needs to be taken while burning using esp_efuse APIs

**Default value:**
- No (disabled) if SOC_ECDSA_SUPPORTED

CONFIG_MBEDTLS_HARDWARE_ECDSA_VERIFY
Enable ECDSA signature verification using on-chip ECDSA peripheral

*Found in: Component config > mbedTLS*
Enable hardware accelerated ECDSA peripheral to verify signature on curve SECP192R1 and SECP256R1 in mbedTLS.

**Default value:**
- Yes (enabled) if SOC_ECDSA_SUPPORTED
CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN

Enable hardware ECDSA sign acceleration when using ATECC608A

Found in: Component config > mbedTLS

This option enables hardware acceleration for ECDSA sign function, only when using ATECC608A cryptoauth chip (integrated with ESP32-WROOM-32SE)

Default value:
- No (disabled)

CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY

Enable hardware ECDSA verify acceleration when using ATECC608A

Found in: Component config > mbedTLS

This option enables hardware acceleration for ECDSA sign function, only when using ATECC608A cryptoauth chip (integrated with ESP32-WROOM-32SE)

Default value:
- No (disabled)

CONFIG_MBEDTLS_HAVE_TIME

Enable mbedTLS time support

Found in: Component config > mbedTLS

Enable use of time.h functions (time() and gmtime()) by mbedTLS.

This option doesn’t require the system time to be correct, but enables functionality that requires relative timekeeping - for example periodic expiry of TLS session tickets or session cache entries.

Disabling this option will save some firmware size, particularly if the rest of the firmware doesn’t call any standard timekeeping functions.

Default value:
- Yes (enabled)

CONFIG_MBEDTLS_PLATFORM_TIME_ALT

Enable mbedTLS time support: platform-specific

Found in: Component config > mbedTLS > CONFIG_MBEDTLS_HAVE_TIME

Enabling this config will provide users with a function `mbedtls_platform_set_time()` that allows to set an alternative time function pointer.

Default value:
- No (disabled)

CONFIG_MBEDTLS_HAVE_TIME_DATE

Enable mbedTLS certificate expiry check

Found in: Component config > mbedTLS > CONFIG_MBEDTLS_HAVE_TIME

Enables X.509 certificate expiry checks in mbedTLS.

If this option is disabled (default) then X.509 certificate “valid from” and “valid to” timestamp fields are ignored.

If this option is enabled, these fields are compared with the current system date and time. The time is retrieved using the standard time() and gmtime() functions. If the certificate is not valid for the
current system time then verification will fail with code \texttt{MBEDTLS_X509\_BADCERT\_FUTURE} or \texttt{MBEDTLS_X509\_BADCERT\_EXPIRED}.

Enabling this option requires adding functionality in the firmware to set the system clock to a valid timestamp before using TLS. The recommended way to do this is via ESP-IDF’s SNTP functionality, but any method can be used.

In the case where only a small number of certificates are trusted by the device, please carefully consider the tradeoffs of enabling this option. There may be undesired consequences, for example if all trusted certificates expire while the device is offline and a TLS connection is required to update. Or if an issue with the SNTP server means that the system time is invalid for an extended period after a reset.

**Default value:**
- No (disabled)

\textbf{CONFIG\_MBEDTLS\_ECDSA\_DETERMINISTIC}

Enable deterministic ECDSA

*Found in: Component config > mbedTLS*

Standard ECDSA is “fragile” in the sense that lack of entropy when signing may result in a compromise of the long-term signing key.

**Default value:**
- Yes (enabled)

\textbf{CONFIG\_MBEDTLS\_SHA512\_C}

Enable the SHA-384 and SHA-512 cryptographic hash algorithms

*Found in: Component config > mbedTLS*

Enable MBEDTLS\_SHA512\_C adds support for SHA-384 and SHA-512.

**Default value:**
- Yes (enabled)

\textbf{CONFIG\_MBEDTLS\_TLS\_MODE}

TLS Protocol Role

*Found in: Component config > mbedTLS*

mbedTLS can be compiled with protocol support for the TLS server, TLS client, or both server and client.

Reducing the number of TLS roles supported saves code size.

Available options:

- Server & Client (CONFIG\_MBEDTLS\_TLS\_SERVER\_AND\_CLIENT)
- Server (CONFIG\_MBEDTLS\_TLS\_SERVER\_ONLY)
- Client (CONFIG\_MBEDTLS\_TLS\_CLIENT\_ONLY)
- None (CONFIG\_MBEDTLS\_TLS\_DISABLED)

\textbf{TLS Key Exchange Methods}  Contains:

- \texttt{CONFIG\_MBEDTLS\_KEY\_EXCHANGE\_DHE\_RSA}
- \texttt{CONFIG\_MBEDTLS\_KEY\_EXCHANGE\_EC\_PAKE}
- \texttt{CONFIG\_MBEDTLS\_PSK\_MODES}
- \texttt{CONFIG\_MBEDTLS\_KEY\_EXCHANGE\_RSA}
- \texttt{CONFIG\_MBEDTLS\_KEY\_EXCHANGE\_ELLIPTIC\_CURVE}
CONFIG_MBEDTLS_PSK_MODES

Enable pre-shared-key ciphersuites

*Found in: Component config > mbedTLS > TLS Key Exchange Methods*

Enable to show configuration for different types of pre-shared-key TLS authentication methods.
Leaving this option disabled will save code size if they are not used.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_KEY_EXCHANGE_PSK

Enable PSK based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_PSK_MODES*

Enable to support symmetric key PSK (pre-shared-key) TLS key exchange modes.

**Default value:**
- No (disabled) if CONFIG_MBEDTLS_PSK_MODES

CONFIG_MBEDTLS_KEY_EXCHANGE_DHE_PSK

Enable DHE-PSK based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_PSK_MODES*

Enable to support Diffie-Hellman PSK (pre-shared-key) TLS authentication modes.

**Default value:**
- Yes (enabled) if CONFIG_MBEDTLS_PSK_MODES && CONFIG_MBEDTLS_DHM_C

CONFIG_MBEDTLS_KEY_EXCHANGE_ECDHE_PSK

Enable ECDHE-PSK based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_PSK_MODES*

Enable to support Elliptic-Curve-Diffie-Hellman PSK (pre-shared-key) TLS authentication modes.

**Default value:**
- Yes (enabled) if CONFIG_MBEDTLS_PSK_MODES && CONFIG_MBEDTLS_ECDH_C

CONFIG_MBEDTLS_KEY_EXCHANGE_RSA_PSK

Enable RSA-PSK based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_PSK_MODES*

Enable to support RSA PSK (pre-shared-key) TLS authentication modes.

**Default value:**
- Yes (enabled) if CONFIG_MBEDTLS_PSK_MODES
CONFIG_MBEDTLS_KEY_EXCHANGE_RSA
Enable RSA-only based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods*

Enable to support ciphersuites with prefix TLS-RSA-WITH-

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_KEY_EXCHANGE_DHE_RSA
Enable DHE-RSA based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods*

Enable to support ciphersuites with prefix TLS-DHE-RSA-WITH-

**Default value:**
- Yes (enabled) if CONFIG_MBEDTLS_DHМ_C

CONFIG_MBEDTLS_KEY_EXCHANGE_ELLIPTIC_CURVE
Support Elliptic Curve based ciphersuites

*Found in: Component config > mbedTLS > TLS Key Exchange Methods*

Enable to show Elliptic Curve based ciphersuite mode options.

Disabling all Elliptic Curve ciphersuites saves code size and can give slightly faster TLS handshakes, provided the server supports RSA-only ciphersuite modes.

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_KEY_EXCHANGE_ECDHE_RSA
Enable ECDHE-RSA based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_KEY_EXCHANGE_ELLIPTIC_CURVE*

Enable to support ciphersuites with prefix TLS-ECDHE-RSA-WITH-

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_KEY_EXCHANGE_ECDHE_ECDSA
Enable ECDHE-ECDSA based ciphersuite modes

*Found in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_KEY_EXCHANGE_ELLIPTIC_CURVE*

Enable to support ciphersuites with prefix TLS-ECDHE-RSA-WITH-

**Default value:**
- Yes (enabled)
CONFIG_MBEDTLS_KEY_EXCHANGE_ECDH_ECDSA
Enable ECDH-ECDSA based ciphersuite modes

FOUND in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_KEY_EXCHANGE_ELLIPTIC_CURVE
Enable to support ciphersuites with prefix TLS-ECDHE-RSA-WITH-

Default value:
• Yes (enabled)

CONFIG_MBEDTLS_KEY_EXCHANGE_ECDH_RSA
Enable ECDH-RSA based ciphersuite modes

FOUND in: Component config > mbedTLS > TLS Key Exchange Methods > CONFIG_MBEDTLS_KEY_EXCHANGE_ELLIPTIC_CURVE
Enable to support ciphersuites with prefix TLS-ECDHE-RSA-WITH-

Default value:
• Yes (enabled)

CONFIG_MBEDTLS_KEY_EXCHANGE_ECJPAKE
Enable ECJPAKE based ciphersuite modes

FOUND in: Component config > mbedTLS > TLS Key Exchange Methods
Enable to support ciphersuites with prefix TLS-ECJPAKE-WITH-

Default value:
• No (disabled) if CONFIG_MBEDTLS_ECJPAKE_C && CONFIG_MBEDTLS_ECP_DP_SECP256R1_ENABLED

CONFIG_MBEDTLS_SSL_RENEGOTIATION
Support TLS renegotiation

FOUND in: Component config > mbedTLS
The two main uses of renegotiation are (1) refresh keys on long-lived connections and (2) client authentication after the initial handshake. If you don’t need renegotiation, disabling it will save code size and reduce the possibility of abuse/vulnerability.

Default value:
• Yes (enabled)

CONFIG_MBEDTLS_SSL_PROTO_TLS1_2
Support TLS 1.2 protocol

FOUND in: Component config > mbedTLS

Default value:
• Yes (enabled)

CONFIG_MBEDTLS_SSL_PROTO_GMTSSL1_1
Support GM/T SSL 1.1 protocol

FOUND in: Component config > mbedTLS
Provisions for GM/T SSL 1.1 support
Default value:
  • No (disabled)

**CONFIG_MBEDTLS_SSL_PROTO_DTLS**
Support DTLS protocol (all versions)

*Found in: Component config > mbedTLS*
Requires TLS 1.2 to be enabled for DTLS 1.2

**Default value:**
  • No (disabled)

**CONFIG_MBEDTLS_SSL_ALPN**
Support ALPN (Application Layer Protocol Negotiation)

*Found in: Component config > mbedTLS*
Disabling this option will save some code size if it is not needed.

**Default value:**
  • Yes (enabled)

**CONFIG_MBEDTLS_CLIENT_SSL_SESSION_TICKETS**
TLS: Client Support for RFC 5077 SSL session tickets

*Found in: Component config > mbedTLS*
Client support for RFC 5077 session tickets. See mbedTLS documentation for more details. Disabling this option will save some code size.

**Default value:**
  • Yes (enabled)

**CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS**
TLS: Server Support for RFC 5077 SSL session tickets

*Found in: Component config > mbedTLS*
Server support for RFC 5077 session tickets. See mbedTLS documentation for more details. Disabling this option will save some code size.

**Default value:**
  • Yes (enabled)

**Symmetric Ciphers**
Contains:

- **CONFIG_MBEDTLS_AES_C**
- **CONFIG_MBEDTLS_BLOWFISH_C**
- **CONFIG_MBEDTLS_CAMELLIA_C**
- **CONFIG_MBEDTLS_CCM_C**
- **CONFIG_MBEDTLS_DES_C**
- **CONFIG_MBEDTLS_GCM_C**
- **CONFIG_MBEDTLS_NIST_KW_C**
- **CONFIG_MBEDTLS_XTEA_C**
### CONFIG_MBEDTLS_AES_C

AES block cipher

*Found in: Component config > mbedTLS > Symmetric Ciphers*

**Default value:**
- Yes (enabled)

### CONFIG_MBEDTLS_CAMELLIA_C

Camellia block cipher

*Found in: Component config > mbedTLS > Symmetric Ciphers*

**Default value:**
- No (disabled)

### CONFIG_MBEDTLS_DES_C

DES block cipher (legacy, insecure)

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enables the DES block cipher to support 3DES-based TLS ciphersuites.

3DES is vulnerable to the Sweet32 attack and should only be enabled if absolutely necessary.

**Default value:**
- No (disabled)

### CONFIG_MBEDTLS_BLOWFISH_C

Blowfish block cipher (read help)

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enables the Blowfish block cipher (not used for TLS sessions.)

The Blowfish cipher is not used for mbedTLS TLS sessions but can be used for other purposes. Read up on the limitations of Blowfish (including Sweet32) before enabling.

**Default value:**
- No (disabled)

### CONFIG_MBEDTLS_XTEA_C

XTEA block cipher

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enables the XTEA block cipher.

**Default value:**
- No (disabled)

### CONFIG_MBEDTLS_CCM_C

CCM (Counter with CBC-MAC) block cipher modes

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enable Counter with CBC-MAC (CCM) modes for AES and/or Camellia ciphers.

Disabling this option saves some code size.

**Default value:**
• Yes (enabled)

**CONFIG_MBEDTLS_GCM_C**
GCM (Galois/Counter) block cipher modes

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enable Galois/Counter Mode for AES and/or Camellia ciphers.
This option is generally faster than CCM.

**Default value:**
• Yes (enabled)

**CONFIG_MBEDTLS_NIST_KW_C**
NIST key wrapping (KW) and KW padding (KWP)

*Found in: Component config > mbedTLS > Symmetric Ciphers*

Enable NIST key wrapping and key wrapping padding.

**Default value:**
• No (disabled)

**CONFIG_MBEDTLS_RIPEMD160_C**
Enable RIPEMD-160 hash algorithm

*Found in: Component config > mbedTLS*

Enable the RIPEMD-160 hash algorithm.

**Default value:**
• No (disabled)

**Certificates** Contains:

• **CONFIG_MBEDTLS_PEM_PARSE_C**
• **CONFIG_MBEDTLS_PEM_WRITE_C**
• **CONFIG_MBEDTLS_X509_CRL_PARSE_C**
• **CONFIG_MBEDTLS_X509_CSR_PARSE_C**

**CONFIG_MBEDTLS_PEM_PARSE_C**
Read & Parse PEM formatted certificates

*Found in: Component config > mbedTLS > Certificates*

Enable decoding/parsing of PEM formatted certificates.
If your certificates are all in the simpler DER format, disabling this option will save some code size.

**Default value:**
• Yes (enabled)

**CONFIG_MBEDTLS_PEM_WRITE_C**
Write PEM formatted certificates

*Found in: Component config > mbedTLS > Certificates*

Enable writing of PEM formatted certificates.
If writing certificate data only in DER format, disabling this option will save some code size.
Default value:
- Yes (enabled)

**CONFIG_MBEDTLS_X509_CRL_PARSE_C**

X.509 CRL parsing

*Found in: Component config > mbedTLS > Certificates*


Default value:
- Yes (enabled)

**CONFIG_MBEDTLS_X509_CSR_PARSE_C**

X.509 CSR parsing

*Found in: Component config > mbedTLS > Certificates*

Support for parsing X.509 Certificate Signing Requests

Default value:
- Yes (enabled)

**CONFIG_MBEDTLS_ECP_C**

Elliptic Curve Ciphers

*Found in: Component config > mbedTLS*

Default value:
- Yes (enabled)

**CONFIG_MBEDTLS_DHM_C**

Diffie-Hellman-Merkle key exchange (DHM)

*Found in: Component config > mbedTLS*

Enable DHM. Needed to use DHE-xxx TLS ciphersuites.

Note that the security of Diffie-Hellman key exchanges depends on a suitable prime being used for the exchange. Please see detailed warning text about this in file `mbedtls/dhm.h` file.

Default value:
- No (disabled)

**CONFIG_MBEDTLS_ECDH_C**

Elliptic Curve Diffie-Hellman (ECDH)

*Found in: Component config > mbedTLS*

Enable ECDH. Needed to use ECDHE-xxx TLS ciphersuites.

Default value:
- Yes (enabled)
CONFIG_MBEDTLS_ECDSA_C
Elliptic Curve DSA
*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_ECDH_C*
Enable ECDSA. Needed to use ECDSA-xxx TLS ciphersuites.
**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_ECJPAKE_C
Elliptic curve J-PAKE
*Found in: Component config > mbedTLS*
Enable ECJPAKE. Needed to use ECJPAKE-xxx TLS ciphersuites.
**Default value:**
- No (disabled)

CONFIG_MBEDTLS_ECP_DP_SECP192R1_ENABLED
Enable SECP192R1 curve
*Found in: Component config > mbedTLS*
Enable support for SECP192R1 Elliptic Curve.
**Default value:**
- Yes (enabled) if 
  
  (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_SECP224R1_ENABLED
Enable SECP224R1 curve
*Found in: Component config > mbedTLS*
Enable support for SECP224R1 Elliptic Curve.
**Default value:**
- Yes (enabled) if 
  
  (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_SECP256R1_ENABLED
Enable SECP256R1 curve
*Found in: Component config > mbedTLS*
Enable support for SECP256R1 Elliptic Curve.
**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_ECP_DP_SECP384R1_ENABLED
Enable SECP384R1 curve
*Found in: Component config > mbedTLS*
Enable support for SECP384R1 Elliptic Curve.
**Default value:**

• Yes (enabled) if \((\text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_SIGN} \lor \text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_VERIFY}) \land \text{CONFIG\_MBEDTLS\_ECP\_C})\)

**CONFIG\_MBEDTLS\_ECP\_DP\_SECP521R1\_ENABLED**

Enable SECP521R1 curve

Found in: Component config > mbedTLS

Enable support for SECP521R1 Elliptic Curve.

Default value:

• Yes (enabled) if \((\text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_SIGN} \lor \text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_VERIFY}) \land \text{CONFIG\_MBEDTLS\_ECP\_C})\)

**CONFIG\_MBEDTLS\_ECP\_DP\_SECP192K1\_ENABLED**

Enable SECP192K1 curve

Found in: Component config > mbedTLS

Enable support for SECP192K1 Elliptic Curve.

Default value:

• Yes (enabled) if \((\text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_SIGN} \lor \text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_VERIFY}) \land \text{CONFIG\_MBEDTLS\_ECP\_C})\)

**CONFIG\_MBEDTLS\_ECP\_DP\_SECP224K1\_ENABLED**

Enable SECP224K1 curve

Found in: Component config > mbedTLS

Enable support for SECP224K1 Elliptic Curve.

Default value:

• Yes (enabled) if \((\text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_SIGN} \lor \text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_VERIFY}) \land \text{CONFIG\_MBEDTLS\_ECP\_C})\)

**CONFIG\_MBEDTLS\_ECP\_DP\_SECP256K1\_ENABLED**

Enable SECP256K1 curve

Found in: Component config > mbedTLS

Enable support for SECP256K1 Elliptic Curve.

Default value:

• Yes (enabled) if \((\text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_SIGN} \lor \text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_VERIFY}) \land \text{CONFIG\_MBEDTLS\_ECP\_C})\)

**CONFIG\_MBEDTLS\_ECP\_DP\_BP256R1\_ENABLED**

Enable BP256R1 curve

Found in: Component config > mbedTLS

Enable support for DP Elliptic Curve.

Default value:

• Yes (enabled) if \((\text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_SIGN} \lor \text{CONFIG\_MBEDTLS\_ATCA\_HW\_ECDSA\_VERIFY}) \land \text{CONFIG\_MBEDTLS\_ECP\_C})\)
Chapter 2. API Reference

CONFIG_MBEDTLS_ECP_DP_BP384R1_ENABLED
Enable BP384R1 curve

*Found in: Component config > mbedTLS*

support for DP Elliptic Curve.

**Default value:**
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_BP512R1_ENABLED
Enable BP512R1 curve

*Found in: Component config > mbedTLS*

support for DP Elliptic Curve.

**Default value:**
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_CURVE25519_ENABLED
Enable CURVE25519 curve

*Found in: Component config > mbedTLS*

Enable support for CURVE25519 Elliptic Curve.

**Default value:**
- Yes (enabled) if (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_NIST_OPTIM
NIST ‘modulo p’ optimisations

*Found in: Component config > mbedTLS*

NIST ‘modulo p’ optimisations increase Elliptic Curve operation performance.

Disabling this option saves some code size.

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_ECP_FIXED_POINT_OPTIM
Enable fixed-point multiplication optimisations

*Found in: Component config > mbedTLS*

This configuration option enables optimizations to speedup (about 3 ~ 4 times) the ECP fixed point multiplication using pre-computed tables in the flash memory. Disabling this configuration option saves flash footprint (about 29KB if all Elliptic Curve selected) in the application binary.

# end of Elliptic Curve options

**Default value:**
- Yes (enabled)
CONFIG_MBEDTLS_POLY1305_C
Poly1305 MAC algorithm

*Found in: Component config > mbedTLS*
Enable support for Poly1305 MAC algorithm.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_CHACHA20_C
Chacha20 stream cipher

*Found in: Component config > mbedTLS*
Enable support for Chacha20 stream cipher.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_CHACHAPOLY_C
Chacha20-Poly1305 AEAD algorithm

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_CHACHA20_C*
Enable support for Chacha20-Poly1305 AEAD algorithm.

**Default value:**
- No (disabled) if CONFIG_MBEDTLS_CHACHA20_C && CONFIG_MBEDTLS_POLY1305_C

CONFIG_MBEDTLS_HKDF_C
HKDF algorithm (RFC 5869)

*Found in: Component config > mbedTLS*
Enable support for the Hashed Message Authentication Code (HMAC)-based key derivation function (HKDF).

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_THREADING_C
Enable the threading abstraction layer

*Found in: Component config > mbedTLS*
If you do intend to use contexts between threads, you will need to enable this layer to prevent race conditions.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_THREADING_ALT
Enable threading alternate implementation

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_THREADING_C*
Enable threading alt to allow your own alternate threading implementation.

**Default value:**
Chapter 2. API Reference

- Yes (enabled) if CONFIG_MBEDTLS_THREADING_C

**CONFIG_MBEDTLS_THREADING_PTHREAD**
Enable threading pthread implementation

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_THREADING_C*

Enable the pthread wrapper layer for the threading layer.

**Default value:**
- No (disabled) if CONFIG_MBEDTLS_THREADING_C

**CONFIG_MBEDTLS_LARGE_KEY_SOFTWARE_MPI**
Fallback to software implementation for larger MPI values

*Found in: Component config > mbedTLS*

Fallback to software implementation for RSA key lengths larger than SOC_RSA_MAX_BIT_LEN. If this is not active then the ESP will be unable to process keys greater than SOC_RSA_MAX_BIT_LEN.

**Default value:**
- No (disabled)

**ESP-MQTT Configurations**   Contains:
- CONFIG_MQTT_CUSTOM_OUTBOX
- CONFIG_MQTT_TRANSPORT_SSL
- CONFIG_MQTT_TRANSPORT_WEBSOCKET
- CONFIG_MQTT_PROTOCOL_311
- CONFIG_MQTT_PROTOCOL_5
- CONFIG_MQTT_TASK_CORE_SELECTION_ENABLED
- CONFIG_MQTT_USE_CUSTOM_CONFIG
- CONFIG_MQTT_OUTBOX_EXPIRED_TIMEOUT_MS
- CONFIG_MQTT_REPORT_DELETED_MESSAGES
- CONFIG_MQTT_SKIP_PUBLISH_IF_DISCONNECTED
- CONFIG_MQTT_OUTBOX_DATA_ON_EXTERNAL_MEMORY
- CONFIG_MQTT_MSG_ID_INCREMENTAL

**CONFIG_MQTT_PROTOCOL_311**
Enable MQTT protocol 3.1.1

*Found in: Component config > ESP-MQTT Configurations*

If not, this library will use MQTT protocol 3.1

**Default value:**
- Yes (enabled)

**CONFIG_MQTT_PROTOCOL_5**
Enable MQTT protocol 5.0

*Found in: Component config > ESP-MQTT Configurations*

If not, this library will not support MQTT 5.0

**Default value:**
- No (disabled)
**CONFIG_MQTT_TRANSPORT_SSL**

Enable MQTT over SSL

*Found in: Component config > ESP-MQTT Configurations*

Enable MQTT transport over SSL with mbedtls

**Default value:**
- Yes (enabled)

**CONFIG_MQTT_TRANSPORT_WEBSOCKET**

Enable MQTT over Websocket

*Found in: Component config > ESP-MQTT Configurations*

Enable MQTT transport over Websocket.

**Default value:**
- Yes (enabled)

**CONFIG_MQTT_TRANSPORT_WEBSOCKET_SECURE**

Enable MQTT over Websocket Secure

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_TRANSPORT_WEBSOCKET*

Enable MQTT transport over Websocket Secure.

**Default value:**
- Yes (enabled)

**CONFIG_MQTT_MSG_ID_INCREMENTAL**

Use Incremental Message Id

*Found in: Component config > ESP-MQTT Configurations*

Set this to true for the message id (2.3.1 Packet Identifier) to be generated as an incremental number rather then a random value (used by default)

**Default value:**
- No (disabled)

**CONFIG_MQTT_SKIP_PUBLISH_IF_DISCONNECTED**

Skip publish if disconnected

*Found in: Component config > ESP-MQTT Configurations*

Set this to true to avoid publishing (enqueueing messages) if the client is disconnected. The MQTT client tries to publish all messages by default, even in the disconnected state (where the qos1 and qos2 packets are stored in the internal outbox to be published later) The MQTT_SKIP_PUBLISH_IF_DISCONNECTED option allows applications to override this behaviour and not enqueue publish packets in the disconnected state.

**Default value:**
- No (disabled)
CONFIG_MQTT_REPORT_DELETED_MESSAGES

Report deleted messages

*Found in: Component config > ESP-MQTT Configurations*

Set this to true to post events for all messages which were deleted from the outbox before being correctly sent and confirmed.

**Default value:**
- No (disabled)

CONFIG_MQTT_USE_CUSTOM_CONFIG

MQTT Using custom configurations

*Found in: Component config > ESP-MQTT Configurations*

Custom MQTT configurations.

**Default value:**
- No (disabled)

CONFIG_MQTT_TCP_DEFAULT_PORT

Default MQTT over TCP port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over TCP port

**Default value:**
- 1883 if CONFIG_MQTT_USE_CUSTOM_CONFIG

CONFIG_MQTT_SSL_DEFAULT_PORT

Default MQTT over SSL port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over SSL port

**Default value:**
- 8883 if CONFIG_MQTT_USE_CUSTOM_CONFIG && CONFIG_MQTT_TRANSPORT_SSL

CONFIG_MQTT_WS_DEFAULT_PORT

Default MQTT over Websocket port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over Websocket port

**Default value:**
- 80 if CONFIG_MQTT_USE_CUSTOM_CONFIG && CONFIG_MQTT_TRANSPORT_WEBSOCKET

CONFIG_MQTT_WSS_DEFAULT_PORT

Default MQTT over Websocket Secure port

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default MQTT over Websocket Secure port

**Default value:**
CONFIG_MQTT_BUFFER_SIZE

Default MQTT Buffer Size

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

This buffer size is used for both transmit and receive.

**Default value:**
- 1024 if `CONFIG_MQTT_USE_CUSTOM_CONFIG`

CONFIG_MQTT_TASK_STACK_SIZE

MQTT task stack size

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default value:
- 6144 if `CONFIG_MQTT_USE_CUSTOM_CONFIG`

CONFIG_MQTT_DISABLE_API_LOCKS

Disable API locks

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default config employs API locks to protect internal structures. It is possible to disable these locks if the user code doesn’t access MQTT API from multiple concurrent tasks.

**Default value:**
- No (disabled) if `CONFIG_MQTT_USE_CUSTOM_CONFIG`

CONFIG_MQTT_TASK_PRIORITY

MQTT task priority

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Default value:
- 5 if `CONFIG_MQTT_USE_CUSTOM_CONFIG`

CONFIG_MQTT_POLL_READ_TIMEOUT_MS

MQTT transport poll read timeout

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

Timeout when polling underlying transport for read.

**Default value:**
- 1000 if `CONFIG_MQTT_USE_CUSTOM_CONFIG`
CONFIG_MQTT_EVENT_QUEUE_SIZE

Number of queued events.

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

A value higher than 1 enables multiple queued events.

**Default value:**
- 1 if CONFIG_MQTT_USE_CUSTOM_CONFIG

CONFIG_MQTT_TASK_CORE_SELECTION_ENABLED

Enable MQTT task core selection

*Found in: Component config > ESP-MQTT Configurations*

This will enable core selection

CONFIG_MQTT_TASK_CORE_SELECTION

Core to use?

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_TASK_CORE_SELECTION_ENABLED*

Available options:

- Core 0 (CONFIG_MQTT_USE_CORE_0)
- Core 1 (CONFIG_MQTT_USE_CORE_1)

CONFIG_MQTT_OUTBOX_DATA_ON_EXTERNAL_MEMORY

Use external memory for outbox data

*Found in: Component config > ESP-MQTT Configurations*

Set to true to use external memory for outbox data.

**Default value:**
- No (disabled) if CONFIG_MQTT_USE_CUSTOM_CONFIG

CONFIG_MQTT_CUSTOM_OUTBOX

Enable custom outbox implementation

*Found in: Component config > ESP-MQTT Configurations*

Set to true if a specific implementation of message outbox is needed (e.g. persistent outbox in NVM or similar). Note: Implementation of the custom outbox must be added to the mqtt component. These CMake commands could be used to append the custom implementation to lib-mqtt sources: `idf_component_get_property(mqtt mqtt COMPONENT_LIB) set_property(TARGET ${mqtt} PROPERTY SOURCES ${PROJECT_DIR}/custom_outbox.c APPEND)`

**Default value:**
- No (disabled)

CONFIG_MQTT_OUTBOX_EXPIRED_TIMEOUT_MS

Outbox message expired timeout[ms]

*Found in: Component config > ESP-MQTT Configurations*

Messages which stays in the outbox longer than this value before being published will be discarded.
Default value:
- 30000 if `CONFIG_MQTT_USE_CUSTOM_CONFIG`

**Newlib** Contains:
- `CONFIG_NEWLIB_NANO_FORMAT`
- `CONFIG_NEWLIB_STDIN_LINE_ENDING`
- `CONFIG_NEWLIB_STDOUT_LINE_ENDING`
- `CONFIG_NEWLIB_TIME_SYSCALL`

**CONFIG_NEWLIB_STDOUT_LINE_ENDING**
Line ending for UART output

*Found in: Component config > Newlib*

This option allows configuring the desired line endings sent to UART when a newline (\n, LF) appears on stdout. Three options are possible:

- **CRLF**: whenever LF is encountered, prepend it with CR
- **LF**: no modification is applied, stdout is sent as is
- **CR**: each occurrence of LF is replaced with CR

This option doesn’t affect behavior of the UART driver (drivers/uart.h).

Available options:
- CRLF (`CONFIG_NEWLIB_STDOUT_LINE_ENDING_CRLF`)
- LF (`CONFIG_NEWLIB_STDOUT_LINE_ENDING_LF`)
- CR (`CONFIG_NEWLIB_STDOUT_LINE_ENDING_CR`)

**CONFIG_NEWLIB_STDIN_LINE_ENDING**
Line ending for UART input

*Found in: Component config > Newlib*

This option allows configuring which input sequence on UART produces a newline (\n, LF) on stdin. Three options are possible:

- **CRLF**: CRLF is converted to LF
- **LF**: no modification is applied, input is sent to stdin as is
- **CR**: each occurrence of CR is replaced with LF

This option doesn’t affect behavior of the UART driver (drivers/uart.h).

Available options:
- CRLF (`CONFIG_NEWLIB_STDIN_LINE_ENDING_CRLF`)
- LF (`CONFIG_NEWLIB_STDIN_LINE_ENDING_LF`)
- CR (`CONFIG_NEWLIB_STDIN_LINE_ENDING_CR`)

**CONFIG_NEWLIB_NANO_FORMAT**

Enable ‘nano’ formatting options for printf/scanf family

*Found in: Component config > Newlib*
In most chips the ROM contains parts of newlib C library, including printf/scanf family of functions. These functions have been compiled with so-called “nano” formatting option. This option doesn’t support 64-bit integer formats and C99 features, such as positional arguments.

For more details about “nano” formatting option, please see newlib readme file, search for ‘-enable-newlib-nano-formatted-io’ : https://sourceware.org/newlib/README

If this option is enabled and the ROM contains functions from newlib-nano, the build system will use functions available in ROM, reducing the application binary size. Functions available in ROM run faster than functions which run from flash. Functions available in ROM can also run when flash instruction cache is disabled.

Some chips (e.g. ESP32-C6) has the full formatting versions of printf/scanf in ROM instead of the nano versions and in this building with newlib nano might actually increase the size of the binary. Which functions are present in ROM can be seen from ROM caps: ESP_ROM_HAS_NEWLIB_NANO_FORMAT and ESP_ROM_HAS_NEWLIB_NORMAL_FORMAT.

If you need 64-bit integer formatting support or C99 features, keep this option disabled.

**CONFIG_NEWLIB_TIME_SYSCALL**

Timers used for gettimeofday function

*Found in: Component config > Newlib*

This setting defines which hardware timers are used to implement ‘gettimeofday’ and ‘time’ functions in C library.

- **If both high-resolution (systimer for all targets except ESP32) and RTC timers are used,** timekeeping will continue in deep sleep. Time will be reported at 1 microsecond resolution. This is the default, and the recommended option.
- **If only high-resolution timer (systimer) is used, gettimeofday will** provide time at microsecond resolution. Time will not be preserved when going into deep sleep mode.
- **If only RTC timer is used, timekeeping will continue in** deep sleep, but time will be measured at 6.6 microseconds resolution. Also the gettimeofday function itself may take longer to run.
- **If no timers are used, gettimeofday and time functions** return -1 and set errno to ENOSYS.
- **When RTC is used for timekeeping, two RTC_STORE registers are** used to keep time in deep sleep mode.

Available options:

- RTC and high-resolution timer (CONFIG_NEWLIB_TIME_SYSCALL_USE_RTC_HRT)
- RTC (CONFIG_NEWLIB_TIME_SYSCALL_USE_RTC)
- High-resolution timer (CONFIG_NEWLIB_TIME_SYSCALL_USE_HRT)
- None (CONFIG_NEWLIB_TIME_SYSCALL_USE_NONE)

**NVS**

Contains:

- **CONFIG_NVS_ENCRYPTION**
- **CONFIG_NVS_COMPATIBLE_PRE_V4_3_ENCRYPTION_FLAG**
- **CONFIG_NVS_ASSERT_ERROR_CHECK**

**CONFIG_NEWLIB_ENCRYPTION**

Enable NVS encryption

*Found in: Component config > NVS*

This option enables encryption for NVS. When enabled, AES-XTS is used to encrypt the complete NVS data, except the page headers. It requires XTS encryption keys to be stored in an encrypted partition. This means enabling flash encryption is a pre-requisite for this feature.
Default value:
• Yes (enabled) if `CONFIG_SECURE_FLASH_ENC_ENABLED`

**CONFIG_NVS_COMPATIBLE_PRE_V4_3_ENCRYPTION_FLAG**

NVS partition encrypted flag compatible with ESP-IDF before v4.3

*Found in: Component config > NVS*

Enabling this will ignore “encrypted” flag for NVS partitions. NVS encryption scheme is different than hardware flash encryption and hence it is not recommended to have “encrypted” flag for NVS partitions. This was not being checked in pre v4.3 IDF. Hence, if you have any devices where this flag is kept enabled in partition table then enabling this config will allow to have same behavior as pre v4.3 IDF.

**CONFIG_NVS_ASSERT_ERROR_CHECK**

Use assertions for error checking

*Found in: Component config > NVS*

This option switches error checking type between assertions (y) or return codes (n).

Default value:
• No (disabled)

**OpenThread**

Contains:

• `CONFIG_OPENTHREAD_PLATFORM_MSGPOOL_MANAGEMENT`
• `CONFIG_OPENTHREAD_DEVICE_TYPE`
• `CONFIG_OPENTHREAD_RADIO_TYPE`
• `CONFIG_OPENTHREAD_BORDER_ROUTER`
• `CONFIG_OPENTHREAD_COMMISSIONER`
• `CONFIG_OPENTHREAD_CSL_DEBUG_ENABLE`
• `CONFIG_OPENTHREAD_CSL_ENABLE`
• `CONFIG_OPENTHREAD_DIAG`
• `CONFIG_OPENTHREAD_DNS_CLIENT`
• `CONFIG_OPENTHREAD_DUA_ENABLE`
• `CONFIG_OPENTHREAD_JOINER`
• `CONFIG_OPENTHREAD_LINK_METRICS`
• `CONFIG_OPENTHREAD_MACFILTER_ENABLE`
• `CONFIG_OPENTHREAD_CLI`
• `CONFIG_OPENTHREAD_SRPN_CLIENT`
• `CONFIG_OPENTHREAD_TIME_SYNC`
• `CONFIG_OPENTHREAD_ENABLED`
• `CONFIG_OPENTHREAD_XTAL_ACCURACY`
• `CONFIG_OPENTHREAD_CSL_UNCERTAIN`
• `CONFIG_OPENTHREAD_CSL_ACCURACY`
• `CONFIG_OPENTHREAD_NUM_MESSAGE_BUFFERS`
• `CONFIG_OPENTHREAD_RCP_TRANSPORT`
• `CONFIG_OPENTHREAD_MLE_MAX_CHILDREN`
• `CONFIG_OPENTHREAD_TMF_ADDR_CACHE_ENTRIES`
• `CONFIG_OPENTHREAD_SPINEL_RX_FRAME_BUFFER_SIZE`
• `CONFIG_OPENTHREAD_UART_BUFFER_SIZE`
• Thread Operational Dataset
• `CONFIG_OPENTHREAD_DNS64_CLIENT`

**CONFIG_OPENTHREAD_ENABLED**
OpenThread

*Found in: Component config > OpenThread*

Select this option to enable OpenThread and show the submenu with OpenThread configuration choices.

**Default value:**
- No (disabled)

**CONFIG_OPENTHREAD_LOG_LEVEL_DYNAMIC**

Enable dynamic log level control

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

Select this option to enable dynamic log level control for OpenThread

**Default value:**
- Yes (enabled) if CONFIG_OPENTHREAD_ENABLED

**CONFIG_OPENTHREAD_CONSOLE_TYPE**

OpenThread console type

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

Select OpenThread console type

Available options:

- OpenThread console type UART (CONFIG_OPENTHREAD_CONSOLE_TYPE_UART)
- OpenThread console type USB Serial/JTAG Controller (CONFIG_OPENTHREAD_CONSOLE_TYPE_USB_SERIAL_JTAG)

**CONFIG_OPENTHREAD_LOG_LEVEL**

OpenThread log verbosity

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

Select OpenThread log level.

Available options:

- No logs (CONFIG_OPENTHREAD_LOG_LEVEL_NONE)
- Error logs (CONFIG_OPENTHREAD_LOG_LEVEL_CRIT)
- Warning logs (CONFIG_OPENTHREAD_LOG_LEVEL_WARN)
- Notice logs (CONFIG_OPENTHREAD_LOG_LEVEL_NOTE)
- Info logs (CONFIG_OPENTHREAD_LOG_LEVEL_INFO)
- Debug logs (CONFIG_OPENTHREAD_LOG_LEVEL_DEBG)

**Thread Operational Dataset**

Contains:

- `CONFIG_OPENTHREAD_NETWORK_EXTPANID`
- `CONFIG_OPENTHREAD_MESH_LOCAL_PREFIX`
- `CONFIG_OPENTHREAD_NETWORK_CHANNEL`
- `CONFIG_OPENTHREAD_NETWORK_MASTERKEY`
- `CONFIG_OPENTHREAD_NETWORK_NAME`
- `CONFIG_OPENTHREAD_NETWORK_PANID`
- `CONFIG_OPENTHREAD_NETWORK_PSKC`
CONFIG_OPENTHREAD_NETWORK_NAME

OpenThread network name

*Found in:* Component config > OpenThread > Thread Operational Dataset

**Default value:**
- “OpenThread-ESP”

CONFIG_OPENTHREAD_MESH_LOCAL_PREFIX

OpenThread mesh local prefix, format `<address>/<plen>`

*Found in:* Component config > OpenThread > Thread Operational Dataset

A string in the format “`<address>/<plen>`”, where `<address>` is an IPv6 address and `<plen>` is a prefix length. For example “fd00:db8:a0:0::/64”

**Default value:**
- “fd00:db8:a0:0::/64”

CONFIG_OPENTHREAD_NETWORK_CHANNEL

OpenThread network channel

*Found in:* Component config > OpenThread > Thread Operational Dataset

**Range:**
- from 11 to 26

**Default value:**
- 15

CONFIG_OPENTHREAD_NETWORK_PANID

OpenThread network pan id

*Found in:* Component config > OpenThread > Thread Operational Dataset

**Range:**
- from 0 to 0xFFFFE

**Default value:**
- “0x1234”

CONFIG_OPENTHREAD_NETWORK_EXTPANID

OpenThread extended pan id

*Found in:* Component config > OpenThread > Thread Operational Dataset

The OpenThread network extended pan id in hex string format

**Default value:**
- dead00beef00cafe

CONFIG_OPENTHREAD_NETWORK_MASTERKEY

OpenThread network key

*Found in:* Component config > OpenThread > Thread Operational Dataset

The OpenThread network network key in hex string format

**Default value:**
- 00112233445566778899aabbccddeeff
CONFIG_OPENTHREAD_NETWORK_PSKC

OpenThread pre-shared commissioner key

*Found in: Component config > OpenThread > Thread Operational Dataset*

The OpenThread pre-shared commissioner key in hex string format

*Default value:

- 104810e2315100afd6be9215a6bfac53*

CONFIG_OPENTHREAD_RADIO_TYPE

Config the Thread radio type

*Found in: Component config > OpenThread*

Configure how OpenThread connects to the 15.4 radio

Available options:

- Native 15.4 radio (CONFIG_OPENTHREAD_RADIO_NATIVE)
  Select this to use the native 15.4 radio.
- Connect via UART (CONFIG_OPENTHREAD_RADIO_SPINEL_UART)
  Select this to connect to a Radio Co-Processor via UART.
- Connect via SPI (CONFIG_OPENTHREAD_RADIO_SPINEL_SPI)
  Select this to connect to a Radio Co-Processor via SPI.

CONFIG_OPENTHREAD_DEVICE_TYPE

Config the Thread device type

*Found in: Component config > OpenThread*

OpenThread can be configured to different device types (FTD, MTD, Radio)

Available options:

- Full Thread Device (CONFIG_OPENTHREAD_FTD)
  Select this to enable Full Thread Device which can act as router and leader in a Thread network.
- Minimal Thread Device (CONFIG_OPENTHREAD_MTD)
  Select this to enable Minimal Thread Device which can only act as end device in a Thread network. This will reduce the code size of the OpenThread stack.
- Radio Only Device (CONFIG_OPENTHREAD_RADIO)
  Select this to enable Radio Only Device which can only forward 15.4 packets to the host. The OpenThread stack will be run on the host and OpenThread will have minimal footprint on the radio only device.

CONFIG_OPENTHREAD_RCP_TRANSPORT

The RCP transport type

*Found in: Component config > OpenThread*

Available options:

- UART RCP (CONFIG_OPENTHREAD_RCP_UART)
  Select this to enable UART connection to host.
- SPI RCP (CONFIG_OPENTHREAD_RCP_SPI)
  Select this to enable SPI connection to host.
Chapter 2. API Reference

**CONFIG_OPENTHREAD_CLI**

Enable OpenThread Command-Line Interface

*Found in: Component config > OpenThread*

Select this option to enable Command-Line Interface in OpenThread.

**Default value:**
- Yes (enabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_DIAG**

Enable diag

*Found in: Component config > OpenThread*

Select this option to enable Diag in OpenThread. This will enable diag mode and a series of diag commands in the OpenThread command line. These commands allow users to manipulate low-level features of the storage and 15.4 radio.

**Default value:**
- Yes (enabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_COMMSSIONER**

Enable Commissioner

*Found in: Component config > OpenThread*

Select this option to enable commissioner in OpenThread. This will enable the device to act as a commissioner in the Thread network. A commissioner checks the pre-shared key from a joining device with the Thread commissioning protocol and shares the network parameter with the joining device upon success.

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_COMM_MAX_JOINER_ENTRIES**

The size of max commissioning joiner entries

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_COMMISSIONER*

**Range:**
- from 2 to 50 if `CONFIG_OPENTHREAD_COMMISSIONER`

**Default value:**
- 2 if `CONFIG_OPENTHREAD_COMMISSIONER`

**CONFIG_OPENTHREAD_JOINER**

Enable Joiner

*Found in: Component config > OpenThread*

Select this option to enable Joiner in OpenThread. This allows a device to join the Thread network with a pre-shared key using the Thread commissioning protocol.

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`
**CONFIG_OPENTHREAD_SR_P_CLIENT**
Enable SRP Client

*Found in: Component config > OpenThread*

Select this option to enable SRP Client in OpenThread. This allows a device to register SRP services to SRP Server.

**Default value:**
- Yes (enabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_SR_P_CLIENT_MAX_SERVICES**
Specifies number of service entries in the SRP client service pool

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_SR_P_CLIENT*

Set the max buffer size of service entries in the SRP client service pool.

**Range:**
- from 2 to 20 if `CONFIG_OPENTHREAD_SR_P_CLIENT`

**Default value:**
- 5 if `CONFIG_OPENTHREAD_SR_P_CLIENT`

**CONFIG_OPENTHREAD_DNS_CLIENT**
Enable DNS Client

*Found in: Component config > OpenThread*

Select this option to enable DNS Client in OpenThread.

**Default value:**
- Yes (enabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_BORDER_ROUTER**
Enable Border Router

*Found in: Component config > OpenThread*

Select this option to enable border router features in OpenThread.

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_PLATFORM_MSGPOOL_MANAGEMENT**
Allocate message pool buffer from PSRAM

*Found in: Component config > OpenThread*

If enabled, the message pool is managed by platform defined logic.

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED` && (CONFIG_SPIRAM_USE_CAPS_ALLOC || CONFIG_SPIRAM_USE_MALLOC)

**CONFIG_OPENTHREAD_NUM_MESSAGE_BUFFERS**
The number of openthread message buffers

*Found in: Component config > OpenThread*

**Range:**
Chapter 2. API Reference

- from 10 to 100 if `CONFIG_OPENTHREAD_PLATFORM_MSGPOOL_MANAGEMENT` &&
  `CONFIG_OPENTHREAD_ENABLED`
- from 10 to 8191 if `CONFIG_OPENTHREAD_PLATFORM_MSGPOOL_MANAGEMENT` &&
  `CONFIG_OPENTHREAD_ENABLED`

Default value:
- 65 if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_SPINEL_RX_FRAME_BUFFER_SIZE**

The size of openthread spinel rx frame buffer

*Found in: Component config > OpenThread*

**Range:**
- from 512 to 8192 if `CONFIG_OPENTHREAD_ENABLED`

**Default value:**
- 1024 if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_MLE_MAX_CHILDREN**

The size of max MLE children entries

*Found in: Component config > OpenThread*

**Range:**
- from 5 to 50 if `CONFIG_OPENTHREAD_ENABLED`

**Default value:**
- 10 if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_TMF_ADDR_CACHE_ENTRIES**

The size of max TMF address cache entries

*Found in: Component config > OpenThread*

**Range:**
- from 5 to 50 if `CONFIG_OPENTHREAD_ENABLED`

**Default value:**
- 20 if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_DNS64_CLIENT**

Use dns64 client

*Found in: Component config > OpenThread*

Select this option to acquire NAT64 address from dns servers.

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED` && `CONFIG_LWIP_IPV4`

**CONFIG_OPENTHREAD_DNS_SERVER_ADDR**

DNS server address (IPv4)

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_DNS64_CLIENT*

Set the DNS server IPv4 address.

**Default value:**
- “8.8.8.8” if `CONFIG_OPENTHREAD_DNS64_CLIENT`
**CONFIG_OPENTHREAD_UART_BUFFER_SIZE**

The uart received buffer size of openthread

*Found in: Component config > OpenThread*

Set the OpenThread UART buffer size.

**Range:**
- from 128 to 1024 if `CONFIG_OPENTHREAD_ENABLED`

**Default value:**
- 256 if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_LINK_METRICS**

Enable link metrics feature

*Found in: Component config > OpenThread*

Select this option to enable link metrics feature

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_MACFILTER_ENABLE**

Enable mac filter feature

*Found in: Component config > OpenThread*

Select this option to enable mac filter feature

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_CSL_ENABLE**

Enable CSL feature

*Found in: Component config > OpenThread*

Select this option to enable CSL feature

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

**CONFIG_OPENTHREAD_XTAL_ACCURACY**

The accuracy of the XTAL

*Found in: Component config > OpenThread*

The device’s XTAL accuracy, in ppm.

**Default value:**
- 130

**CONFIG_OPENTHREAD_CSL_ACCURACY**

The current CSL rx/tx scheduling drift, in units of ± ppm

*Found in: Component config > OpenThread*

The current accuracy of the clock used for scheduling CSL operations

**Default value:**
- 1 if `CONFIG_OPENTHREAD_CSL_ENABLE`
CONFIG_OPENTHREAD_CSL_UNCERTAIN

The CSL Uncertainty in units of 10 us.

*Found in: Component config > OpenThread*

The fixed uncertainty of the Device for scheduling CSL Transmissions in units of 10 microseconds.

**Default value:**
- 1 if `CONFIG_OPENTHREAD_CSL_ENABLE`

CONFIG_OPENTHREAD_CSL_DEBUG_ENABLE

Enable CSL debug

*Found in: Component config > OpenThread*

Select this option to set rx on when sleep in CSL feature, only for debug

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_CSL_ENABLE`

CONFIG_OPENTHREAD_DUA_ENABLE

Enable Domain Unicast Address feature

*Found in: Component config > OpenThread*

Only used for Thread1.2 certification

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

CONFIG_OPENTHREAD_TIME_SYNC

Enable the time synchronization service feature

*Found in: Component config > OpenThread*

Select this option to enable time synchronization feature, the devices in the same Thread network could sync to the same network time.

**Default value:**
- No (disabled) if `CONFIG_OPENTHREAD_ENABLED`

Protocomm

Contains:

- `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_0`
- `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_1`
- `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_2`

CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_0

Support protocomm security version 0 (no security)

*Found in: Component config > Protocomm*

Enable support of security version 0. Disabling this option saves some code size. Consult the Enabling protocomm security version section of the Protocomm documentation in ESP-IDF Programming guide for more details.

**Default value:**
- Yes (enabled)
**CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_1**

Support protocomm security version 1 (Curve25519 key exchange + AES-CTR encryption/decryption)

*Found in: Component config > Protocomm*

Enable support of security version 1. Disabling this option saves some code size. Consult the Enabling protocomm security version section of the Protocomm documentation in ESP-IDF Programming guide for more details.

**Default value:**
- Yes (enabled)

**CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_2**

Support protocomm security version 2 (SRP6a-based key exchange + AES-GCM encryption/decryption)

*Found in: Component config > Protocomm*

Enable support of security version 2. Disabling this option saves some code size. Consult the Enabling protocomm security version section of the Protocomm documentation in ESP-IDF Programming guide for more details.

**Default value:**
- Yes (enabled)

**PThreads**

Contains:
- **CONFIG_PTHREAD_TASK_NAME_DEFAULT**
- **CONFIG_PTHREAD_TASK_CORE_DEFAULT**
- **CONFIG_PTHREAD_TASK_PRIO_DEFAULT**
- **CONFIG_PTHREAD_TASK_STACK_SIZE_DEFAULT**
- **CONFIG_PTHREAD_STACK_MIN**

**CONFIG_PTHREAD_TASK_PRIO_DEFAULT**

Default task priority

*Found in: Component config > PThreads*

Priority used to create new tasks with default pthread parameters.

**Range:**
- from 0 to 255

**Default value:**
- 5

**CONFIG_PTHREAD_TASK_STACK_SIZE_DEFAULT**

Default task stack size

*Found in: Component config > PThreads*

Stack size used to create new tasks with default pthread parameters.

**Default value:**
- 3072
Chapter 2. API Reference

CONFIG_PTHREAD_STACK_MIN

Minimum allowed pthread stack size

Found in: Component config > PThreads

Minimum allowed pthread stack size set in attributes passed to pthread_create

Default value:

- 768

CONFIG_PTHREAD_TASK_CORE_DEFAULT

Default pthread core affinity

Found in: Component config > PThreads

The default core to which pthreads are pinned.

Available options:

- No affinity (CONFIG_PTHREAD_DEFAULT_CORE_NO_AFFINITY)
- Core 0 (CONFIG_PTHREAD_DEFAULT_CORE_0)
- Core 1 (CONFIG_PTHREAD_DEFAULT_CORE_1)

CONFIG_PTHREAD_TASK_NAME_DEFAULT

Default name of pthreads

Found in: Component config > PThreads

The default name of pthreads.

Default value:

- “pthread”

SoC Settings  Contains:

- MMU Config

MMU Config

SPI Flash driver  Contains:

- Auto-detect flash chips
- CONFIG_SPI_FLASH_BYPASS_BLOCK_ERASE
- CONFIG_SPI_FLASH_ENABLE_ENCRYPTED_READ_WRITE
- CONFIG_SPI_FLASH_ENABLE_COUNTERS
- CONFIG_SPI_FLASH_ROM_DRIVER_PATCH
- CONFIG_SPI_FLASH_YIELD_DURING_ERASE
- CONFIG_SPI_FLASH_CHECK_ERASE_TIMEOUT_DISABLED
- CONFIG_SPI_FLASH_WRITE_CHUNK_SIZE
- CONFIG_SPI_FLASH_OVERRIDE_CHIP_DRIVER_LIST
- CONFIG_SPI_FLASH_SIZE_OVERRIDE
- SPI Flash behavior when brownout
- CONFIG_SPI_FLASH_SHARE_SPI1_BUS
- CONFIG_SPI_FLASH_ROM_IMPL
- CONFIG_SPI_FLASH_VERIFY_WRITE
- CONFIG_SPI_FLASH_DANGEROUS_WRITE
Chapter 2. API Reference

**CONFIG_SPI_FLASH_VERIFY_WRITE**

Verify SPI flash writes

*Found in: Component config > SPI Flash driver*

If this option is enabled, any time SPI flash is written then the data will be read back and verified. This can catch hardware problems with SPI flash, or flash which was not erased before verification.

**Default value:**

- No (disabled) if `CONFIG_SPI_FLASH_ROM_IMPL && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_SPI_FLASH_LOG_FAILED_WRITE**

Log errors if verification fails

*Found in: Component config > SPI Flash driver > CONFIG_SPI_FLASH_VERIFY_WRITE*

If this option is enabled, if SPI flash write verification fails then a log error line will be written with the address, expected & actual values. This can be useful when debugging hardware SPI flash problems.

**Default value:**

- No (disabled) if `CONFIG_SPI_FLASH_VERIFY_WRITE && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_SPI_FLASH_WARN_SETTING_ZERO_TO_ONE**

Log warning if writing zero bits to ones

*Found in: Component config > SPI Flash driver > CONFIG_SPI_FLASH_VERIFY_WRITE*

If this option is enabled, any SPI flash write which tries to set zero bits in the flash to ones will log a warning. Such writes will not result in the requested data appearing identically in flash once written, as SPI NOR flash can only set bits to one when an entire sector is erased. After erasing, individual bits can only be written from one to zero.

Note that some software (such as SPIFFS) which is aware of SPI NOR flash may write one bits as an optimisation, relying on the data in flash becoming a bitwise AND of the new data and any existing data. Such software will log spurious warnings if this option is enabled.

**Default value:**

- No (disabled) if `CONFIG_SPI_FLASH_VERIFY_WRITE && CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

**CONFIG_SPI_FLASH_ENABLE_COUNTERS**

Enable operation counters

*Found in: Component config > SPI Flash driver*

This option enables the following APIs:

- esp_flash_reset_counters
- esp_flash_dump_counters
- esp_flash_get_counters

These APIs may be used to collect performance data for spi_flash APIs and to help understand behaviour of libraries which use SPI flash.

**Default value:**

- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
CONFIG_SPI_FLASH_ROM_DRIVER_PATCH

Enable SPI flash ROM driver patched functions

*Found in: Component config > SPI Flash driver*

Enable this flag to use patched versions of SPI flash ROM driver functions. This option should be enabled, if any one of the following is true: (1) need to write to flash on ESP32-D2WD; (2) main SPI flash is connected to non-default pins; (3) main SPI flash chip is manufactured by ISSI.

*Default value:*
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_ROM_IMPL

Use esp_flash implementation in ROM

*Found in: Component config > SPI Flash driver*

Enable this flag to use new SPI flash driver functions from ROM instead of ESP-IDF.

If keeping this as “n” in your project, you will have less free IRAM. But you can use all of our flash features.

If making this as “y” in your project, you will increase free IRAM. But you may miss out on some flash features and support for new flash chips.

Currently the ROM cannot support the following features:
- SPI_FLASH_AUTO_SUSPEND (C3, S3)

*Default value:*
- No (disabled) if `ESP_ROM_HAS_SPI_FLASH` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_DANGEROUS_WRITE

Writing to dangerous flash regions

*Found in: Component config > SPI Flash driver*

SPI flash APIs can optionally abort or return a failure code if erasing or writing addresses that fall at the beginning of flash (covering the bootloader and partition table) or that overlap the app partition that contains the running app.

It is not recommended to ever write to these regions from an IDF app, and this check prevents logic errors or corrupted firmware memory from damaging these regions.

Note that this feature *does not* check calls to the esp_rom_xxx SPI flash ROM functions. These functions should not be called directly from IDF applications.

*Available options:*
- Aborts (`CONFIG_SPI_FLASH_DANGEROUS_WRITE_ABORTS`)
- Fails (`CONFIG_SPI_FLASH_DANGEROUS_WRITE_FAILS`)
- Allowed (`CONFIG_SPI_FLASH_DANGEROUS_WRITE_ALLOWED`)

CONFIG_SPI_FLASH_SHARE_SPI1_BUS

Support other devices attached to SPI1 bus

*Found in: Component config > SPI Flash driver*

Each SPI bus needs a lock for arbitration among devices. This allows multiple devices on a same bus, but may reduce the speed of esp_flash driver access to the main flash chip.
If you only need to use esp_flash driver to access the main flash chip, disable this option, and the lock will be bypassed on SPI1 bus. Otherwise if extra devices are needed to attach to SPI1 bus, enable this option.

**Default value:**

- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

---

**CONFIG_SPI_FLASH_BYPASS_BLOCK_ERASE**

Bypass a block erase and always do sector erase

*Found in: Component config > SPI Flash driver*

Some flash chips can have very high “max” erase times, especially for block erase (32KB or 64KB). This option allows to bypass “block erase” and always do sector erase commands. This will be much slower overall in most cases, but improves latency for other code to run.

**Default value:**

- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

---

**CONFIG_SPI_FLASH_YIELD_DURING_ERASE**

Enables yield operation during flash erase

*Found in: Component config > SPI Flash driver*

This allows to yield the CPUs between erase commands. Prevents starvation of other tasks. Please use this configuration together with `SPI\_FLASH\_ERASE\_YIELD\_DURATION\_MS` and `SPI\_FLASH\_ERASE\_YIELD\_Ticks` after carefully checking flash datasheet to avoid a watchdog timeout. For more information, please check `SPI Flash API` reference documentation under section `OS Function`.

**Default value:**

- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

---

**CONFIG_SPI_FLASH_ERASE_YIELD_DURATION_MS**

Duration of erasing to yield CPUs (ms)

*Found in: Component config > SPI Flash driver > CONFIG_SPI_FLASH_YIELD_DURING_ERASE*

If a duration of one erase command is large then it will yield CPUs after finishing a current command.

**Default value:**

- 20 if `CONFIG_SPI_FLASH_YIELD_DURING_ERASE` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

---

**CONFIG_SPI_FLASH_ERASE_YIELD_TICKS**

CPU release time (tick) for an erase operation

*Found in: Component config > SPI Flash driver > CONFIG_SPI_FLASH_YIELD_DURING_ERASE*

Defines how many ticks will be before returning to continue a erasing.

**Default value:**

- 1 if `CONFIG_SPI_FLASH_YIELD_DURING_ERASE` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
Chapter 2. API Reference

CONFIG_SPI_FLASH_WRITE_CHUNK_SIZE

Flash write chunk size

*Found in: Component config > SPI Flash driver*

Flash write is broken down in terms of multiple (smaller) write operations. This configuration option helps to set individual write chunk size, smaller value here ensures that cache (and non-IRAM resident interrupts) remains disabled for shorter duration.

**Range:**
- from 256 to 8192 if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

**Default value:**
- 8192 if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPI_FLASH_SIZE_OVERRIDE

Override flash size in bootloader header by ESPTOOLPY_FLASHSIZE

*Found in: Component config > SPI Flash driver*

SPI Flash driver uses the flash size configured in bootloader header by default. Enable this option to override flash size with latest ESPTOOLPY_FLASHSIZE value from the app header if the size in the bootloader header is incorrect.

**Default value:**
- No (disabled) if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPI_FLASH_CHECK_ERASE_TIMEOUT_DISABLED

Flash timeout checkout disabled

*Found in: Component config > SPI Flash driver*

This option is helpful if you are using a flash chip whose timeout is quite large or unpredictable.

**Default value:**
- No (disabled) if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

CONFIG_SPI_FLASH_OVERRIDE_CHIP_DRIVER_LIST

Override default chip driver list

*Found in: Component config > SPI Flash driver*

This option allows the chip driver list to be customized, instead of using the default list provided by ESP-IDF.

When this option is enabled, the default list is no longer compiled or linked. Instead, the default_registered_chips structure must be provided by the user.

See example: custom_chip_driver under examples/storage for more details.

**Default value:**
- No (disabled) if CONFIG_APP_BUILD_TYPE_PURE_RAM_APP

SPI Flash behavior when brownout

Contains:
- CONFIG_SPI_FLASH_BROWNOUT_RESET_XMC
CONFIG_SPI_FLASH_BROWNOUT_RESET_XMC

Enable sending reset when brownout for XMC flash chips

*Found in: Component config > SPI Flash driver > SPI Flash behavior when brownout*

When this option is selected, the patch will be enabled for XMC. Follow the recommended flow by XMC for better stability.

DO NOT DISABLE UNLESS YOU KNOW WHAT YOU ARE DOING.

*Default value:*
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

Auto-detect flash chips

Contains:
- `CONFIG_SPI_FLASH_SUPPORT_BOYA_CHIP`
- `CONFIG_SPI_FLASH_SUPPORT_GD_CHIP`
- `CONFIG_SPI_FLASH_SUPPORT_ISSI_CHIP`
- `CONFIG_SPI_FLASH_SUPPORT_MXIC_CHIP`
- `CONFIG_SPI_FLASH_SUPPORT_TH_CHIP`
- `CONFIG_SPI_FLASH_SUPPORT_WINBOND_CHIP`

CONFIG_SPI_FLASH_SUPPORT_ISSI_CHIP

ISSI

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of ISSI chips if chip vendor not directly given by `chip_drv` member of the chip struct. This adds support for variant chips, however will extend detecting time.

*Default value:*
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_SUPPORT_MXIC_CHIP

MXIC

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of MXIC chips if chip vendor not directly given by `chip_drv` member of the chip struct. This adds support for variant chips, however will extend detecting time.

*Default value:*
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_SUPPORT_GD_CHIP

GigaDevice

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of GD (GigaDevice) chips if chip vendor not directly given by `chip_drv` member of the chip struct. If you are using Wrover modules, please don’t disable this, otherwise your flash may not work in 4-bit mode.

This adds support for variant chips, however will extend detecting time and image size. Note that the default chip driver supports the GD chips with product ID 60H.

*Default value:*
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
CONFIG_SPI_FLASH_SUPPORT_WINBOND_CHIP

Winbond

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of Winbond chips if chip vendor not directly given by `chip_drv` member of the chip struct. This adds support for variant chips, however will extend detecting time.

**Default value:**
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_SUPPORT_BOYA_CHIP

BOYA

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of BOYA chips if chip vendor not directly given by `chip_drv` member of the chip struct. This adds support for variant chips, however will extend detecting time.

**Default value:**
- Yes (enabled) if `SPI_FLASH_VENDOR_BOYA_SUPPORTED` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_SUPPORT_TH_CHIP

TH

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of TH chips if chip vendor not directly given by `chip_drv` member of the chip struct. This adds support for variant chips, however will extend detecting time.

**Default value:**
- Yes (enabled) if `SPI_FLASH_VENDOR_TH_SUPPORTED` && `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`
- No (disabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

CONFIG_SPI_FLASH_ENABLE_ENCRYPTED_READ_WRITE

Enable encrypted partition read/write operations

*Found in: Component config > SPI Flash driver*

This option enables flash read/write operations to encrypted partition/s. This option is kept enabled irrespective of state of flash encryption feature. However, in case application is not using flash encryption feature and is in need of some additional memory from IRAM region (~1KB) then this config can be disabled.

**Default value:**
- Yes (enabled) if `CONFIG_APP_BUILD_TYPE_PURE_RAM_APP`

SPIFFS Configuration Contains:

- Debug Configuration
- `CONFIG_SPIFFS_USE_MAGIC`
- `CONFIG_SPIFFS_GC_STATS`
- `CONFIG_SPIFFS_PAGE_CHECK`
- `CONFIG_SPIFFS_FOLLOW_SYMLINKS`
- `CONFIG_SPIFFS_MAX_PARTITIONS`
- `CONFIG_SPIFFS_USE_MTIME`
Chapter 2. API Reference

- CONFIG_SPIFFS_GC_MAX_RUNS
- CONFIG_SPIFFS_OBJ_NAME_LEN
- CONFIG_SPIFFS_META_LENGTH
- SPIFFS Cache Configuration
- CONFIG_SPIFFS_PAGE_SIZE
- CONFIG_SPIFFS_MTIME_WIDE_64_BITS

**CONFIG_SPIFFS_MAX_PARTITIONS**

Maximum Number of Partitions

*Found in: Component config > SPIFFS Configuration*

Define maximum number of partitions that can be mounted.

**Range:**
- from 1 to 10

**Default value:**
- 3

**SPIFFS Cache Configuration** Contains:

- CONFIG_SPIFFS_CACHE

**CONFIG_SPIFFS_CACHE**

Enable SPIFFS Cache

*Found in: Component config > SPIFFS Configuration > SPIFFS Cache Configuration*

Enables/disables memory read caching of nucleus file system operations.

**Default value:**
- Yes (enabled)

**CONFIG_SPIFFS_CACHE_WR**

Enable SPIFFS Write Caching

*Found in: Component config > SPIFFS Configuration > SPIFFS Cache Configuration > CONFIG_SPIFFS_CACHE*

Enables memory write caching for file descriptors in hydrogen.

**Default value:**
- Yes (enabled)

**CONFIG_SPIFFS_CACHE_STATS**

Enable SPIFFS Cache Statistics

*Found in: Component config > SPIFFS Configuration > SPIFFS Cache Configuration > CONFIG_SPIFFS_CACHE*

Enable/disable statistics on caching. Debug/test purpose only.

**Default value:**
- No (disabled)
CONFIG_SPIFFS_PAGE_CHECK
Enable SPIFFS Page Check

*Found in: Component config > SPIFFS Configuration*

Always check header of each accessed page to ensure consistent state. If enabled it will increase number of reads from flash, especially if cache is disabled.

**Default value:**
- Yes (enabled)

CONFIG_SPIFFS_GC_MAX_RUNS
Set Maximum GC Runs

*Found in: Component config > SPIFFS Configuration*

Define maximum number of GC runs to perform to reach desired free pages.

**Range:**
- from 1 to 10000

**Default value:**
- 10

CONFIG_SPIFFS_GC_STATS
Enable SPIFFS GC Statistics

*Found in: Component config > SPIFFS Configuration*

Enable/disable statistics on gc. Debug/test purpose only.

**Default value:**
- No (disabled)

CONFIG_SPIFFS_PAGE_SIZE
SPIFFS logical page size

*Found in: Component config > SPIFFS Configuration*

Logical page size of SPIFFS partition, in bytes. Must be multiple of flash page size (which is usually 256 bytes). Larger page sizes reduce overhead when storing large files, and improve filesystem performance when reading large files. Smaller page sizes reduce overhead when storing small (< page size) files.

**Range:**
- from 256 to 1024

**Default value:**
- 256

CONFIG_SPIFFS_OBJ_NAME_LEN
Set SPIFFS Maximum Name Length

*Found in: Component config > SPIFFS Configuration*

Object name maximum length. Note that this length include the zero-termination character, meaning maximum string of characters can at most be SPIFFS_OBJ_NAME_LEN - 1.

SPIFFS_OBJ_NAME_LEN + SPIFFS_META_LENGTH should not exceed SPIFFS_PAGE_SIZE - 64.

**Range:**
- from 1 to 256

**Default value:**
**CONFIG_SPIFFS_FOLLOW_SYMLINKS**

Enable symbolic links for image creation

*Found in: Component config > SPIFFS Configuration*

If this option is enabled, symbolic links are taken into account during partition image creation.

**Default value:**

- No (disabled)

**CONFIG_SPIFFS_USE_MAGIC**

Enable SPIFFS Filesystem Magic

*Found in: Component config > SPIFFS Configuration*

Enable this to have an identifiable spiffs filesystem. This will look for a magic in all sectors to determine if this is a valid spiffs system or not at mount time.

**Default value:**

- Yes (enabled)

**CONFIG_SPIFFS_USE_MAGIC_LENGTH**

Enable SPIFFS Filesystem Length Magic

*Found in: Component config > SPIFFS Configuration > CONFIG_SPIFFS_USE_MAGIC*

If this option is enabled, the magic will also be dependent on the length of the filesystem. For example, a filesystem configured and formatted for 4 megabytes will not be accepted for mounting with a configuration defining the filesystem as 2 megabytes.

**Default value:**

- Yes (enabled)

**CONFIG_SPIFFS_META_LENGTH**

Size of per-file metadata field

*Found in: Component config > SPIFFS Configuration*

This option sets the number of extra bytes stored in the file header. These bytes can be used in an application-specific manner. Set this to at least 4 bytes to enable support for saving file modification time.

SPIFFS_OBJ_NAME_LEN + SPIFFS_META_LENGTH should not exceed SPIFFS_PAGE_SIZE - 64.

**Default value:**

- 4

**CONFIG_SPIFFS_USE_MTIME**

Save file modification time

*Found in: Component config > SPIFFS Configuration*

If enabled, then the first 4 bytes of per-file metadata will be used to store file modification time (mtime), accessible through stat/fstat functions. Modification time is updated when the file is opened.

**Default value:**

- Yes (enabled)
**CONFIG_SPIFFS_MTIME_WIDE_64_BITS**

The time field occupies 64 bits in the image instead of 32 bits

*Found in: Component config > SPIFFS Configuration*

If this option is not set, the time field is 32 bits (up to 2106 year), otherwise it is 64 bits and make sure it matches SPIFFS_META_LENGTH. If the chip already has the spiffs image with the time field = 32 bits then this option cannot be applied in this case. Erase it first before using this option. To resolve the Y2K38 problem for the spiffs, use a toolchain with 64-bit time_t support.

**Default value:**
- No (disabled) if `CONFIG_SPIFFS_META_LENGTH >= 8`

**Debug Configuration**

Contains:

- `CONFIG_SPIFFS_DBG`
- `CONFIG_SPIFFS_API_DBG`
- `CONFIG_SPIFFS_CACHE_DBG`
- `CONFIG_SPIFFS_CHECK_DBG`
- `CONFIG_SPIFFS_TEST_VISUALISATION`
- `CONFIG_SPIFFS_GC_DBG`

**CONFIG_SPIFFS_DBG**

Enable general SPIFFS debug

*Found in: Component config > SPIFFS Configuration > Debug Configuration*

Enabling this option will print general debug messages to the console.

**Default value:**
- No (disabled)

**CONFIG_SPIFFS_API_DBG**

Enable SPIFFS API debug

*Found in: Component config > SPIFFS Configuration > Debug Configuration*

Enabling this option will print API debug messages to the console.

**Default value:**
- No (disabled)

**CONFIG_SPIFFS_GC_DBG**

Enable SPIFFS Garbage Cleaner debug

*Found in: Component config > SPIFFS Configuration > Debug Configuration*

Enabling this option will print GC debug messages to the console.

**Default value:**
- No (disabled)

**CONFIG_SPIFFS_CACHE_DBG**

Enable SPIFFS Cache debug

*Found in: Component config > SPIFFS Configuration > Debug Configuration*

Enabling this option will print cache debug messages to the console.

**Default value:**
**CONFIG_SPIFFS_CHECK_DBG**

Enable SPIFFS Filesystem Check debug

*Found in: Component config > SPIFFS Configuration > Debug Configuration*

Enabling this option will print Filesystem Check debug messages to the console.

**Default value:**

- No (disabled)

**CONFIG_SPIFFS_TEST_VISUALISATION**

Enable SPIFFS Filesystem Visualization

*Found in: Component config > SPIFFS Configuration > Debug Configuration*

Enable this option to enable SPIFFS_vis function in the API.

**Default value:**

- No (disabled)

**TCP Transport** Contains:

- **Websocket**

**Websocket** Contains:

- **CONFIG_WS_TRANSPORT**

**CONFIG_WS_TRANSPORT**

Enable Websocket Transport

*Found in: Component config > TCP Transport > Websocket*

Enable support for creating websocket transport.

**Default value:**

- Yes (enabled)

**CONFIG_WS_BUFFER_SIZE**

Websocket transport buffer size

*Found in: Component config > TCP Transport > Websocket > CONFIG_WS_TRANSPORT*

Size of the buffer used for constructing the HTTP Upgrade request during connect.

**Default value:**

- 1024

**CONFIG_WS_DYNAMIC_BUFFER**

Using dynamic websocket transport buffer

*Found in: Component config > TCP Transport > Websocket > CONFIG_WS_TRANSPORT*

If enable this option, websocket transport buffer will be freed after connection succeed to save more heap.

**Default value:**
• No (disabled)

Ultra Low Power (ULP) Co-processor Contains:
  • CONFIG_ULP_COPROC_ENABLED
  • ULP RISC-V Settings

CONFIG_ULP_COPROC_ENABLED
Enable Ultra Low Power (ULP) Co-processor

Found in: Component config > Ultra Low Power (ULP) Co-processor

Enable this feature if you plan to use the ULP Co-processor. Once this option is enabled, further ULP co-processor configuration will appear in the menu.

Default value:
• No (disabled)

CONFIG_ULP_COPROC_TYPE
ULP Co-processor type

Found in: Component config > Ultra Low Power (ULP) Co-processor > CONFIG_ULP_COPROC_ENABLED

Choose the ULP Coprocessor type: ULP FSM (Finite State Machine) or ULP RISC-V.

Available options:
• ULP FSM (Finite State Machine) (CONFIG_ULP_COPROC_TYPE_FSM)
• ULP RISC-V (CONFIG_ULP_COPROC_TYPE_RISCV)
• LP core RISC-V (CONFIG_ULP_COPROC_TYPE_LP_CORE)

CONFIG_ULP_COPROC_reserve_MEM
RTC slow memory reserved for coprocessor

Found in: Component config > Ultra Low Power (ULP) Co-processor > CONFIG_ULP_COPROC_ENABLED

Bytes of memory to reserve for ULP Co-processor firmware & data. Data is reserved at the beginning of RTC slow memory.

Range:
• from 32 to 8176 if CONFIG_ULP_COPROC_ENABLED

Default value:
• 512 if CONFIG_ULP_COPROC_ENABLED
• 4096 if CONFIG_ULP_COPROC_ENABLED

ULP RISC-V Settings Contains:
• CONFIG_ULP_RISCV_UART_BAUDRATE
• CONFIG_ULP_RISCV_I2C_RW_TIMEOUT
Chapter 2. API Reference

**CONFIG_ULP_RISCV_UART_BAUDRATE**

Baudrate used by the bitbanged ULP RISC-V UART driver

*Found in: Component config > Ultra Low Power (ULP) Co-processor > ULP RISC-V Settings*

The accuracy of the bitbanged UART driver is limited, it is not recommend to increase the value above 19200.

**Default value:**
- 9600 if `CONFIG_ULP_COPROC_TYPE_RISCV`

**CONFIG_ULP_RISCV_I2C_RW_TIMEOUT**

Set timeout for ULP RISC-V I2C transaction timeout in ticks.

*Found in: Component config > Ultra Low Power (ULP) Co-processor > ULP RISC-V Settings*

Set the ULP RISC-V I2C read/write timeout. Set this value to -1 if the ULP RISC-V I2C read and write APIs should wait forever. Please note that the tick rate of the ULP co-processor would be different than the OS tick rate of the main core and therefore can have different timeout value depending on which core the API is invoked on.

**Range:**
- from -1 to 4294967295 if `CONFIG_ULP_COPROC_TYPE_RISCV`

**Default value:**
- 500 if `CONFIG_ULP_COPROC_TYPE_RISCV`

**Unity unit testing library**

Contains:
- `CONFIG_UNITY_ENABLE_COLOR`
- `CONFIG_UNITY_ENABLE_IDF_TEST_RUNNER`
- `CONFIG_UNITY_ENABLE_FIXTURE`
- `CONFIG_UNITY_ENABLE_BACKTRACE_ON_FAIL`
- `CONFIG_UNITY_ENABLE_64BIT`
- `CONFIG_UNITY_ENABLE_DOUBLE`
- `CONFIG_UNITY_ENABLE_FLOAT`

**CONFIG_UNITY_ENABLE_FLOAT**

Support for float type

*Found in: Component config > Unity unit testing library*

If not set, assertions on float arguments will not be available.

**Default value:**
- Yes (enabled)

**CONFIG_UNITY_ENABLE_DOUBLE**

Support for double type

*Found in: Component config > Unity unit testing library*

If not set, assertions on double arguments will not be available.

**Default value:**
- Yes (enabled)
**CONFIG_UNITY_ENABLE_64BIT**

Support for 64-bit integer types

*Found in: Component config > Unity unit testing library*

If not set, assertions on 64-bit integer types will always fail. If this feature is enabled, take care not to pass pointers (which are 32 bit) to UNITY_ASSERT_EQUAL, as that will cause pointer-to-int-cast warnings.

**Default value:**
- No (disabled)

**CONFIG_UNITY_ENABLE_COLOR**

Colorize test output

*Found in: Component config > Unity unit testing library*

If set, Unity will colorize test results using console escape sequences.

**Default value:**
- No (disabled)

**CONFIG_UNITY_ENABLE_IDF_TEST_RUNNER**

Include ESP-IDF test registration/running helpers

*Found in: Component config > Unity unit testing library*

If set, then the following features will be available:

- TEST_CASE macro which performs automatic registration of test functions
- Functions to run registered test functions: unity_run_all_tests, unity_run_tests_with_filter, unity_run_single_test_by_name.
- Interactive menu which lists test cases and allows choosing the tests to be run, available via unity_run_menu function.

Disable if a different test registration mechanism is used.

**Default value:**
- Yes (enabled)

**CONFIG_UNITY_ENABLE_FIXTURE**

Include Unity test fixture

*Found in: Component config > Unity unit testing library*

If set, unity_fixture.h header file and associated source files are part of the build. These provide an optional set of macros and functions to implement test groups.

**Default value:**
- No (disabled)

**CONFIG_UNITY_ENABLE_BACKTRACE_ON_FAIL**

Print a backtrace when a unit test fails

*Found in: Component config > Unity unit testing library*

If set, the unity framework will print the backtrace information before jumping back to the test menu. The jumping is usually occurs in assert functions such as TEST_ASSERT, TEST_FAIL etc.

**Default value:**
- No (disabled)
Virtual file system  Contains:
  •  \textit{CONFIG\_VFS\_SUPPORT\_IO}

\textbf{CONFIG\_VFS\_SUPPORT\_IO}

Provide basic I/O functions

\textit{Found in: Component config > Virtual file system}

If enabled, the following functions are provided by the VFS component.

\texttt{open, close, read, write, pread, pwrite, lseek, fstat, fsync, ioctl, fcntl}

Filesystem drivers can then be registered to handle these functions for specific paths.

Disabling this option can save memory when the support for these functions is not required.

Note that the following functions can still be used with socket file descriptors when this option is disabled:

\texttt{close, read, write, ioctl, fcntl}.

\textbf{Default value:}
  • Yes (enabled)

\textbf{CONFIG\_VFS\_SUPPORT\_DIR}

Provide directory related functions

\textit{Found in: Component config > Virtual file system > CONFIG\_VFS\_SUPPORT\_IO}

If enabled, the following functions are provided by the VFS component.

\texttt{stat, link, unlink, rename, utime, access, truncate, rmdir, mkdir, opendir, closedir, readdir, readdir\_r, seekdir, telldir, rewinddir}

Filesystem drivers can then be registered to handle these functions for specific paths.

Disabling this option can save memory when the support for these functions is not required.

\textbf{Default value:}
  • Yes (enabled)

\textbf{CONFIG\_VFS\_SUPPORT\_SELECT}

Provide select function

\textit{Found in: Component config > Virtual file system > CONFIG\_VFS\_SUPPORT\_IO}

If enabled, select function is provided by the VFS component, and can be used on peripheral file descriptors (such as UART) and sockets at the same time.

If disabled, the default select implementation will be provided by LWIP for sockets only.

Disabling this option can reduce code size if support for “select” on UART file descriptors is not required.

\textbf{Default value:}
  • Yes (enabled)  
  \hspace{1cm} if  \texttt{CONFIG\_VFS\_SUPPORT\_IO}  
  \hspace{2cm} \&\&  \texttt{CONFIG\_LWIP\_USE\_ONLY\_LWIP\_SELECT}
**CONFIG_VFS_SUPPRESS_SELECT_DEBUG_OUTPUT**

Suppress select() related debug outputs

*Found in:* Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO > CONFIG_VFS_SUPPORT_SELECT

Select() related functions might produce an unconveniently lot of debug outputs when one sets the default log level to DEBUG or higher. It is possible to suppress these debug outputs by enabling this option.

**Default value:**
- Yes (enabled)

**CONFIG_VFS_SUPPORT_TERMIOS**

Provide termios.h functions

*Found in:* Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO

Disabling this option can save memory when the support for termios.h is not required.

**Default value:**
- Yes (enabled)

**CONFIG_VFS_MAX_COUNT**

Maximum Number of Virtual Filesystems

*Found in:* Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO

Define maximum number of virtual filesystems that can be registered.

**Range:**
- from 1 to 20

**Default value:**
- 8

**Host File System I/O (Semihosting)** Contains:
- CONFIG_VFS_SEMIHOSTFS_MAX_MOUNT_POINTS

**CONFIG_VFS_SEMIHOSTFS_MAX_MOUNT_POINTS**

Host FS: Maximum number of the host filesystem mount points

*Found in:* Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO > Host File System I/O (Semihosting)

Define maximum number of host filesystem mount points.

**Default value:**
- 1

**Wear Levelling** Contains:
- CONFIG_WL_SECTOR_MODE
- CONFIG_WL_SECTOR_SIZE
**CONFIG_WL_SECTOR_SIZE**

Wear Levelling library sector size

*Found in: Component config > Wear Levelling*

Sector size used by wear levelling library. You can set default sector size or size that will fit to the flash device sector size.

With sector size set to 4096 bytes, wear levelling library is more efficient. However if FAT filesystem is used on top of wear levelling library, it will need more temporary storage: 4096 bytes for each mounted filesystem and 4096 bytes for each opened file.

With sector size set to 512 bytes, wear levelling library will perform more operations with flash memory, but less RAM will be used by FAT filesystem library (512 bytes for the filesystem and 512 bytes for each file opened).

Available options:

- 512 (CONFIG_WL_SECTOR_SIZE_512)
- 4096 (CONFIG_WL_SECTOR_SIZE_4096)

**CONFIG_WL_SECTOR_MODE**

Sector store mode

*Found in: Component config > Wear Levelling*

Specify the mode to store data into flash:

- In Performance mode a data will be stored to the RAM and then stored back to the flash. Compared to the Safety mode, this operation is faster, but if power will be lost when erase sector operation is in progress, then the data from complete flash device sector will be lost.
- In Safety mode data from complete flash device sector will be read from flash, modified, and then stored back to flash. Compared to the Performance mode, this operation is slower, but if power is lost during erase sector operation, then the data from full flash device sector will not be lost.

Available options:

- Performance (CONFIG_WL_SECTOR_MODE_PERF)
- Safety (CONFIG_WL_SECTOR_MODE_SAFE)

**Wi-Fi Provisioning Manager**

Contains:

- CONFIG_WIFI_PROV_BLE_BONDING
- CONFIG_WIFI_PROV_BLE_SEC_CONN
- CONFIG_WIFI_PROV_BLE_FORCE_ENCRYPTION
- CONFIG_WIFI_PROV_KEEP_BLE_ON_AFTER_PROV
- CONFIG_WIFI_PROV_SCAN_MAX_ENTRIES
- CONFIG_WIFI_PROV_AUTOSTOP_TIMEOUT
- CONFIG_WIFI_PROV_STA_SCAN_METHOD

**CONFIG_WIFI_PROV_SCAN_MAX_ENTRIES**

Max Wi-Fi Scan Result Entries

*Found in: Component config > Wi-Fi Provisioning Manager*

This sets the maximum number of entries of Wi-Fi scan results that will be kept by the provisioning manager

*Range:*
Chapter 2. API Reference

• from 1 to 255

**Default value:**
• 16

**CONFIG WIFI PROV AUTOSTOP TIMEOUT**

Provisioning auto-stop timeout

*Found in: Component config > Wi-Fi Provisioning Manager*

Time (in seconds) after which the Wi-Fi provisioning manager will auto-stop after connecting to a Wi-Fi network successfully.

**Range:**
• from 5 to 600

**Default value:**
• 30

**CONFIG WIFI PROV BLE BONDING**

Enable BLE bonding

*Found in: Component config > Wi-Fi Provisioning Manager*

This option is applicable only when provisioning transport is BLE.

**CONFIG WIFI PROV BLE SEC_CONN**

Enable BLE Secure connection flag

*Found in: Component config > Wi-Fi Provisioning Manager*

Used to enable Secure connection support when provisioning transport is BLE.

**Default value:**
• Yes (enabled) if `CONFIG_BT_NIMBLE_ENABLED`

**CONFIG WIFI PROV BLE FORCE ENCRYPTION**

Force Link Encryption during characteristic Read / Write

*Found in: Component config > Wi-Fi Provisioning Manager*

Used to enforce link encryption when attempting to read / write characteristic

**CONFIG WIFI PROV KEEP_BLE_ON_AFTER_PROV**

Keep BT on after provisioning is done

*Found in: Component config > Wi-Fi Provisioning Manager*

**CONFIG WIFI PROV DISCONNECT_AFTER_PROV**

Terminate connection after provisioning is done

*Found in: Component config > Wi-Fi Provisioning Manager > CONFIG_WIFI_PROV_KEEP_BLE_ON_AFTER_PROV*

**Default value:**
• Yes (enabled) if `CONFIG_WIFI_PROV_KEEP_BLE_ON_AFTER_PROV`
CONFIG_WIFI_PROV_STA_SCAN_METHOD

Wifi Provisioning Scan Method

Found in: Component config > Wi-Fi Provisioning Manager

Available options:

• All Channel Scan (CONFIG_WIFI_PROV_STA_ALL_CHANNEL_SCAN)
  Scan will end after scanning the entire channel. This option is useful in Mesh WiFi Systems.
• Fast Scan (CONFIG_WIFI_PROV_STA_FAST_SCAN)
  Scan will end after an AP matching with the SSID has been detected.

CONFIG_IDF_EXPERIMENTAL_FEATURES

Make experimental features visible

Found in:

By enabling this option, ESP-IDF experimental feature options will be visible.

Note you should still enable a certain experimental feature option to use it, and you should read the corresponding risk warning and known issue list carefully.

Default value:
• No (disabled)

Deprecated options and their replacements

• CONFIG_A2DP_ENABLE (CONFIG_BT_A2DP_ENABLE)
• CONFIG_A2D_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_A2D_TRACE_LEVEL)
  - CONFIG_A2D_TRACE_LEVEL_NONE
  - CONFIG_A2D_TRACE_LEVEL_ERROR
  - CONFIG_A2D_TRACE_LEVEL_WARNING
  - CONFIG_A2D_TRACE_LEVEL_API
  - CONFIG_A2D_TRACE_LEVEL_EVENT
  - CONFIG_A2D_TRACE_LEVEL_DEBUG
  - CONFIG_A2D_TRACE_LEVEL_VERBOSE
• CONFIG_ADC2_DISABLE_DAC (CONFIG_ADC_DISABLE_DAC)
• CONFIG_APPL_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_APPL_TRACE_LEVEL)
  - CONFIG_APPL_TRACE_LEVEL_NONE
  - CONFIG_APPL_TRACE_LEVEL_ERROR
  - CONFIG_APPL_TRACE_LEVEL_WARNING
  - CONFIG_APPL_TRACE_LEVEL_API
  - CONFIG_APPL_TRACE_LEVEL_EVENT
  - CONFIG_APPL_TRACE_LEVEL_DEBUG
  - CONFIG_APPL_TRACE_LEVEL_VERBOSE
• CONFIG_APP_ANTI_ROLLBACK (CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK)
• CONFIG_APP_ROLLBACK_ENABLE (CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE)
• CONFIG_APP_SECURE_VERSION (CONFIG_BOOTLOADER_APP_SECURE_VERSION)
• CONFIG_APP_SECURE_VERSION_SIZE_EFUSE_FIELD (CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD)
• CONFIG_AVCT_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_AVCT_TRACE_LEVEL)
  - CONFIG_AVCT_TRACE_LEVEL_NONE
  - CONFIG_AVCT_TRACE_LEVEL_ERROR
  - CONFIG_AVCT_TRACE_LEVEL_WARNING
  - CONFIG_AVCT_TRACE_LEVEL_API
  - CONFIG_AVCT_TRACE_LEVEL_EVENT
  - CONFIG_AVCT_TRACE_LEVEL_DEBUG
Chapter 2. API Reference

- CONFIG_AVCT_TRACE_LEVEL_VERBOSE

• CONFIG_AVDT_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_AVDT_TRACE_LEVEL)
  - CONFIG_AVDT_TRACE_LEVEL_NONE
  - CONFIG_AVDT_TRACE_LEVEL_ERROR
  - CONFIG_AVDT_TRACE_LEVEL_WARNING
  - CONFIG_AVDT_TRACE_LEVEL_API
  - CONFIG_AVDT_TRACE_LEVEL_EVENT
  - CONFIG_AVDT_TRACE_LEVEL_DEBUG
  - CONFIG_AVDT_TRACE_LEVEL_VERBOSE

• CONFIG_AVRC_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_AVRC_TRACE_LEVEL)
  - CONFIG_AVRC_TRACE_LEVEL_NONE
  - CONFIG_AVRC_TRACE_LEVEL_ERROR
  - CONFIG_AVRC_TRACE_LEVEL_WARNING
  - CONFIG_AVRC_TRACE_LEVEL_API
  - CONFIG_AVRC_TRACE_LEVEL_EVENT
  - CONFIG_AVRC_TRACE_LEVEL_DEBUG
  - CONFIG_AVRC_TRACE_LEVEL_VERBOSE

• CONFIG_BNEP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BNEP_TRACE_LEVEL)

• CONFIG_BROWNOUT_DET_LVL_SEL (CONFIG_ESP_BROWNOUT_DET_LVL_SEL)
  - CONFIG_BROWNOUT_DET_LVL_SEL_0
  - CONFIG_BROWNOUT_DET_LVL_SEL_1
  - CONFIG_BROWNOUT_DET_LVL_SEL_2
  - CONFIG_BROWNOUT_DET_LVL_SEL_3
  - CONFIG_BROWNOUT_DET_LVL_SEL_4
  - CONFIG_BROWNOUT_DET_LVL_SEL_5
  - CONFIG_BROWNOUT_DET_LVL_SEL_6
  - CONFIG_BROWNOUT_DET_LVL_SEL_7

• CONFIG_BTC_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BTC_TRACE_LEVEL)
  - CONFIG_BTC_TRACE_LEVEL_NONE
  - CONFIG_BTC_TRACE_LEVEL_ERROR
  - CONFIG_BTC_TRACE_LEVEL_WARNING
- CONFIG_BTC_TRACE_LEVEL_API
- CONFIG_BTC_TRACE_LEVEL_EVENT
- CONFIG_BTC_TRACE_LEVEL_DEBUG
- CONFIG_BTC_TRACE_LEVEL_VERBOSE

• CONFIG_BTC_TASK_STACK_SIZE (CONFIG_BT_BTC_TASK_STACK_SIZE)
• CONFIG_BTDVM_CONTROLLER_BLE_MAX_CONN (CONFIG_BTDVM_CTRL_BLE_MAX_CONN)
• CONFIG_BTDVM_CONTROLLER_BR_EDR_MAX_ACL_CONN (CONFIG_BTDVM_CTRL_BR_EDR_MAX_ACL_CONN)
• CONFIG_BTDVM_CONTROLLER_BR_EDR_MAX_SYNC_CONN (CONFIG_BTDVM_CTRL_BR_EDR_MAX_SYNC_CONN)
• CONFIG_BTDVM_CONTROLLER_FULL_SCAN_SUPPORTED (CONFIG_BTDVM_CTRL_FULL_SCAN_SUPPORTED)
• CONFIG_BTDVM_CONTROLLER_HCI_MODE_CHOICE (CONFIG_BTDVM_CTRL_HCI_MODE_CHOICE)
  - CONFIG_BTDVM_CONTROLLER_HCI_MODE_VHCI
  - CONFIG_BTDVM_CONTROLLER_HCI_MODE_UART_H4
• CONFIG_BTDVM_CONTROLLER_MODE (CONFIG_BTDVM_CTRL_MODE)
  - CONFIG_BTDVM_CONTROLLER_MODE_BLE_ONLY
  - CONFIG_BTDVM_CONTROLLER_MODE_BR_EDR_ONLY
  - CONFIG_BTDVM_CONTROLLER_MODE_BTDM
• CONFIG_BTDVM_CONTROLLER_MODEM_SLEEP (CONFIG_BTDVM_CTRL_MODEM_SLEEP)
• CONFIG_BTDVM_CONTROLLER_PINNED_TO_CORE_CHOICE (CONFIG_BTDVM_CTRL_PINNED_TO_CORE_CHOICE)
• CONFIG_BTH_LOG_SDP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_SDP_TRACE_LEVEL)
  - CONFIG_SDP_TRACE_LEVEL_NONE
  - CONFIG_SDP TRACE_LEVEL_ERROR
  - CONFIG_SDP_TRACE_LEVEL_WARNING
  - CONFIG_SDP_TRACE_LEVEL_API
  - CONFIG_SDP_TRACE_LEVEL_EVENT
  - CONFIG_SDP_TRACE_LEVEL_DEBUG
  - CONFIG_SDP_TRACE_LEVEL_VERBOSE
• CONFIG_BTIF_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BTIF_TRACE_LEVEL)
  - CONFIG_BTIF_TRACE_LEVEL_NONE
  - CONFIG_BTIF_TRACE_LEVEL_ERROR
  - CONFIG_BTIF_TRACE_LEVEL_WARNING
  - CONFIG_BTIF_TRACE_LEVEL_API
  - CONFIG_BTIF_TRACE_LEVEL_EVENT
  - CONFIG_BTIF_TRACE_LEVEL_DEBUG
  - CONFIG_BTIF_TRACE_LEVEL_VERBOSE
• CONFIG_BTM_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_BTM_TRACE_LEVEL)
  - CONFIG_BTM_TRACE_LEVEL_NONE
  - CONFIG_BTM TRACE_LEVEL_ERROR
  - CONFIG_BTM_TRACE_LEVEL_WARNING
  - CONFIG_BTM_TRACE_LEVEL_API
  - CONFIG_BTM_TRACE_LEVEL_EVENT
  - CONFIG_BTM_TRACE_LEVEL_DEBUG
  - CONFIG_BTM_TRACE_LEVEL_VERBOSE
• CONFIG_BTU_TASK_STACK_SIZE (CONFIG_BT_BTU_TASK_STACK_SIZE)
• CONFIG_BT_NIMBLE_ACL_BUF_COUNT (CONFIG_BT_NIMBLE_TRANSPORT_ACL_FROM_LL_COUNT)
• CONFIG_BT_NIMBLE_ACL_BUF_SIZE (CONFIG_BT_NIMBLE_TRANSPORT_ACL_SIZE)
• CONFIG_BT_NIMBLE_HCI_EVT_BUF_COUNT (CONFIG_BT_NIMBLE_TRANSPORT_EVT_COUNT)
• CONFIG_BT_NIMBLE_HCI_EVT_BUFF_SIZE (CONFIG_BT_NIMBLE_TRANSPORT_EVT_DISCARD_COUNT)
• CONFIG_BT_NIMBLE_MSYS1_BLOCK_COUNT (CONFIG_BT_NIMBLE_HOST_TASK_STACK_SIZE)
• CONFIG_CLASSIC_BT_ENABLED (CONFIG_BT_CLASSIC_ENABLED)
• CONFIG_CONSOLE_UART (CONFIG_ESP_CONSOLE_UART)
  - CONFIG_CONSOLE_UART_DEFAULT
- CONFIG_CONSOLE_UART_CUSTOM
- CONFIG_CONSOLE_UART_NONE, CONFIG_ESP_CONSOLE_UART_NONE
  • CONFIG_CONSOLE_UART_BAUDRATE (CONFIG_ESP_CONSOLE_UART_BAUDRATE)
  • CONFIG_CONSOLE_UART_NUM (CONFIG_ESP_CONSOLE_UART_NUM)
    - CONFIG_CONSOLE_UART_CUSTOM_NUM_0
    - CONFIG_CONSOLE_UART_CUSTOM_NUM_1
    • CONFIG_CONSOLE_UART_RX_GPIO (CONFIG_ESP_CONSOLE_UART_RX_GPIO)
    • CONFIG_CONSOLE_UART_TX_GPIO (CONFIG_ESP_CONSOLE_UART_TX_GPIO)
  • CONFIG_CXX_EXCEPTIONS (CONFIG_COMPILER_CXX_EXCEPTIONS)
  • CONFIG_CXX_EXCEPTIONS_EMG_POOL_SIZE (CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE)
  • CONFIG_DUPLICATE_SCAN_CACHE_SIZE (CONFIG_BTDM_SCAN_DUPL_CACHE_SIZE)
  • CONFIG_EFUSE_SECURE_VERSION_EMULATE (CONFIG_BOOTLOADER_EFUSE_SECURE_VERSION_EMULATE)
  • CONFIG_ENABLE_STATIC_TASK_CLEAN_UP_HOOK (CONFIG_FREERTOS_ENABLE_STATIC_TASK_CLEAN_UP)
  • CONFIG_ESP32_APPTRACE_ONPANIC_HOST_FLUSH_TMO (CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO)
  • CONFIG_ESP32_APPTRACE_PENDING_DATA_SIZE_MAX (CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX)
  • CONFIG_ESP32_APPTRACE_POSTMORTEM_FLUSH_TRAX_THRESH (CONFIG_APPTRACE_POSTMORTEM_FLUSH_TRAX_THRESH)
  • CONFIG_ESP32_COMPATIBLE_PRE_V2_1_BOOTLOADERS (CONFIG_APP_COMPATIBLE_PRE_V2_1_BOOTLOADERS)
  • CONFIG_ESP32_COMPATIBLE_PRE_V3_1_BOOTLOADERS (CONFIG_APP_COMPATIBLE_PRE_V3_1_BOOTLOADERS)
  • CONFIG_ESP32_CORE_DUMP_DECODE (CONFIG_ESP32_CORE_DUMP_DECODE_INFO)
    - CONFIG_ESP32_CORE_DUMP_DECODE_DISABLE
    - CONFIG_ESP32_CORE_DUMP_DECODE_INFO
    • CONFIG_ESP32_CORE_DUMP_MAX_TASKS_NUM (CONFIG_ESP32_CORE_DUMP_MAX_TASKS_NUM)
    • CONFIG_ESP32_CORE_DUMP_STACK_SIZE (CONFIG_ESP32_CORE_DUMP_STACK_SIZE)
    • CONFIG_ESP32_CORE_DUMP_UART_DELAY (CONFIG_ESP32_CORE_DUMP_UART_DELAY)
    • CONFIG_ESP32_DEBUG_STUBS_ENABLE (CONFIG_ESP32_DEBUG_STUBS_ENABLE)
    • CONFIG_ESP32_GCOV_ENABLE (CONFIG_ESP32_GCOV_ENABLE)
    • CONFIG_ESP32_PHY_CALIBRATION_AND_DATA_STORAGE (CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE)
    • CONFIG_ESP32_PHY_DEFAULT_INIT_IF_INVALID (CONFIG_ESP32_PHY_DEFAULT_INIT_IF_INVALID)
    • CONFIG_ESP32_PHY_INIT_DATA_ERROR (CONFIG_ESP32_PHY_INIT_DATA_ERROR)
    • CONFIG_ESP32_PHY_INIT_DATA_IN_PARTITION (CONFIG_ESP32_PHY_INIT_DATA_IN_PARTITION)
    • CONFIG_ESP32_PHY_MAC_BB_PD (CONFIG_ESP32_PHY_MAC_BB_PD)
    • CONFIG_ESP32_PHY_MAX_WIFI_TX_POWER (CONFIG_ESP32_PHY_MAX_WIFI_TX_POWER)
    • CONFIG_ESP32_PTHREAD_STACK_MIN (CONFIG_ESP32_PTHREAD_STACK_MIN)
  • CONFIG_ESP32_PTHREAD_TASK_CORE_DEFAULT (CONFIG_ESP32_PTHREAD_TASK_CORE_DEFAULT)
    - CONFIG_ESP32_DEFAULT_PTHREAD_CORE_NO_AFFINITY
    - CONFIG_ESP32_DEFAULT_PTHREAD_CORE_0
    - CONFIG_ESP32_DEFAULT_PTHREAD_CORE_1
    • CONFIG_ESP32_PTHREAD_TASK_NAME_DEFAULT (CONFIG_ESP32_PTHREAD_TASK_NAME_DEFAULT)
    • CONFIG_ESP32_PTHREAD_TASK_PRIO_DEFAULT (CONFIG_ESP32_PTHREAD_TASK_PRIO_DEFAULT)
    • CONFIG_ESP32_PTHREAD_TASK_STACK_SIZE_DEFAULT (CONFIG_ESP32_PTHREAD_TASK_STACK_SIZE_DEFAULT)
    • CONFIG_ESP32_REDUCE_PHY_TX_POWER (CONFIG_ESP32_REDUCE_PHY_TX_POWER)
    • CONFIG_ESP32_RTC_XTAL_BOOTSTRAP_CYCLES (CONFIG_ESP32_RTC_XTAL_BOOTSTRAP_CYCLES)
    • CONFIG_ESP32_SUPPORT_MULTIPLE_PHY_INIT_DATA_BIN (CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN)
    • CONFIG_ESP32_WIFI_AMPDU_RX_ENABLED (CONFIG_ESP32_WIFI_AMPDU_RX_ENABLED)
    • CONFIG_ESP32_WIFI_AMPDU_TX_ENABLED (CONFIG_ESP32_WIFI_AMPDU_TX_ENABLED)
    • CONFIG_ESP32_WIFI_AMSDU_TX_ENABLED (CONFIG_ESP32_WIFI_AMSDU_TX_ENABLED)
    • CONFIG_ESP32_WIFI_CACHE_TX_BUFFER_NUM (CONFIG_ESP32_WIFI_CACHE_TX_BUFFER_NUM)
    • CONFIG_ESP32_WIFI_CSI_ENABLED (CONFIG_ESP32_WIFI_CSI_ENABLED)
    • CONFIG_ESP32_WIFI_DYNAMIC_RX_BUFFER_NUM (CONFIG_ESP32_WIFI_DYNAMIC_RX_BUFFER_NUM)
    • CONFIG_ESP32_WIFI_DYNAMIC_TX_BUFFER_NUM (CONFIG_ESP32_WIFI_DYNAMIC_TX_BUFFER_NUM)
    • CONFIG_ESP32_WIFI_ENABLE_WPA3_OWE_STA (CONFIG_ESP32_WIFI_ENABLE_WPA3_OWE_STA)
• CONFIG_ESP32_WIFI_ENABLE_WPA3_SAE (CONFIG_ESP_WIFI_ENABLE_WPA3_SAE)
• CONFIG_ESP32_WIFI_IRAM_OPT (CONFIG_ESP_WIFI_IRAM_OPT)
• CONFIG_ESP32_WIFI_MGMT_SBUF_NUM (CONFIG_ESP_WIFI_MGMT_SBUF_NUM)
• CONFIG_ESP32_WIFI_NVS_ENABLED (CONFIG_ESP_WIFI_NVS_ENABLED)
• CONFIG_ESP32_WIFI_RX_BA_WIN (CONFIG_ESP_WIFI_RX_BA_WIN)
• CONFIG_ESP32_WIFI_RX_IRAM_OPT (CONFIG_ESP_WIFI_RX_IRAM_OPT)
• CONFIG_ESP32_WIFI_SOFTAP_BEACON_MAX_LEN (CONFIG_ESP_WIFI_SOFTAP_BEACON_MAX_LEN)
• CONFIG_ESP32_WIFI_STATIC_RX_BUFFER_NUM (CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM)
• CONFIG_ESP32_WIFI_STATIC_TX_BUFFER_NUM (CONFIG_ESP_WIFI_STATIC_TX_BUFFER_NUM)
• CONFIG_ESP32_WIFI_SW_COEXIST_ENABLE (CONFIG_ESP_COEX_SW_COEXIST_ENABLE)

• CONFIG_ESP32_WIFI_TASK_CORE_ID (CONFIG_ESP_WIFI_TASK_CORE_ID)
  – CONFIG_ESP32_WIFI_TASK_PINNED_TO_CORE_0
  – CONFIG_ESP32_WIFI_TASK_PINNED_TO_CORE_1
• CONFIG_ESP32_WIFI_TX_BA_WIN (CONFIG_ESP_WIFI_TX_BA_WIN)
• CONFIG_ESP32_WIFI_TX_BUFFER (CONFIG_ESP_WIFI_TX_BUFFER)
  – CONFIG_ESP32_WIFI_STATIC_TX_BUFFER
  – CONFIG_ESP32_WIFI_DYNAMIC_TX_BUFFER
• CONFIG_ESP_GATT_ENABLE (CONFIG_BT_GATT_ENABLE)
• CONFIG_ESP_GATT_SEND_SERVICE_CHANGE_MODE (CONFIG_BT_GATT_SEND_SERVICE_CHANGE_MODE)
  – CONFIG_GATT_SEND_SERVICE_CHANGE_MANUAL
  – CONFIG_GATT_SEND_SERVICE_CHANGE_AUTO
• CONFIG_GATT_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_GATT_TRACE_LEVEL)
  – CONFIG_GATT_TRACE_LEVEL_NONE
  – CONFIG_GATT_TRACE_LEVEL_ERROR
  – CONFIG_GATT_TRACE_LEVEL_WARNING
  – CONFIG_GATT_TRACE_LEVEL_API
  – CONFIG_GATT_TRACE_LEVEL_EVENT
  – CONFIG_GATT_TRACE_LEVEL_DEBUG
  – CONFIG_GATT_TRACE_LEVEL_VERBOSE
• CONFIG_GAP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_GAP_TRACE_LEVEL)
  – CONFIG_GAP_TRACE_LEVEL_NONE
  – CONFIG_GAP_TRACE_LEVEL_ERROR
  – CONFIG_GAP_TRACE_LEVEL_WARNING
  – CONFIG_GAP_TRACE_LEVEL_API
  – CONFIG_GAP_TRACE_LEVEL_EVENT
  – CONFIG_GAP_TRACE_LEVEL_DEBUG
  – CONFIG_GAP_TRACE_LEVEL_VERBOSE
• CONFIG_GMRP_TMR_INTERVAL (CONFIG_LWIP_GARP_TMR_INTERVAL)
• CONFIG_GATT_CACHENVS_FLASH (CONFIG_BT_GATTCACHE_NVS_FLASH)
• CONFIG_GATTC_ENABLE (CONFIG_BT_GATTC_ENABLE)
• CONFIG_GATTS_ENABLE (CONFIG_BT_GATTS_ENABLE)
• CONFIG_GATTSEND_SERVICE_CHANGE_MODE (CONFIG_BT_GATTS_SEND_SERVICE_CHANGE_MODE)
  – CONFIG_GATTS_SEND_SERVICE_CHANGE_MANUAL
  – CONFIG_GATTS_SEND_SERVICE_CHANGE_AUTO
• CONFIG_GATT_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_GATT_TRACE_LEVEL)
  – CONFIG_GATT_TRACE_LEVEL_NONE
  – CONFIG_GATT_TRACE_LEVEL_ERROR
  – CONFIG_GATT_TRACE_LEVEL_WARNING
  – CONFIG_GATT_TRACE_LEVEL_API
  – CONFIG_GATT_TRACE_LEVEL_EVENT
  – CONFIG_GATT_TRACE_LEVEL_DEBUG
  – CONFIG_GATT_TRACE_LEVEL_VERBOSE
• CONFIG_GDBSTUB_MAX_TASKS (CONFIG_ESP_GDBSTUB_MAX_TASKS)
• CONFIG_GDBSTUB_SUPPORT_TASKS (CONFIG_ESP_GDBSTUB_SUPPORT_TASKS)
• CONFIG_HCI_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_HCI_TRACE_LEVEL)
  – CONFIG_HCI_TRACE_LEVEL_NONE
- CONFIG_HCI_TRACE_LEVEL_ERROR
- CONFIG_HCI_TRACE_LEVEL_WARNING
- CONFIG_HCI_TRACE_LEVEL_API
- CONFIG_HCI_TRACE_LEVEL_EVENT
- CONFIG_HCI_TRACE_LEVEL_DEBUG
- CONFIG_HCI_TRACE_LEVEL_VERBOSE

• CONFIG_HFP_AUDIO_DATA_PATH (CONFIG_BT_HFP_AUDIO_DATA_PATH)
  - CONFIG_HFP_AUDIO_DATA_PATH_PCM
  - CONFIG_HFP_AUDIO_DATA_PATH_HCI

• CONFIG_HFP_ENABLE (CONFIG_BT_HFP_ENABLE)

• CONFIG_HFP_ROLE (CONFIG_BT_HFP_ROLE)
  - CONFIG_HFP_CLIENT_ENABLE
  - CONFIG_HFP_AG_ENABLE

• CONFIG_HID_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_HID_TRACE_LEVEL)
  - CONFIG_HID_TRACE_LEVEL_NONE
  - CONFIG_HID_TRACE_LEVEL_ERROR
  - CONFIG_HID_TRACE_LEVEL_WARNING
  - CONFIG_HID_TRACE_LEVEL_API
  - CONFIG_HID_TRACE_LEVEL_EVENT
  - CONFIG_HID_TRACE_LEVEL_DEBUG
  - CONFIG_HID_TRACE_LEVEL_VERBOSE

• CONFIG_INT_WDT (CONFIG_ESP_INT_WDT)
• CONFIG_INT_WDT_CHECK_CPU1 (CONFIG_ESP_INT_WDT_CHECK_CPU1)
• CONFIG_INT_WDT_TIMEOUT_MS (CONFIG_ESP_INT_WDT_TIMEOUT_MS)
• CONFIG_IPC_TASK_STACK_SIZE (CONFIG_ESP_IPC_TASK_STACK_SIZE)

• CONFIG_L2CAP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_L2CAP_TRACE_LEVEL)
  - CONFIG_L2CAP_TRACE_LEVEL_NONE
  - CONFIG_L2CAP_TRACE_LEVEL_ERROR
  - CONFIG_L2CAP_TRACE_LEVEL_WARNING
  - CONFIG_L2CAP_TRACE_LEVEL_API
  - CONFIG_L2CAP_TRACE_LEVEL_EVENT
  - CONFIG_L2CAP_TRACE_LEVEL_DEBUG
  - CONFIG_L2CAP_TRACE_LEVEL_VERBOSE

• CONFIG_L2_TO_L3_COPY (CONFIG_LWIP_L2_TO_L3_COPY)
• CONFIG_LOG_BOOTLOADER_LEVEL (CONFIG_BOOTLOADER_LOG_LEVEL)
  - CONFIG_LOG_BOOTLOADER_LEVEL_NONE
  - CONFIG_LOG_BOOTLOADER_LEVEL_ERROR
  - CONFIG_LOG_BOOTLOADER_LEVEL_WARN
  - CONFIG_LOG_BOOTLOADER_LEVEL_INFO
  - CONFIG_LOG_BOOTLOADER_LEVEL_DEBUG
  - CONFIG_LOG_BOOTLOADER_LEVEL_VERBOSE

• CONFIG_MAC_BB_PD (CONFIG_ESP_PHY_MAC_BB_PD)
• CONFIG_MAIN_TASK_STACK_SIZE (CONFIG_ESP_MAIN_TASK_STACK_SIZE)

• CONFIG_MCA_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_MCA_TRACE_LEVEL)
  - CONFIG_MCA_TRACE_LEVEL_NONE
  - CONFIG_MCA_TRACE_LEVEL_ERROR
  - CONFIG_MCA_TRACE_LEVEL_WARNING
  - CONFIG_MCA_TRACE_LEVEL_API
  - CONFIG_MCA_TRACE_LEVEL_EVENT
  - CONFIG_MCA_TRACE_LEVEL_DEBUG
  - CONFIG_MCA_TRACE_LEVEL_VERBOSE

• CONFIG_MCPWM_ISR_IN_IRAM (CONFIG_MCPWM_ISR_IRAM_SAFE)
• CONFIG_MESH_DUPLICATE_SCAN_CACHE_SIZE (CONFIG_BTDM_MESH_DUPL_SCAN_CACHE_SIZE)
• CONFIG_NIMBLE_ATT_PREFERRED_MTU (CONFIG_BT_NIMBLE_ATT_PREFERRED_MTU)
• CONFIG_NIMBLE_CRYPTO_STACK_MBEDTLS (CONFIG_BT_NIMBLE_CRYPTO_STACK_MBEDTLS)
• CONFIG_NIMBLE_DEBUG (CONFIG_BT_NIMBLE_DEBUG)
• CONFIG_NIMBLE_GAP_DEVICE_NAME_MAX_LEN (CONFIG_BT_NIMBLE_GAP_DEVICE_NAME_MAX_LEN)
• CONFIG_NIMBLE_HS_FLOW_CTRL (CONFIG_BT_NIMBLE_HS_FLOW_CTRL)
• CONFIG_NIMBLE_HS_FLOW_CTRL_ITVL (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_ITVL)
• CONFIG_NIMBLE_HS_FLOW_CTRL_THRESH (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_THRESH)
• CONFIG_NIMBLE_HS_FLOW_CTRL_TX_ON_DISCONNECT (CONFIG_BT_NIMBLE_HS_FLOW_CTRL_TX_ON_DISCONNECT)
• CONFIG_NIMBLE_L2CAP_COC_MAX_NUM (CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM)
• CONFIG_NIMBLE_MAX_BONDS (CONFIG_BT_NIMBLE_MAX_BONDS)
• CONFIG_NIMBLE_MAX_CCCDS (CONFIG_BT_NIMBLE_MAX_CCCDS)
• CONFIG_NIMBLE_MAX_CONNECTIONS (CONFIG_BT_NIMBLE_MAX_CONNECTIONS)
• CONFIG_NIMBLE_MEM_ALLOC_MODE (CONFIG_BT_NIMBLE_MEM_ALLOC_MODE)
  – CONFIG_NIMBLE_MEM_ALLOC_MODE_INTERNAL
  – CONFIG_NIMBLE_MEM_ALLOC_MODE_EXTERNAL
  – CONFIG_NIMBLE_MEM_ALLOC_MODE_DEFAULT
• CONFIG_NIMBLE_MESH (CONFIG_BT_NIMBLE_MESH)
• CONFIG_NIMBLE_MESH_DEVICE_NAME (CONFIG_BT_NIMBLE_MESH_DEVICE_NAME)
• CONFIG_NIMBLE_MESH_FRIEND (CONFIG_BT_NIMBLE_MESH_FRIEND)
• CONFIG_NIMBLE_MESH_GATT_PROXY (CONFIG_BT_NIMBLE_MESH_GATT_PROXY)
• CONFIG_NIMBLE_MESH_LOW_POWER (CONFIG_BT_NIMBLE_MESH_LOW_POWER)
• CONFIG_NIMBLE_MESH_PB_ADV (CONFIG_BT_NIMBLE_MESH_PB_ADV)
• CONFIG_NIMBLE_MESH_PB_GATT (CONFIG_BT_NIMBLE_MESH_PB_GATT)
• CONFIG_NIMBLE_MESH_PROV (CONFIG_BT_NIMBLE_MESH_PROV)
• CONFIG_NIMBLE_MESH_PROXY (CONFIG_BT_NIMBLE_MESH_PROXY)
• CONFIG_NIMBLE_MESH_RELAY (CONFIG_BT_NIMBLE_MESH_RELAY)
• CONFIG_NIMBLE_NVS_PERSIST (CONFIG_BT_NIMBLE_NVS_PERSIST)
• CONFIG_NIMBLE_PINNED_TO_CORE_CHOICE (CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE)
  – CONFIG_NIMBLE_PINNED_TO_CORE_0
  – CONFIG_NIMBLE_PINNED_TO_CORE_1
• CONFIG_NIMBLE_ROLE_BROADCASTER (CONFIG_BT_NIMBLE_ROLE_BROADCASTER)
• CONFIG_NIMBLE_ROLE_CENTRAL (CONFIG_BT_NIMBLE_ROLE_CENTRAL)
• CONFIG_NIMBLE_ROLE_OBSERVER (CONFIG_BT_NIMBLE_ROLE_OBSERVER)
• CONFIG_NIMBLE_ROLE_PERIPHERAL (CONFIG_BT_NIMBLE_ROLE_PERIPHERAL)
• CONFIG_NIMBLE_RPA_TIMEOUT (CONFIG_BT_NIMBLE_RPA_TIMEOUT)
• CONFIG_NIMBLE_SM_LEGACY (CONFIG_BT_NIMBLE_SM_LEGACY)
• CONFIG_NIMBLE_SM_SC (CONFIG_BT_NIMBLE_SM_SC)
• CONFIG_NIMBLE_SM_SC_DEBUG_KEYS (CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS)
• CONFIG_NIMBLE_SVC_GAP_APPEARANCE (CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE)
• CONFIG_NIMBLE_SVC_GAP_DEVICE_NAME (CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_NAME)
• CONFIG_NIMBLE_TASK_STACK_SIZE (CONFIG_BT_NIMBLE_HOST_TASK_STACK_SIZE)
• CONFIG_NO_BLOBS (CONFIG_APP_NO_BLOBS)
• CONFIG_NUMBER_OF_UNIVERSAL_MAC_ADDRESS (CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES)
  – CONFIG_TWO_UNIVERSAL_MAC_ADDRESS
  – CONFIG_FOUR_UNIVERSAL_MAC_ADDRESS
• CONFIG_OPTIMIZATION_ASSERTION_LEVEL (CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL)
  – CONFIG_OPTIMIZATION_ASSERTIONS_ENABLED
  – CONFIG_OPTIMIZATION_ASSERTIONS_SILENT
  – CONFIG_OPTIMIZATION_ASSERTIONS_DISABLED
• CONFIG_OPTIMIZATION_COMPILER (CONFIG_COMPILER_OPTIMIZATION)
  – CONFIG_OPTIMIZATION_LEVEL_DEBUG, CONFIG_COMPILER_OPTIMIZATION_LEVEL_DEBUG
  – CONFIG_OPTIMIZATION_LEVEL_RELEASE, CONFIG_COMPILER_OPTIMIZATION_LEVEL_RELEASE
• CONFIG_OSI_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_OSI_TRACE_LEVEL)
  – CONFIG_OSI_TRACE_LEVEL_NONE
  – CONFIG_OSI_TRACE_LEVEL_ERROR
  – CONFIG_OSI_TRACE_LEVEL_WARNING
  – CONFIG_OSI_TRACE_LEVEL_API
  – CONFIG_OSI_TRACE_LEVEL_EVENT
  – CONFIG_OSI_TRACE_LEVEL_DEBUG
Chapter 2. API Reference

- CONFIG_OSI_TRACE_LEVEL_VERBOSE
  • CONFIG_OTA_ALLOW_HTTP (CONFIG_ESP_HTTPS_OTA_ALLOW_HTTP)
  • CONFIG_PAN_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_PAN_TRACE_LEVEL)
    - CONFIG_PAN_TRACE_LEVEL_NONE
    - CONFIG_PAN_TRACE_LEVEL_ERROR
    - CONFIG_PAN_TRACE_LEVEL_WARNING
    - CONFIG_PAN_TRACE_LEVEL_API
    - CONFIG_PAN_TRACE_LEVEL_EVENT
    - CONFIG_PAN_TRACE_LEVEL_DEBUG
    - CONFIG_PAN_TRACE_LEVEL_VERBOSE
  • CONFIG_POST_EVENTS_FROM_IRAM_ISR (CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR)
  • CONFIG_POST_EVENTS_FROM_ISR (CONFIG_ESP_EVENT_POST_FROM_ISR)
  • CONFIG_PPP_CHAP_SUPPORT (CONFIG_LWIP_PPP_CHAP_SUPPORT)
  • CONFIG_PPP_DEBUG_ON (CONFIG_LWIP_PPP_DEBUG_ON)
  • CONFIG_PPP_MPPE_SUPPORT (CONFIG_LWIP_PPP_MPPE_SUPPORT)
  • CONFIG_PPP_MSCAP_SUPPORT (CONFIG_LWIP_PPP_MSCAP_SUPPORT)
  • CONFIG_PPP_NOTIFY_PHASE_SUPPORT (CONFIG_LWIP_PPP_NOTIFY_PHASE_SUPPORT)
  • CONFIG_PPP_PAP_SUPPORT (CONFIG_LWIP_PPP_PAP_SUPPORT)
  • CONFIG_PPP_SUPPORT (CONFIG_LWIP_PPP_SUPPORT)
  • CONFIG_REDUCE_PHY_TX_POWER (CONFIG_ESP_PHY_REDUCE_TX_POWER)
  • CONFIG_RFCOMM_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL)
    - CONFIG_RFCOMM_TRACE_LEVEL_NONE
    - CONFIG_RFCOMM_TRACE_LEVEL_ERROR
    - CONFIG_RFCOMM_TRACE_LEVEL_WARNING
    - CONFIG_RFCOMM_TRACE_LEVEL_API
    - CONFIG_RFCOMM_TRACE_LEVEL_EVENT
    - CONFIG_RFCOMM_TRACE_LEVEL_DEBUG
    - CONFIG_RFCOMM_TRACE_LEVEL_VERBOSE
  • CONFIG_SCAN_DUPLICATE_TYPE (CONFIG_BTDM_SCAN_DUPL_TYPE)
    - CONFIG_SCAN_DUPLICATE_BY_DEVICE_ADDR
    - CONFIG_SCAN_DUPLICATE_BY_ADV_DATA
    - CONFIG_SCAN_DUPLICATE_BY_ADV_DATA_AND_DEVICE_ADDR
  • CONFIG_SEMIHOSTFS_MAX_MOUNT_POINTS (CONFIG_VFS_SEMIHOSTFS_MAX_MOUNT_POINTS)
  • CONFIG_SMP_INITIAL_TRACE_LEVEL (CONFIG_BT_LOG_SMP_TRACE_LEVEL)
    - CONFIG_SMP_TRACE_LEVEL_NONE
    - CONFIG_SMP_TRACE_LEVEL_ERROR
    - CONFIG_SMP_TRACE_LEVEL_WARNING
    - CONFIG_SMP_TRACE_LEVEL_API
    - CONFIG_SMP_TRACE_LEVEL_EVENT
    - CONFIG_SMP_TRACE_LEVEL_DEBUG
    - CONFIG_SMP_TRACE_LEVEL_VERBOSE
  • CONFIG_SMP_SLAVE_CON_PARAMS_UPD_ENABLE (CONFIG_BT_SMP_SLAVE_CON_PARAMS_UPD_ENABLE)
  • CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS (CONFIG_SPI_FLASH_DANGEROUS_WRITE)
    - CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS_ABORTS
    - CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS_FAILS
    - CONFIG_SPI_FLASH_WRITING_DANGEROUS_REGIONS_ALLOWED
  • CONFIG_STACK_CHECK_MODE (CONFIG_COMPILER_STACK_CHECK_MODE)
    - CONFIG_STACK_CHECK_NONE
    - CONFIG_STACK_CHECK_NORM
    - CONFIG_STACK_CHECK_STRONG
    - CONFIG_STACK_CHECK_ALL
  • CONFIG_SUPPORT_TERMIOS (CONFIG_VFS_SUPPORT_TERMIOS)
  • CONFIG_SUPPRESS_SELECT_DEBUG_OUTPUT (CONFIG_VFS_SUPPRESS_SELECT_DEBUG_OUTPUT)
  • CONFIG_SW_COEXIST_ENABLE (CONFIG_ESP_COEX_SW_COEXIST_ENABLE)
  • CONFIG_SYSTEM_EVENT_QUEUE_SIZE (CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE)
  • CONFIG_SYSTEM_EVENT_TASK_STACK_SIZE (CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE)
  • CONFIG_SYSVIEW_BUF_WAIT_TMO (CONFIG_APTRACE_SV_BUF_WAIT_TMO)
Chapter 2. API Reference

- `CONFIG_SYSVIEW_ENABLE` (`CONFIG_APPTRACE_SV_ENABLE`)
- `CONFIG_SYSVIEW_EVT_IDLE_ENABLE` (`CONFIG_APPTRACE_SV_EVT_IDLE_ENABLE`)
- `CONFIG_SYSVIEW_EVT_ISR_ENTER_ENABLE` (`CONFIG_APPTRACE_SV_EVT_ISR_ENTER_ENABLE`)
- `CONFIG_SYSVIEW_EVT_ISR_EXIT_ENABLE` (`CONFIG_APPTRACE_SV_EVT_ISR_EXIT_ENABLE`)
- `CONFIG_SYSVIEW_EVT_ISR_TO_SCHEDULER_ENABLE` (`CONFIG_APPTRACE_SV_EVT_ISR_TO_SCHED_ENABLE`)
- `CONFIG_SYSVIEW_EVT_OVERFLOW_ENABLE` (`CONFIG_APPTRACE_SV_EVT_OVERFLOW_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TASK_CREATE_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TASK_CREATE_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TASK_START_EXEC_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TASK_START_EXEC_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TASK_START_READY_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TASK_START_READY_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TASK_STOP_EXEC_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TASK_STOP_EXEC_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TASK_STOP_READY_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TASK_STOP_READY_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TASK_TERMINATE_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TASK_TERMINATE_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TIMER_ENTER_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TIMER_ENTER_ENABLE`)
- `CONFIG_SYSVIEW_EVT_TIMER_EXIT_ENABLE` (`CONFIG_APPTRACE_SV_EVT_TIMER_EXIT_ENABLE`)
- `CONFIG_SYSVIEW_MAX_TASKS` (`CONFIG_APPTRACE_SV_MAX_TASKS`)
- `CONFIG_SYSVIEW_TS_SOURCE` (`CONFIG_APPTRACE_SV_TS_SOURCE`)
  - `CONFIG_SYSVIEW_TS_SOURCE_CCOUNT`
  - `CONFIG_SYSVIEW_TS_SOURCE_ESP_TIMER`
- `CONFIG_TASK_WDT` (`CONFIG_ESP_TASK_WDT_INIT`)
- `CONFIG_TASK_WDT_CHECK_IDLE_TASK_CPU0` (`CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU0`)
- `CONFIG_TASK_WDT_CHECK_IDLE_TASK_CPU1` (`CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU1`)
- `CONFIG_TASK_WDT_PANIC` (`CONFIG_ESP_TASK_WDT_PANIC`)
- `CONFIG_TASK_WDT_TIMEOUT_S` (`CONFIG_ESP_TASK_WDT_TIMEOUT_S`)
- `CONFIG_TCPIP_RECVMBOX_SIZE` (`CONFIG_LWIP_TCPIP_RECVMBOX_SIZE`)
- `CONFIG_TCPIP_TASK_AFFINITY` (`CONFIG_LWIP_TCPIP_TASK_AFFINITY`)
  - `CONFIG_TCPIP_TASK_AFFINITY_NO_AFFINITY`
  - `CONFIG_TCPIP_TASK_AFFINITY_CPU0`
  - `CONFIG_TCPIP_TASK_AFFINITY_CPU1`
- `CONFIG_TCPIP_TASK_STACK_SIZE` (`CONFIG_LWIP_TCPIP_TASK_STACK_SIZE`)
- `CONFIG_TCP_MAXRTX` (`CONFIG_LWIP_TCP_MAXRTX`)
- `CONFIG_TCP_MSL` (`CONFIG_LWIP_TCP_MSL`)
- `CONFIG_TCP_MSS` (`CONFIG_LWIP_TCP_MSS`)
- `CONFIG_TCP_QUEUE_OOSEQ` (`CONFIG_LWIP_TCP_QUEUE_OOSEQ`)
- `CONFIG_TCP_RECVMBOX_SIZE` (`CONFIG_LWIP_TCP_RECVMBOX_SIZE`)
- `CONFIG_TCP_SYNMAXRTX` (`CONFIG_LWIP_TCP_SYNMAXRTX`)
- `CONFIG_TCP_WND_DEFAULT` (`CONFIG_LWIP_TCP_WND_DEFAULT`)
- `CONFIG_TIMER_QUEUE_LENGTH` (`CONFIG_FREERTOS_TIMER_QUEUE_LENGTH`)
- `CONFIG_TIMER_TASK_PRIORITY` (`CONFIG_FREERTOS_TIMER_TASK_PRIORITY`)
- `CONFIG_TIMER_TASK_STACK_DEPTH` (`CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH`)
- `CONFIG_UDP_RECVMBOX_SIZE` (`CONFIG_LWIP_UDP_RECVMBOX_SIZE`)
- `CONFIG_WARN_WRITE_STRINGS` (`CONFIG_COMPILER_WARN_WRITE_STRINGS`)
- `CONFIG_WPA_11KV_SUPPORT` (`CONFIG_ESP_WIFI_11KV_SUPPORT`)
- `CONFIG_WPA_11R_SUPPORT` (`CONFIG_ESP_WIFI_11R_SUPPORT`)
- `CONFIG_WPA_DEBUG_PRINT` (`CONFIG_ESP_WIFI_DEBUG_PRINT`)
- `CONFIG_WPA_DPP_SUPPORT` (`CONFIG_ESP_WIFI_DPP_SUPPORT`)
- `CONFIG_WPA_MBO_SUPPORT` (`CONFIG_ESP_WIFI_MBO_SUPPORT`)
- `CONFIG_WPA_SCAN_CACHE` (`CONFIG_ESP_WIFI_SCAN_CACHE`)
- `CONFIG_WPA_SUITE_B_192` (`CONFIG_ESP_WIFI_SUITE_B_192`)
- `CONFIG_WPA_TESTING_OPTIONS` (`CONFIG_ESP_WIFI_TESTING_OPTIONS`)
- `CONFIG_WPA_WAPI_PSK` (`CONFIG_ESP_WIFI_WAPI_PSK`)
2.8 Provisioning API

2.8.1 Protocol Communication

Overview

The Protocol Communication (protocomm) component manages secure sessions and provides the framework for multiple transports. The application can also use the protocomm layer directly to have application-specific extensions for the provisioning or non-provisioning use cases.

Following features are available for provisioning:

- Communication security at the application level
  - protocomm_security0 (no security)
  - protocomm_security1 (Curve25519 key exchange + AES-CTR encryption/decryption)
  - protocomm_security2 (SRP6a-based key exchange + AES-GCM encryption/decryption)
- Proof-of-possession (support with protocomm_security1 only)
- Salt and Verifier (support with protocomm_security2 only)

Protocomm internally uses protobuf (protocol buffers) for secure session establishment. Users can choose to implement their own security (even without using protobuf). Protocomm can also be used without any security layer.

Protocomm provides the framework for various transports:

- Bluetooth LE
- Wi-Fi (SoftAP + HTTPD)
- Console, in which case the handler invocation is automatically taken care of on the device side. See Transport Examples below for code snippets.

Note that for protocomm_security1 and protocomm_security2, the client still needs to establish sessions by performing the two-way handshake. See Unified Provisioning for more details about the secure handshake logic.

Enabling Protocomm Security Version

The protocomm component provides a project configuration menu to enable/disable support of respective security versions. The respective configuration options are as follows:

- Support protocomm_security0 with no security: `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_0`, this option is enabled by default.
- Support protocomm_security1 with Curve25519 key exchange + AES-CTR encryption/decryption: `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_1`, this option is enabled by default.
- Support protocomm_security2 with SRP6a-based key exchange + AES-GCM encryption/decryption: `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_2`.

Note: Enabling multiple security versions at once offers the ability to control them dynamically but also increases the firmware size.
SoftAP + HTTP Transport Example with Security 2

For sample usage, see wifi_provisioning/src/scheme_softap.c.

```c
/* The endpoint handler to be registered with protocomm. This simply echoes back the received data. */
esp_err_t echo_req_handler (uint32_t session_id,
const uint8_t *inbuf, ssize_t inlen,
const uint8_t **outbuf, ssize_t *outlen,
void *priv_data)
{
    /* Session ID may be used for persistence. */
    printf("Session ID : %d", session_id);

    /* Echo back the received data. */
    *outlen = inlen;  /* Output the data length updated. */
    *outbuf = malloc(inlen);  /* This is to be deallocated outside. */
    memcpy(*outbuf, inbuf, inlen);

    /* Private data that was passed at the time of endpoint creation. */
    uint32_t *priv = (uint32_t *) priv_data;
    if (priv) {
        printf("Private data : %d", *priv);
    }
    return ESP_OK;
}

static const char sec2_salt[] = {0xf7, 0x5f, 0xe2, 0xbe, 0xba, 0x7c, 0x81, 0xcd};
static const char sec2_verifier[] = {0xbf, 0x86, 0xce, 0x63, 0x8a, 0xbb, 0x7e};
```

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/* The example function for launching a protocomm instance over HTTP. */
protocomm_t *start_pc()
{
    protocomm_t *pc = protocomm_new();

    /* Config for protocomm_httpd_start(). */
    protocomm_httpd_config_t pc_config = {
        .data = {
            .config = PROTOCOL_HTTPD_DEFAULT_CONFIG()
        }
    };

    /* Start the protocomm server on top of HTTP. */
    protocomm_httpd_start(pc, &pc_config);

    /* Create Security2 params object from salt and verifier. It must be valid
    throughout the scope of protocomm endpoint. This does not need to be static, i.e.
    could be dynamically allocated and freed at the time of endpoint removal. */
    const static protocomm_security2_params_t sec2_params = {
        .salt = (const uint8_t *) salt,
        .salt_len = sizeof(salt),
        .verifier = (const uint8_t *) verifier,
        .verifier_len = sizeof(verifier),
    };

    /* Set security for communication at the application level. Just like for...
    request handlers, setting security creates an endpoint and registers the handler...
    one type of security can be set for a protocomm instance at a time. */
    protocomm_set_security(pc, "security_endpoint", &protocomm_security2, &sec2_
    params);

    /* Private data passed to the endpoint must be valid throughout the scope of...
    protocomm endpoint. This need not be static, i.e., could be dynamically...
    allocated and freed at the time of endpoint removal. */
    static uint32_t priv_data = 1234;

    /* Add a new endpoint for the protocomm instance, identified by a unique name,...
    register a handler function along with the private data to be passed at the...
    time of handler execution. Multiple endpoints can be added as long as they are...
    identified by unique names. */
    protocomm_add_endpoint(pc, "echo_req_endpoint", echo_req_handler, (void *) &priv_data);
    return pc;
}

/* The example function for stopping a protocomm instance. */
void stop_pc(protocomm_t *pc)
{
    /* Remove the endpoint identified by its unique name. */
    protocomm_remove_endpoint(pc, "echo_req_endpoint");
/* Remove the security endpoint identified by its name. */
protocomm_unset_security(pc, "security_endpoint");

/* Stop the HTTP server. */
protocomm_httpd_stop(pc);

/* Delete, namely deallocate the protocomm instance. */
protocomm_delete(pc);

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SoftAP + HTTP Transport Example with Security 1

For sample usage, see wifi_provisioning/src/scheme_softap.c.

/* The endpoint handler to be registered with protocomm. This simply echoes back...--the received data. */
esp_err_t echo_req_handler (uint32_t session_id,
    const uint8_t *inbuf, ssize_t inlen,
    uint8_t **outbuf, ssize_t *outlen,
    void *priv_data)
{
    /* Session ID may be used for persistence. */
    printf("Session ID : %d", session_id);

    /* Echo back the received data. */
    *outlen = inlen; /* Output the data length updated. */
    *outbuf = malloc(inlen); /* This is to be deallocated outside. */
    memcpy(*outbuf, inbuf, inlen);

    /* Private data that was passed at the time of endpoint creation. */
    uint32_t *priv = (uint32_t *) priv_data;
    if (priv) {
        printf("Private data : %d", *priv);
    }

    return ESP_OK;
}

/* The example function for launching a protocomm instance over HTTP. */
protocomm_t *start_pc(const char *pop_string)
{
    protocomm_t *pc = protocomm_new();

    /* Config for protocomm_httpd_start(). */
    protocomm_httpd_config_t pc_config = {
        .data = {
            .config = PROTOCOMM_HTTPD_DEFAULT_CONFIG()
        }
    };

    /* Start the protocomm server on top of HTTP. */
    protocomm_httpd_start(pc, &pc_config);

    /* Create secl_params object from pop_string. It must be valid throughout...--the scope of protocomm endpoint. This need not be static, i.e., could be...--dynamically allocated and freed at the time of endpoint removal. */
    const static protocomm_security1_params_t secl_params = {
        .data = (const uint8_t *) strdup(pop_string),
        .len = strlen(pop_string)
    };

    /* The example function for launching a protocomm instance over HTTP. */
    protocomm_t *start_pc(const char *pop_string)
    {
        protocomm_t *pc = protocomm_new();

        /* Config for protocomm_httpd_start(). */
        protocomm_httpd_config_t pc_config = {
            .data = {
                .config = PROTOCOMM_HTTPD_DEFAULT_CONFIG()
            }
        };

        /* Start the protocomm server on top of HTTP. */
        protocomm_httpd_start(pc, &pc_config);

        /* Create secl_params object from pop_string. It must be valid throughout...--the scope of protocomm endpoint. This need not be static, i.e., could be...--dynamically allocated and freed at the time of endpoint removal. */
        const static protocomm_security1_params_t secl_params = {
            .data = (const uint8_t *) strdup(pop_string),
            .len = strlen(pop_string)
        };
    }"
Chapter 2. API Reference

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};

/* Set security for communication at the application level. Just like for-
request handlers, setting security creates an endpoint and registers the handler-
provided by protocomm_security1. One can similarly use protocomm_security0. Only-
one type of security can be set for a protocomm instance at a time. */
protocomm_set_security(pc, "security_endpoint", sprotocomm_security1, &sec1_
params);

/* Private data passed to the endpoint must be valid throughout the scope of-
protocomm endpoint. This need not be static, i.e., could be dynamically-
allocated and freed at the time of endpoint removal. */
static uint32_t priv_data = 1234;

/* Add a new endpoint for the protocomm instance identified by a unique name,_
and register a handler function along with the private data to be passed at the-
time of handler execution. Multiple endpoints can be added as long as they are-
identified by unique names. */
protocomm_add_endpoint(pc, "echo_req_endpoint", 
    echo_req_handler, (void *) &priv_data);

return pc;
}

/* The example function for stopping a protocomm instance. */
void stop_pc(protocomm_t *pc)
{
    /* Remove the endpoint identified by its unique name. */
    protocomm_remove_endpoint(pc, "echo_req_endpoint");

    /* Remove the security endpoint identified by its name. */
    protocomm_unset_security(pc, "security_endpoint");

    /* Stop the HTTP server. */
    protocomm_httpd_stop(pc);

    /* Delete, namely deallocate the protocomm instance. */
    protocomm_delete(pc);
}

Bluetooth LE Transport Example with Security 0

For sample usage, see wifi_provisioning/src/scheme_ble.c.

/* The example function for launching a secure protocomm instance over Bluetooth_-
LE. */
protocomm_t *start_pc()
{
    protocomm_t *pc = protocomm_new();

    /* Endpoint UUIDs */
    protocomm_ble_name_uuid_t nu_lookup_table[] = {
        {"security_endpoint", 0xFF51},
        {"echo_req_endpoint", 0xFF52}
    };

    /* Config for protocomm_ble_start(). */
    protocomm_ble_config_t config = {
        .service_uuid = {
            /* LSB <---------------------------------------
             * ---------------------------------------> MSB */
            /* LSB <---------------------------------------
             * ---------------------------------------> MSB */
        }
    }

(continues on next page)
Chapter 2. API Reference

(continued from previous page)

0xfb, 0x34, 0x9b, 0x5f, 0x80, 0x00, 0x00, 0x80,
0x00, 0x10, 0x00, 0x00, 0xFF, 0xFF, 0x00, 0x00,
},
nu_lookup_count = sizeof(nu_lookup_table)/sizeof(nu_lookup_table[0]),
nu_lookup = nu_lookup_table
};

/* Start protocomm layer on top of Bluetooth LE. */
protocomm_ble_start(pc, &config);

/* For protocomm_security0, Proof of Possession is not used, and can be kept NULL. */
protocomm_set_security(pc, "security_endpoint", &protocomm_security0, NULL);
protocomm_add_endpoint(pc, "echo_req_endpoint", echo_req_handler, NULL);
return pc;
}

/* The example function for stopping a protocomm instance. */
void stop_pc(protocomm_t *pc)
{
    protocomm_remove_endpoint(pc, "echo_req_endpoint");
    protocomm_unset_security(pc, "security_endpoint");

    /* Stop the Bluetooth LE protocomm service. */
    protocomm_ble_stop(pc);
    protocomm_delete(pc);
}

API Reference

Header File

• components/protocomm/include/common/protocomm.h

Functions

protocomm_t *protocomm_new(void)
Create a new protocomm instance.

This API will return a new dynamically allocated protocomm instance with all elements of the protocomm_t structure initialized to NULL.

Returns

• protocomm_t*: On success
• NULL: No memory for allocating new instance

void protocomm_delete(protocomm_t *pc)
Delete a protocomm instance.

This API will deallocate a protocomm instance that was created using protocomm_new().

Parameters pc — [in] Pointer to the protocomm instance to be deleted

esp_err_t protocomm_add_endpoint(protocomm_t *pc, const char *ep_name, protocomm_req_handler_t h,
void *priv_data)
Add endpoint request handler for a protocomm instance.

This API will bind an endpoint handler function to the specified endpoint name, along with any private data that needs to be pass to the handler at the time of call.

Note:
An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.
This function internally calls the registered `add_endpoint()` function of the selected transport which is a member of the `protocomm_t` instance structure.

### Parameters
- `pc` - [in] Pointer to the protocomm instance
- `ep_name` - [in] Endpoint identifier (name) string
- `h` - [in] Endpoint handler function
- `priv_data` - [in] Pointer to private data to be passed as a parameter to the handler function on call. Pass NULL if not needed.

### Returns
- `ESP_OK` : Success
- `ESP_FAIL` : Error adding endpoint / Endpoint with this name already exists
- `ESP_ERR_NO_MEM` : Error allocating endpoint resource
- `ESP_ERR_INVALID_ARG` : Null instance/name/handler arguments

```c
esp_err_t protocomm_remove_endpoint (protocomm_t *pc, const char *ep_name)
```
Remove endpoint request handler for a protocomm instance.
This API will remove a registered endpoint handler identified by an endpoint name.

### Note:
- This function internally calls the registered `remove_endpoint()` function which is a member of the `protocomm_t` instance structure.

### Parameters
- `pc` - [in] Pointer to the protocomm instance
- `ep_name` - [in] Endpoint identifier (name) string

### Returns
- `ESP_OK` : Success
- `ESP_ERR_NOT_FOUND` : Endpoint with specified name doesn’t exist
- `ESP_ERR_INVALID_ARG` : Null instance/name arguments

```c
esp_err_t protocomm_open_session (protocomm_t *pc, uint32_t session_id)
```
Allocates internal resources for new transport session.

### Note:
- An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.

### Parameters
- `pc` - [in] Pointer to the protocomm instance
- `session_id` - [in] Unique ID for a communication session

### Returns
- `ESP_OK` : Request handled successfully
- `ESP_ERR_NO_MEM` : Error allocating internal resource
- `ESP_ERR_INVALID_ARG` : Null instance/name arguments

```c
esp_err_t protocomm_close_session (protocomm_t *pc, uint32_t session_id)
```
Frees internal resources used by a transport session.

### Note:
- An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.
Parameters
  • `pc` - [in] Pointer to the protocomm instance
  • `session_id` - [in] Unique ID for a communication session

Returns
  • ESP_OK : Request handled successfully
  • ESP_ERR_INVALID_ARG : Null instance/name arguments

```c
esp_err_t protocomm_req_handle (protocomm_t *pc, const char *ep_name, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen)
```

Calls the registered handler of an endpoint session for processing incoming data and generating the response.

**Note:**
  * An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.
  * Resulting output buffer must be deallocated by the caller.

Parameters
  • pc - [in] Pointer to the protocomm instance
  • ep_name –[in] Endpoint identifier(name) string
  • session_id –[in] Unique ID for a communication session
  • inbuf –[in] Input buffer contains input request data which is to be processed by the registered handler
  • inlen –[in] Length of the input buffer
  • outbuf –[out] Pointer to internally allocated output buffer, where the resulting response data output from the registered handler is to be stored
  • outlen –[out] Buffer length of the allocated output buffer

Returns
  • ESP_OK : Request handled successfully
  • ESP_FAIL : Internal error in execution of registered handler
  • ESP_ERR_NO_MEM : Error allocating internal resource
  • ESP_ERR_NOT_FOUND : Endpoint with specified name doesn’t exist
  • ESP_ERR_INVALID_ARG : Null instance/name arguments

```c
esp_err_t protocomm_set_security (protocomm_t *pc, const char *ep_name, const protocomm_security_t *sec, const void *sec_params)
```

Add endpoint security for a protocomm instance.

This API will bind a security session establisher to the specified endpoint name, along with any proof of possession that may be required for authenticating a session client.

**Note:**
  * An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.
  * The choice of security can be any `protocomm_security_t` instance. Choices `protocomm_security0` and `protocomm_security1` and `protocomm_security2` are readily available.

Parameters
  • pc - [in] Pointer to the protocomm instance
  • ep_name –[in] Endpoint identifier(name) string
  • sec –[in] Pointer to endpoint security instance
  • sec_params –[in] Pointer to security params (NULL if not needed) The pointer should contain the security params struct of appropriate security version. For protocomm security version 1 and 2 sec_params should contain pointer to struct of type pro-
tocomm_security1_params_t and protocomm_security2_params_t respectively. The contents of this pointer must be valid till the security session has been running and is not closed.

**Returns**
- ESP_OK : Success
- ESP_FAIL : Error adding endpoint / Endpoint with this name already exists
- ESP_ERR_INVALID_STATE : Security endpoint already set
- ESP_ERR_NO_MEM : Error allocating endpoint resource
- ESP_ERR_INVALID_ARG : Null instance/name/handler arguments

```c
esp_err_t protocomm_unset_security (protocomm_t *pc, const char *ep_name)
```

Remove endpoint security for a protocomm instance.

This API will remove a registered security endpoint identified by an endpoint name.

**Parameters**
- `pc` : [in] Pointer to the protocomm instance
- `ep_name` : [in] Endpoint identifier (name) string

**Returns**
- ESP_OK : Success
- ESP_ERR_NOT_FOUND : Endpoint with specified name doesn’t exist
- ESP_ERR_INVALID_ARG : Null instance/name arguments

```c
esp_err_t protocomm_set_version (protocomm_t *pc, const char *ep_name, const char *version)
```

Set endpoint for version verification.

This API can be used for setting an application specific protocol version which can be verified by clients through the endpoint.

**Note:**
- An endpoint must be bound to a valid protocomm instance, created using `protocomm_new()`.

**Parameters**
- `pc` : [in] Pointer to the protocomm instance
- `ep_name` : [in] Endpoint identifier (name) string
- `version` : [in] Version identifier (name) string

**Returns**
- ESP_OK : Success
- ESP_FAIL : Error adding endpoint / Endpoint with this name already exists
- ESP_ERR_INVALID_STATE : Version endpoint already set
- ESP_ERR_NO_MEM : Error allocating endpoint resource
- ESP_ERR_INVALID_ARG : Null instance/name/handler arguments

```c
esp_err_t protocomm_unset_version (protocomm_t *pc, const char *ep_name)
```

Remove version verification endpoint from a protocomm instance.

This API will remove a registered version endpoint identified by an endpoint name.

**Parameters**
- `pc` : [in] Pointer to the protocomm instance
- `ep_name` : [in] Endpoint identifier (name) string

**Returns**
- ESP_OK : Success
- ESP_FAIL : Error adding endpoint / Endpoint with this name already exists
- ESP_ERR_NOT_FOUND : Endpoint with specified name doesn’t exist
- ESP_ERR_INVALID_ARG : Null instance/name arguments

**Type Definitions**
typedef `esp_err_t (*protocomm_req_handler_t)(uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen, void *priv_data)`

Function prototype for protocomm endpoint handler.

typedef struct protocomm `protocomm_t`

This structure corresponds to a unique instance of protocomm returned when the API `protocomm_new()` is called. The remaining Protocomm APIs require this object as the first parameter.

**Note:** Structure of the protocomm object is kept private

---

**Header File**

- components/protocomm/include/security/protocomm_security.h

**Structures**

`struct protocomm_security1_params`

Protocomm Security 1 parameters: Proof Of Possession.

**Public Members**

- `const uint8_t *data`
  Pointer to buffer containing the proof of possession data

- `uint16_t len`
  Length (in bytes) of the proof of possession data

`struct protocomm_security2_params`

Protocomm Security 2 parameters: Salt and Verifier.

**Public Members**

- `const char *salt`
  Pointer to the buffer containing the salt

- `uint16_t salt_len`
  Length (in bytes) of the salt

- `const char *verifier`
  Pointer to the buffer containing the verifier

- `uint16_t verifier_len`
  Length (in bytes) of the verifier

`struct protocomm_security`

Protocomm security object structure.

The member functions are used for implementing secure protocomm sessions.
Chapter 2. API Reference

**Note:** This structure should not have any dynamic members to allow re-entrancy

### Public Members

**int** `ver`

Unique version number of security implementation

**esp_err_t** (*init*)(`protocomm_security_handle_t *handle`)

Function for initializing/allocating security infrastructure

**esp_err_t** (*cleanup*)(`protocomm_security_handle_t handle`)

Function for deallocating security infrastructure

**esp_err_t** (*new_transport_session*)(`protocomm_security_handle_t handle, uint32_t session_id`)

Starts new secure transport session with specified ID

**esp_err_t** (*close_transport_session*)(`protocomm_security_handle_t handle, uint32_t session_id`)

Closes a secure transport session with specified ID

**esp_err_t** (*security_req_handler*)(`protocomm_security_handle_t handle, const void *sec_params, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen, void *priv_data`)

Handler function for authenticating connection request and establishing secure session

**esp_err_t** (*encrypt*)(`protocomm_security_handle_t handle, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen`)

Function which implements the encryption algorithm

**esp_err_t** (*decrypt*)(`protocomm_security_handle_t handle, uint32_t session_id, const uint8_t *inbuf, ssize_t inlen, uint8_t **outbuf, ssize_t *outlen`)

Function which implements the decryption algorithm

### Type Definitions

typedef struct `protocomm_security1_params` `protocomm_security1_params_t`

Protocomm Security 1 parameters: Proof Of Possession.

typedef `protocomm_security1_params_t` `protocomm_security_pop_t`

typedef struct `protocomm_security2_params` `protocomm_security2_params_t`

Protocomm Security 2 parameters: Salt and Verifier.

typedef void *`protocomm_security_handle_t`

Protocomm security object structure.

The member functions are used for implementing secure protocomm sessions.

**Note:** This structure should not have any dynamic members to allow re-entrancy
Enumerations

enum protocomm_security_session_event_t
    Events generated by the protocomm security layer.
    These events are generated while establishing secured session.
    Values:

enumerator PROTOCOL_COMM_SECURITY_SESSION_SETUP_OK
    Secured session established successfully

enumerator PROTOCOL_COMM_SECURITY_SESSION_INVALID_SECURITY_PARAMS
    Received invalid (NULL) security parameters (username / client public-key)

enumerator PROTOCOL_COMM_SECURITY_SESSION_CREDENTIALS_MISMATCH
    Received incorrect credentials (username / PoP)

Header File

• components/protocomm/include/security/protocomm_security0.h

• components/protocomm/include/security/protocomm_security1.h

• components/protocomm/include/transports/protocomm_httpd.h

Functions

esp_err_t protocomm_httpd_start (protocomm_t *pc, const protocomm_httpd_config_t *config)
    Start HTTPD protocomm transport.
    This API internally creates a framework to allow endpoint registration and security configuration for the protocomm.

    Note: This is a singleton. ie. Protocomm can have multiple instances, but only one instance can be bound to an HTTP transport layer.

Parameters

• pc - [in] Protocomm instance pointer obtained from protocomm_new()
• config - [in] Pointer to config structure for initializing HTTP server

Returns

• ESP_OK : Success
• ESP_ERR_INVALID_ARG : Null arguments
• ESP_ERR_NOT_SUPPORTED : Transport layer bound to another protocomm instance
• ESP_ERR_INVALID_STATE : Transport layer already bound to this protocomm instance
• ESP_ERR_NO_MEM : Memory allocation for server resource failed
• ESP_ERR_HTTPD_* : HTTP server error on start
Chapter 2. API Reference

*esp_err_t* **protocomm_httpd_stop** (*protocomm_t* *pc*)

Stop HTTPD protocomm transport.

This API cleans up the HTTPD transport protocomm and frees all the handlers registered with the protocomm.

**Parameters**

pc – [in] Same protocomm instance that was passed to protocomm_httpd_start()

**Returns**

• ESP_OK : Success
• ESP_ERR_INVALID_ARG : Null / incorrect protocomm instance pointer

**Unions**

union **protocomm_httpd_config_data_t**

#include <protocomm_httpd.h> Protocomm HTTPD Configuration Data

**Public Members**

void *handle

HTTP Server Handle, if ext_handle_provided is set to true

**protocomm_http_server_config_t** config

HTTP Server Configuration, if a server is not already active

**Structures**

struct **protocomm_http_server_config_t**

Config parameters for protocomm HTTP server.

**Public Members**

uint16_t port

Port on which the HTTP server will listen

size_t stack_size

Stack size of server task, adjusted depending upon stack usage of endpoint handler

unsigned task_priority

Priority of server task

struct **protocomm_httpd_config_t**

Config parameters for protocomm HTTP server.

**Public Members**

bool ext_handle_provided

Flag to indicate of an external HTTP Server Handle has been provided. In such as case, protocomm will use the same HTTP Server and not start a new one internally.

**protocomm_httpd_config_data_t** data

Protocomm HTTPD Configuration Data
Macros

PROTOCOMM_HTTPD_DEFAULT_CONFIG()

Header File

- components/protocomm/include/transports/protocomm_ble.h

Functions

**esp_err_t protocomm_ble_start (protocomm_t *pc, const protocomm_ble_config_t *config)**

Start Bluetooth Low Energy based transport layer for provisioning. Initialize and start required BLE service for provisioning. This includes the initialization for characteristics/service for BLE.

**Parameters**

- pc - [in] Protocomm instance pointer obtained from protocomm_new()
- config - [in] Pointer to config structure for initializing BLE

**Returns**

- ESP_OK : Success
- ESP_FAIL : Simple BLE start error
- ESP_ERR_NO_MEM: Error allocating memory for internal resources
- ESP_ERR_INVALID_STATE : Error in ble config
- ESP_ERR_INVALID_ARG : Null arguments

**esp_err_t protocomm_ble_stop (protocomm_t *pc)**

Stop Bluetooth Low Energy based transport layer for provisioning.

Stops service/task responsible for BLE based interactions for provisioning

**Note:** You might want to optionally reclaim memory from Bluetooth. Refer to the documentation of esp_bt_mem_release in that case.

**Parameters** pc - [in] Same protocomm instance that was passed to protocomm_ble_start()

**Returns**

- ESP_OK : Success
- ESP_FAIL : Simple BLE stop error
- ESP_ERR_INVALID_ARG : Null / incorrect protocomm instance

Structures

**struct name_uuid**

This structure maps handler required by protocomm layer to UUIDs which are used to uniquely identify BLE characteristics from a smartphone or a similar client device.

**Public Members**

**const char *name**

Name of the handler, which is passed to protocomm layer

**uint16_t uuid**

UUID to be assigned to the BLE characteristic which is mapped to the handler

**struct protocomm_ble_config**

Config parameters for protocomm BLE service.
Public Members

char device_name[MAX_BLE_DEVNAME_LEN + 1]
BLE device name being broadcast at the time of provisioning

uint8_t service_uuid[BLE_UUID128_VAL_LENGTH]
128 bit UUID of the provisioning service

uint8_t *manufacturer_data
BLE device manufacturer data pointer in advertisement

ssize_t manufacturer_data_len
BLE device manufacturer data length in advertisement

ssize_t nu_lookup_count
Number of entries in the Name-UUID lookup table

protocomm_ble_name_uuid_t *nu_lookup
Pointer to the Name-UUID lookup table

unsigned ble_bonding
BLE bonding

unsigned ble_sm_sc
BLE security flag

unsigned ble_link_encryption
BLE security flag

Macros

MAX_BLE_DEVNAME_LEN
BLE device name cannot be larger than this value 31 bytes (max scan response size) - 1 byte (length) - 1 byte (type) = 29 bytes

BLE_UUID128_VAL_LENGTH

MAX_BLE_MANUFACTURER_DATA_LEN
Theoretically, the limit for max manufacturer length remains same as BLE device name i.e. 31 bytes (max scan response size) - 1 byte (length) - 1 byte (type) = 29 bytes However, manufacturer data goes along with BLE device name in scan response. So, it is important to understand the actual length should be smaller than (29 - (BLE device name length) - 2).

Type Definitions

typedef struct name_uuid protocomm_ble_name_uuid_t
This structure maps handler required by protocomm layer to UUIDs which are used to uniquely identify BLE characteristics from a smartphone or a similar client device.

typedef struct protocomm_ble_config protocomm_ble_config_t
Config parameters for protocomm BLE service.
Enumerations

```c
enum protocomm_transport_ble_event_t {
    PROTOCOMM_TRANSPORT_BLE_CONNECTED,
    PROTOCOMM_TRANSPORT_BLE_DISCONNECTED
};
```

2.8.2 Unified Provisioning

Overview

The unified provisioning support in the ESP-IDF provides an extensible mechanism to the developers to configure the device with the Wi-Fi credentials and/or other custom configuration using various transports and different security schemes. Depending on the use case, it provides a complete and ready solution for Wi-Fi network provisioning along with example iOS and Android applications. The developers can choose to extend the device-side and phone-app side implementations to accommodate their requirements for sending additional configuration data. The followings are the important features of this implementation:

1. Extensible Protocol

The protocol is completely flexible and it offers the ability for the developers to send custom configuration in the provisioning process. The data representation is also left to the application to decide.

2. Transport Flexibility

The protocol can work on Wi-Fi (SoftAP + HTTP server) or on Bluetooth LE as a transport protocol. The framework provides an ability to add support for any other transport easily as long as command-response behavior can be supported on the transport.

3. Security Scheme Flexibility

It is understood that each use case may require different security scheme to secure the data that is exchanged in the provisioning process. Some applications may work with SoftAP that is WPA2 protected or Bluetooth LE with the “just-works” security. Or the applications may consider the transport to be insecure and may want application-level security. The unified provisioning framework allows the application to choose the security as deemed suitable.

4. Compact Data Representation

The protocol uses Google Protobufs as a data representation for session setup and Wi-Fi provisioning. They provide a compact data representation and ability to parse the data in multiple programming languages in native format. Please note that this data representation is not forced on application-specific data and the developers may choose the representation of their choice.

Typical Provisioning Process

Deciding on Transport

The unified provisioning subsystem supports Wi-Fi (SoftAP+HTTP server) and Bluetooth LE (GATT based) transport schemes. The following points need to be considered while selecting the best possible transport for provisioning:

1. The Bluetooth LE-based transport has the advantage of maintaining an intact communication channel between the device and the client during the provisioning, which ensures reliable provisioning feedback.
Fig. 29: Typical Provisioning Process

1. Transport-specific discovery and connection
   - Some form of beaconsing
   - Client connects

2. Session Establishment =
   - Get Version Request
     - Get Version Response
   - Session Setup Request
     - Session Setup Response

   One or multiple steps as per protocol

3. Configuration
   - App-specific Set Config (optional)
     - Set Config Response (optional)
   - Wi-Fi SetConfig(SSID, Passphrase...)
     - Wi-Fi SetConfig response
   - Wi-Fi ApplyConfig cmd
     - Wi-Fi ApplyConfig resp
   - Wi-Fi GetStatus cmd (repeated)
     - Wi-Fi GetStatus resp (repeated)

4. Close connection
   - Close Connection
2. The Bluetooth LE-based provisioning implementation makes the user experience better from the phone apps as on Android and iOS both, the phone app can discover and connect to the device without requiring the user to go out of the phone app.

3. However, the Bluetooth LE transport consumes about 110 KB memory at runtime. If the product does not use the Bluetooth LE or Bluetooth functionality after provisioning is done, almost all the memory can be reclaimed and added into the heap.

4. The SoftAP-based transport is highly interoperable. However, there are a few considerations:
   • The device uses the same radio to host the SoftAP and also to connect to the configured AP. Since these could potentially be on different channels, it may cause connection status updates not to be reliably received by the phone
   • The phone (client) has to disconnect from its current AP in order to connect to the SoftAP. The original network will get restored only when the provisioning process is complete, and the softAP is taken down.

5. The SoftAP transport does not require much additional memory for the Wi-Fi use cases.

6. The SoftAP-based provisioning requires the phone-app user to go to System Settings to connect to the Wi-Fi network hosted by the device in the iOS system. The discovery (scanning) as well as connection APIs are not available for the iOS applications.

**Deciding on Security**

Depending on the transport and other constraints, the security scheme needs to be selected by the application developers. The following considerations need to be given from the provisioning-security perspective:

1. The configuration data sent from the client to the device and the response have to be secured.
2. The client should authenticate the device that it is connected to.
3. The device manufacturer may choose proof-of-possession (PoP), a unique per-device secret to be entered on the provisioning client as a security measure to make sure that only the user can provision the device in their possession.

There are two levels of security schemes, of which the developer may select one or a combination, depending on requirements.

1. **Transport Security**

   For SoftAP provisioning, developers may choose WPA2-protected security with unique per-device passphrase. Unique per-device passphrase can also act as a proof-of-possession. For Bluetooth LE, the “just-works” security can be used as a transport-level security after assessing its provided level of security.

2. **Application Security**

   The unified provisioning subsystem provides the application-level security (*Security 1 Scheme*) that provides data protection and authentication through PoP, if the application does not use the transport-level security, or if the transport-level security is not sufficient for the use case.

**Device Discovery**

The advertisement and device discovery is left to the application and depending on the protocol chosen, the phone apps and device-firmware application can choose appropriate method for advertisement and discovery.

For the SoftAP+HTTP transport, typically the SSID (network name) of the AP hosted by the device can be used for discovery.

For the Bluetooth LE transport, device name or primary service included in the advertisement or a combination of both can be used for discovery.

**Architecture**

The below diagram shows the architecture of unified provisioning:

It relies on the base layer called *Protocol Communication* (protocomm) which provides a framework for security schemes and transport mechanisms. The Wi-Fi Provisioning layer uses protocomm to provide simple callbacks to the
application for setting the configuration and getting the Wi-Fi status. The application has control over implementation of these callbacks. In addition, the application can directly use protocomm to register custom handlers.

The application creates a protocomm instance which is mapped to a specific transport and specific security scheme. Each transport in the protocomm has a concept of an “end-point” which corresponds to the logical channel for communication for specific type of information. For example, security handshake happens on a different endpoint from the Wi-Fi configuration endpoint. Each end-point is identified using a string and depending on the transport internal representation of the end-point changes. In case of the SoftAP+HTTP transport, the end-point corresponds to URI, whereas in case of Bluetooth LE, the end-point corresponds to the GATT characteristic with specific UUID. Developers can create custom end-points and implement handler for the data that is received or sent over the same end-point.

**Security Schemes**

At present, the unified provisioning supports the following security schemes:

1. Security 0
   
   No security (No encryption).

2. Security 1

   Curve25519-based key exchange, shared key derivation and AES256-CTR mode encryption of the data. It supports two modes :

   a. Authorized - Proof of Possession (PoP) string used to authorize session and derive shared key.
   
   b. No Auth (Null PoP) - Shared key derived through key exchange only.

3. Security 2

   SRP6a-based shared key derivation and AES256-GCM mode encryption of the data.
Note: The respective security schemes need to be enabled through the project configuration menu. Please refer to Enabling Protocomm Security Version for more details.

Security 1 Scheme

The Security 1 scheme details are shown in the below sequence diagram:

Security 2 Scheme

The Security 2 scheme is based on the Secure Remote Password (SRP6a) protocol, see RFC 5054.

The protocol requires the Salt and Verifier to be generated beforehand with the help of the identifying username \( I \) and the plaintext password \( p \). The Salt and Verifier are then stored on ESP32.

- The password \( p \) and the username \( I \) are to be provided to the Phone App (Provisioning entity) by suitable means, e.g., QR code sticker.

Details about the Security 2 scheme are shown in the below sequence diagram:

Sample Code

Please refer to Protocol Communication and Wi-Fi Provisioning for API guides and code snippets on example usage. Application implementation can be found as an example under provisioning.

Provisioning Tools

Provisioning applications are available for various platforms, along with source code:

- Android:
  - Bluetooth LE Provisioning app on Play Store.
  - SoftAP Provisioning app on Play Store.
  - Source code on GitHub: esp-idf-provisioning-android.
- iOS:
  - Bluetooth LE Provisioning app on App Store.
  - SoftAP Provisioning app on App Store.
  - Source code on GitHub: esp-idf-provisioning-ios.
- Linux/macOS/Windows: tools/esp_prov, a Python-based command line tool for provisioning.

The phone applications offer simple UI and are thus more user centric, while the command-line application is useful as a debugging tool for developers.

2.8.3 Wi-Fi Provisioning

Overview

This component provides APIs that control the Wi-Fi provisioning service for receiving and configuring Wi-Fi credentials over SoftAP or Bluetooth LE transport via secure Protocol Communication sessions. The set of wifi_prov_mgr_ APIs help quickly implement a provisioning service that has necessary features with minimal amount of code and sufficient flexibility.
Fig. 31: Security 1

Generate Key Pair

{cli_privkey, cli_pubkey} = curve25519_keygen()

SessionCmd0(cli_pubkey)

Generate Key Pair

{dev_privkey, dev_pubkey} = curve25519_keygen()

dev_rand = gen_16byte_random()

Shared Key

shared_key(No PoP) = curve25519(dev_privkey, cli_pubkey)
shared_key(with PoP) = curve25519(dev_privkey, cli_pubkey) ^ SHA256(pop)

SessionResp0(dev_pubkey, dev_rand)

Shared Key

shared_key(No PoP) = curve25519(cli_privkey, dev_pubkey)
shared_key(with PoP) = curve25519(cli_privkey, dev_pubkey) ^ SHA256(pop)

Verification Token

cli_verify = aes ctr enc(key=shared_key, data=dev_pubkey, nonce=dev_rand)

SessionCmd1(cli_verify)

Verify Client

check (dev_pubkey == aes_ctr_dec(cli_verify...))

Verification Token

dev_verify = aes_ctr_enc(key=shared_key, data=cli_pubkey, nonce=(prev-context))

SessionResp1(dev_verify)

Verify Device

check (cli_pubkey == aes_ctr_dec(dev_verify...))
Fig. 32: Security 2

- **Generate Key Pair**
  - \( a \) (cli_privkey) = 256 bit random value,
  - \( A \) (cli_privkey) = \( g^a \)
  - \( g \) - generator, \( N \) - large safe prime,
  - All arithmetic operations are performed in ring of integers modulo \( N \),
  - thus all occurrences like \( y^z \) should be read as \( y \) \( \mod \) \( N \).

- **SessionCmd0(cli_pubkey A, username I)**

- **Obtain Salt and Verifier stored on esp**
  - Salt \( s = 256 \) bit random value,
  - Verifier \( v = g^x \) where \( x = H(s \mid I \mid p) \)

- **Generate Key Pair**
  - \( b \) (dev_privkey) = 256 bit random value
  - \( B \) (dev_privkey) = \( k^v + g^b \) where \( k = H(N, g) \)

- **Shared Key**
  - \( K = H(S) \) where,
  - \( S = (A \cdot v \cdot u) \cdot b \)
  - \( u = H(A, B) \)

- **SessionResp0(dev_pubkey B, dev_rand)**

- **Shared Key**
  - \( shared\_key(K) = H(S) \) where,
  - \( S = (B - k^u)^v \cdot (a + ux) \)
  - \( u = H(A, B) \)
  - \( k = H(N, g) \)
  - \( v = g^x \)
  - \( x = H(s \mid I \mid p) \)

- **SessionCmd1(client_proof M)**

- **Verify Client**
  - \( device\_proof\_M1 = H(H(N) \mid XOR \mid H(g) \mid H(I) \mid s \mid A \mid B \mid K) \)

- **Device generate device\_proof\_M2 = H(A, M, K)**

- **Dev\_rand = gen_16byte_random()**
  - This random number is to be used for AES-GCM operation for encryption and decryption of the data using the shared secret

- **SessionResp1(device\_proof\_M2, dev\_rand)**

- **Verify Device**
  - **Client calculates device\_proof\_M2 as** \( M2 = H(A, M, K) \)
  - **client verifies this M2 with M2 obtained from device**
Initialization  \texttt{wifi_prov_mgr_init()} is called to configure and initialize the provisioning manager, and thus must be called prior to invoking any other \texttt{wifi_prov_mgr} APIs. Note that the manager relies on other components of ESP-IDF, namely NVS, TCP/IP, Event Loop and Wi-Fi, and optionally mDNS, hence these components must be initialized beforehand. The manager can be de-initialized at any moment by making a call to \texttt{wifi_prov_mgr_deinit()}.

```c
wifi_prov_mgr_config_t config = { .scheme = wifi_prov_scheme_ble, .scheme_event_handler = WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BTDM
};
ESP_ERROR_CHECK( wifi_prov_mgr_init(config) );
```

The configuration structure \texttt{wifi_prov_mgr_config_t} has a few fields to specify the desired behavior of the manager:

- \texttt{wifi_prov_mgr_config_t::scheme} - This is used to specify the provisioning scheme. Each scheme corresponds to one of the modes of transport supported by protocomm. Hence, support the following options:
  - \texttt{wifi_prov_scheme_ble} - Bluetooth LE transport and GATT Server for handling the provisioning commands.
  - \texttt{wifi_prov_scheme_softap} - Wi-Fi SoftAP transport and HTTP Server for handling the provisioning commands.
  - \texttt{wifi_prov_scheme_console} - Serial transport and console for handling the provisioning commands.

- \texttt{wifi_prov_mgr_config_t::scheme_event_handler}: An event handler defined along with the scheme. Choosing the appropriate scheme-specific event handler allows the manager to take care of certain matters automatically. Presently, this option is not used for either the SoftAP or Console-based provisioning, but is very convenient for Bluetooth LE. To understand how, we must recall that Bluetooth requires a substantial amount of memory to function, and once the provisioning is finished, the main application may want to reclaim back this memory (or part of it) if it needs to use either Bluetooth LE or classic Bluetooth. Also, upon every future reboot of a provisioned device, this reclamation of memory needs to be performed again. To reduce this complication in using \texttt{wifi_prov_scheme_ble}, the scheme-specific handlers have been defined, and depending upon the chosen handler, the Bluetooth LE/classic Bluetooth/BTDM memory is freed automatically when the provisioning manager is de-initialized. The available options are:
  - \texttt{WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BTDM} - Free both classic Bluetooth and Bluetooth LE/BTDM memory. Used when the main application does not require Bluetooth at all.
  - \texttt{WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BLE} - Free only Bluetooth LE memory. Used when main application requires classic Bluetooth.
  - \texttt{WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BT} - Free only classic Bluetooth. Used when main application requires Bluetooth LE. In this case freeing happens right when the manager is initialized.
  - \texttt{WIFI_PROV_EVENT_HANDLER_NONE} - Do not use any scheme specific handler. Used when the provisioning scheme is not Bluetooth LE, i.e., using SoftAP or Console, or when main application wants to handle the memory reclaiming on its own, or needs both Bluetooth LE and classic Bluetooth to function.

- \texttt{wifi_prov_mgr_config_t::app_event_handler} (Deprecated) - It is now recommended to catch \texttt{WIFI_PROV_EVENT} that is emitted to the default event loop handler. See definition of \texttt{wifi_prov_cb_event_t} for the list of events that are generated by the provisioning service. Here is an excerpt showing some of the provisioning events:

```c
static void event_handler(void* arg, esp_event_base_t event_base, int event_id, void* event_data)
{
    if (event_base == WIFI_PROV_EVENT) {
        switch (event_id) {
            case WIFI_PROV_START:
(continues on next page)
```
The manager can be de-initialized at any moment by making a call to `wifi_prov_mgr_deinit()`. 

**Check the Provisioning State** Whether the device is provisioned or not can be checked at runtime by calling `wifi_prov_mgr_is_provisioned()`. This internally checks if the Wi-Fi credentials are stored in NVS.

Note that presently the manager does not have its own NVS namespace for storage of Wi-Fi credentials, instead it relies on the `esp_wifi_` APIs to set and get the credentials stored in NVS from the default location.

If the provisioning state needs to be reset, any of the following approaches may be taken:

- The associated part of NVS partition has to be erased manually
- The main application must implement some logic to call `esp_wifi_` APIs for erasing the credentials at runtime
- The main application must implement some logic to force start the provisioning irrespective of the provisioning state

```c
bool provisioned = false;
ESP_ERROR_CHECK( wifi_prov_mgr_is_provisioned(&provisioned) );
```

**Start the Provisioning Service** At the time of starting provisioning we need to specify a service name and the corresponding key, that is to say:

- A Wi-Fi SoftAP SSID and a passphrase, respectively, when the scheme is `wifi_prov_scheme_softap`
- Bluetooth LE device name with the service key ignored when the scheme is `wifi_prov_scheme_ble`
Also, since internally the manager uses protocomm, we have the option of choosing one of the security features provided by it:

- Security 1 is secure communication which consists of a prior handshake involving X25519 key exchange along with authentication using a proof of possession pop, followed by AES-CTR for encryption or decryption of subsequent messages.
- Security 0 is simply plain text communication. In this case the pop is simply ignored.

See *Unified Provisioning* for details about the security features.

```c
const char *service_name = "my_device";
const char *service_key = "password";
wifi_prov_security_t security = WIFI_PROV_SECURITY_1;
const char *pop = "abcd1234";
ESP_ERROR_CHECK( wifi_prov_mgr_start_provisioning(security, pop, service_name, service_key) );
```

The provisioning service automatically finishes only if it receives valid Wi-Fi AP credentials followed by successful connection of device to the AP with IP obtained. Regardless of that, the provisioning service can be stopped at any moment by making a call to `wifi_prov_mgr_stop_provisioning()`.

**Note:** If the device fails to connect with the provided credentials, it does not accept new credentials anymore, but the provisioning service keeps on running, only to convey failure to the client, until the device is restarted. Upon restart, the provisioning state turns out to be true this time, as credentials are found in NVS, but the device does fail again to connect with those same credentials, unless an AP with the matching credentials somehow does become available. This situation can be fixed by resetting the credentials in NVS or force starting the provisioning service. This has been explained above in *Check the Provisioning State*.

**Waiting for Completion** Typically, the main application waits for the provisioning to finish, then de-initializes the manager to free up resources, and finally starts executing its own logic.

There are two ways for making this possible. The simpler way is to use a blocking call to `wifi_prov_mgr_wait()`.

```c
// Start provisioning service
ESP_ERROR_CHECK( wifi_prov_mgr_start_provisioning(security, pop, service_name, service_key) );
// Wait for service to complete
wifi_prov_mgr_wait();
// Finally de-initialize the manager
wifi_prov_mgr_deinit();
```

The other way is to use the default event loop handler to catch WIFI_PROV_EVENT and call `wifi_prov_mgr_deinit()` when event ID is WIFI_PROV_END:

```c
static void event_handler(void* arg, esp_event_base_t event_base, int event_id, void* event_data)
{
    if (event_base == WIFI_PROV_EVENT && event_id == WIFI_PROV_END) {
        /* De-initialize the manager once the provisioning is finished */
        wifi_prov_mgr_deinit();
    }
}
```
User Side Implementation When the service is started, the device to be provisioned is identified by the advertised service name, which, depending upon the selected transport, is either the Bluetooth LE device name or the SoftAP SSID.

When using SoftAP transport, for allowing service discovery, mDNS must be initialized before starting provisioning. In this case, the host name set by the main application is used, and the service type is internally set to _esp_wifi_prov.

When using Bluetooth LE transport, a custom 128-bit UUID should be set using wifi_prov_scheme_ble_set_service_uuid(). This UUID is to be included in the Bluetooth LE advertisement and corresponds to the primary GATT service that provides provisioning endpoints as GATT characteristics. Each GATT characteristic is formed using the primary service UUID as the base, with different auto-assigned 12th and 13th bytes, presumably counting from the 0th byte. Since an endpoint characteristic UUID is auto-assigned, it should not be used to identify the endpoint. Instead, client-side applications should identify the endpoints by reading the User Characteristic Description (0x2901) descriptor for each characteristic, which contains the endpoint name of the characteristic. For example, if the service UUID is set to 55cc035e-fb27-4f80-be02-3c60828b7451, each endpoint characteristic is assigned a UUID like 55cc_____fb27-4f80-be02-3c60828b7451, with unique values at the 12th and 13th bytes.

Once connected to the device, the provisioning-related protocomm endpoints can be identified as follows:

<table>
<thead>
<tr>
<th>Endpoint Name i.e., Bluetooth LE + GATT Server</th>
<th>URI, i.e., SoftAP + HTTP Server + mDNS</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>prov-session</td>
<td>http://&lt;mdns-hostname&gt;.local/prov-session</td>
<td>Security endpoint used for session establishment</td>
</tr>
<tr>
<td>prov-scan</td>
<td><a href="http://wifi-prov.local/prov-scan">http://wifi-prov.local/prov-scan</a></td>
<td>the endpoint used for starting Wi-Fi scan and receiving scan results</td>
</tr>
<tr>
<td>prov-ctrl</td>
<td><a href="http://wifi-prov.local/prov-ctrl">http://wifi-prov.local/prov-ctrl</a></td>
<td>the endpoint used for controlling Wi-Fi provisioning state</td>
</tr>
<tr>
<td>prov-config</td>
<td>http://&lt;mdns-hostname&gt;.local/prov-config</td>
<td>the endpoint used for configuring Wi-Fi credentials on device</td>
</tr>
<tr>
<td>proto-ver</td>
<td>http://&lt;mdns-hostname&gt;.local/proto-ver</td>
<td>the endpoint for retrieving version info</td>
</tr>
</tbody>
</table>

Immediately after connecting, the client application may fetch the version/capabilities information from the proto-ver endpoint. All communications to this endpoint are unencrypted, hence necessary information, which may be relevant for deciding compatibility, can be retrieved before establishing a secure session. The response is in JSON format and looks like: prov: { ver: v1.1, cap: [no_pop] }, my_app: { ver: 1.345, cap: [cloud, local_ctrl] }, .... Here label prov provides provisioning service version ver and capabilities cap. For now, only the no_pop capability is supported, which indicates that the service does not require proof of possession for authentication. Any application-related version or capabilities are given by other labels, e.g., my_app in this example. These additional fields are set using wifi_prov_mgr_set_app_info().

User side applications need to implement the signature handshaking required for establishing and authenticating secure protocomm sessions as per the security scheme configured for use, which is not needed when the manager is configured to use protocomm security 0.

See Unified Provisioning for more details about the secure handshake and encryption used. Applications must use the .proto files found under protocomm/proto, which define the Protobuf message structures supported by prov-session endpoint.

Once a session is established, Wi-Fi credentials are configured using the following set of wifi_config commands, serialized as Protobuf messages with the corresponding .proto files that can be found under wifi_provisioning/proto:

- **get_status** - For querying the Wi-Fi connection status. The device responds with a status which is one of connecting, connected or disconnected. If the status is disconnected, a disconnection reason is also to be included in the status response.
- **set_config** - For setting the Wi-Fi connection credentials.
• **apply_config** - For applying the credentials saved during **set_config** and starting the Wi-Fi station.

After session establishment, the client can also request Wi-Fi scan results from the device. The results returned is a list of AP SSIDs, sorted in descending order of signal strength. This allows client applications to display APs nearby to the device at the time of provisioning, and users can select one of the SSIDs and provide the password which is then sent using the **wifi_config** commands described above. The **wifi_scan** endpoint supports the following protobuf commands:

• **scan_start** - For starting Wi-Fi scan with various options:
  - **blocking (input)** - If true, the command returns only when the scanning is finished.
  - **passive (input)** - If true, the scan is started in passive mode, which may be slower, instead of active mode.
  - **group_channels (input)** - This specifies whether to scan all channels in one go when zero, or perform scanning of channels in groups, with 120 ms delay between scanning of consecutive groups, and the value of this parameter sets the number of channels in each group. This is useful when transport mode is SoftAP, where scanning all channels in one go may not give the Wi-Fi driver enough time to send out beacons, and hence may cause disconnection with any connected stations. When scanning in groups, the manager waits for at least 120 ms after completing the scan on a group of channels, and thus allows the driver to send out the beacons. For example, given that the total number of Wi-Fi channels is 14, then setting **group_channels** to 3 creates 5 groups, with each group having 3 channels, except the last one which has 14 % 3 = 2 channels. So, when the scan is started, the first 3 channels will be scanned, followed by a 120 ms delay, and then the next 3 channels, and so on, until all the 14 channels have been scanned. One may need to adjust this parameter as having only a few channels in a group may increase the overall scan time, while having too many may again cause disconnection. Usually, a value of 4 should work for most cases. Note that for any other mode of transport, e.g. Bluetooth LE, this can be safely set to 0, and hence achieve the shortest overall scanning time.
  - **period_ms (input)** - The scan parameter specifying how long to wait on each channel.

• **scan_status** - It gives the status of scanning process:
  - **scan_finished (output)** - When the scan has finished, this returns true.
  - **result_count (output)** - This gives the total number of results obtained till now. If the scan is yet happening, this number keeps on updating.

• **scan_result** - For fetching the scan results. This can be called even if the scan is still on going.
  - **start_index (input)** - Where the index starts from to fetch the entries from the results list.
  - **count (input)** - The number of entries to fetch from the starting index.
  - **entries (output)** - The list of entries returned. Each entry consists of **ssid**, **channel** and **rssi** information.

The client can also control the provisioning state of the device using **wifi_ctrl** endpoint. The **wifi_ctrl** endpoint supports the following protobuf commands:

• **ctrl_reset** - Resets internal state machine of the device and clears provisioned credentials only in case of provisioning failures.

• **ctrl_reprov** - Resets internal state machine of the device and clears provisioned credentials only in case the device is to be provisioned again for new credentials after a previous successful provisioning.

**Additional Endpoints** In case users want to have some additional protocomm endpoints customized to their requirements, this is done in two steps. First is creation of an endpoint with a specific name, and the second step is the registration of a handler for this endpoint. See Protocol Communication for the function signature of an endpoint handler. A custom endpoint must be created after initialization and before starting the provisioning service. Whereas, the protocomm handler is registered for this endpoint only after starting the provisioning service.

```c
wifi_prov_mgr_init(config);
wifi_prov_mgr_endpoint_create("custom-endpoint");
wifi_prov_mgr_start_provisioning(security, pop, service_name, service_
→key);
wifi_prov_mgr_endpoint_register("custom-endpoint", custom_ep_handler,_
→custom_ep_data);
```

When the provisioning service stops, the endpoint is unregistered automatically.
One can also choose to call `wifi_prov_mgr_endpoint_unregister()` to manually deactivate an endpoint at runtime. This can also be used to deactivate the internal endpoints used by the provisioning service.

**When/How to Stop the Provisioning Service?** The default behavior is that once the device successfully connects using the Wi-Fi credentials set by the `apply_config` command, the provisioning service stops, and Bluetooth LE or SoftAP turns off, automatically after responding to the next `get_status` command. If `get_status` command is not received by the device, the service stops after a 30s timeout.

On the other hand, if device is not able to connect using the provided Wi-Fi credentials, due to incorrect SSID or passphrase, the service keeps running, and `get_status` keeps responding with disconnected status and reason for disconnection. Any further attempts to provide another set of Wi-Fi credentials, are to be rejected. These credentials are preserved, unless the provisioning service is force started, or NVS erased.

If this default behavior is not desired, it can be disabled by calling `wifi_prov_mgr_disable_auto_stop()`. Now the provisioning service stops only after an explicit call to `wifi_prov_mgr_stop_provisioning()`, which returns immediately after scheduling a task for stopping the service. The service stops after a certain delay and WIFI_PROV_END event gets emitted. This delay is specified by the argument to `wifi_prov_mgr_disable_auto_stop()`.

The customized behavior is useful for applications which want the provisioning service to be stopped some time after the Wi-Fi connection is successfully established. For example, if the application requires the device to connect to some cloud service and obtain another set of credentials, and exchange these credentials over a custom protocomm endpoint, then after successfully doing so, stop the provisioning service by calling `wifi_prov_mgr_stop_provisioning()` inside the protocomm handler itself. The right amount of delay ensures that the transport resources are freed only after the response from the protocomm handler reaches the client side application.

**Application Examples**

For complete example implementation see `provisioning/wifi_prov_mgr`.

**Provisioning Tools**

Provisioning applications are available for various platforms, along with source code:

- **Android:**
  - Bluetooth LE Provisioning app on Play Store.
  - SoftAP Provisioning app on Play Store.
  - Source code on GitHub: esp-idf-provisioning-android.

- **iOS:**
  - Bluetooth LE Provisioning app on App Store.
  - SoftAP Provisioning app on App Store.
  - Source code on GitHub: esp-idf-provisioning-ios.

- **Linux/MacOS/Windows:** `tools/esp_prov`, a Python-based command-line tool for provisioning.

The phone applications offer simple UI and are thus more user centric, while the command-line application is useful as a debugging tool for developers.

**API Reference**

**Header File**

- `components/wifi_provisioning/include/wifi_provisioning/manager.h`

**Functions**
`esp_err_t wifi_prov_mgr_init(wifi_prov_mgr_config_t config)`

Initialize provisioning manager instance.

Configures the manager and allocates internal resources

Configuration specifies the provisioning scheme (transport) and event handlers

Event WIFI_PROV_INIT is emitted right after initialization is complete

**Parameters**
- `config` - [in] Configuration structure

**Returns**
- ESP_OK : Success
- ESP_FAIL : Fail

`void wifi_prov_mgr_deinit(void)`

Stop provisioning (if running) and release resource used by the manager.

Event WIFI_PROV_DEINIT is emitted right after de-initialization is finished

If provisioning service is still active when this API is called, it first stops the service, hence emitting WIFI_PROV_END, and then performs the de-initialization

`esp_err_t wifi_prov_mgr_is_provisioned(bool *provisioned)`

Checks if device is provisioned.

This checks if Wi-Fi credentials are present on the NVS

The Wi-Fi credentials are assumed to be kept in the same NVS namespace as used by esp_wifi component

If one were to call esp_wifi_set_config() directly instead of going through the provisioning process, this function will still yield true (i.e. device will be found to be provisioned)

**Note:** Calling wifi_prov_mgr_start_provisioning() automatically resets the provision state, irrespective of what the state was prior to making the call.

**Parameters**
- `provisioned` - [out] True if provisioned, else false

**Returns**
- ESP_OK : Retrieved provision state successfully
- ESP_FAIL : Wi-Fi not initialized
- ESP_ERR_INVALID_ARG : Null argument supplied

`esp_err_t wifi_prov_mgr_start_provisioning(wifi_prov_security_t security, const void *wifi_prov_sec_params, const char *service_name, const char *service_key)`

Start provisioning service.

This starts the provisioning service according to the scheme configured at the time of initialization. For scheme :

- `wifi_prov_scheme_ble` : This starts protocomm_ble, which internally initializes BLE transport and starts GATT server for handling provisioning requests
- `wifi_prov_scheme_softap` : This activates SoftAP mode of Wi-Fi and starts protocomm_httpd, which internally starts an HTTP server for handling provisioning requests (If mDNS is active it also starts advertising service with type _esp_wifi_prov._tcp)

Event WIFI_PROV_START is emitted right after provisioning starts without failure

**Note:** This API will start provisioning service even if device is found to be already provisioned, i.e. wifi_prov_mgr_is_provisioned() yields true

**Parameters**
- `security` - [in] Specify which protocomm security scheme to use :
- WIFI_PROV_SECURITY_0: For no security
- WIFI_PROV_SECURITY_1: x25519 secure handshake for session establishment followed by AES-CTR encryption of provisioning messages
- WIFI_PROV_SECURITY_2: SRP6a based authentication and key exchange followed by AES-GCM encryption/decryption of provisioning messages

- wifi_prov_sec_params ⚶ [in] Pointer to security params (NULL if not needed). This is not needed for protocomm security 0. This pointer should hold the struct of type wifi_prov_security1_params_t for protocomm security 1 and wifi_prov_security2_params_t for protocomm security 2 respectively. This pointer and its contents should be valid till the provisioning service is running and has not been stopped or deinit.

- service_name ⚶ [in] Unique name of the service. This translates to:
  - Wi-Fi SSID when provisioning mode is softAP
  - Device name when provisioning mode is BLE

- service_key ⚶ [in] Key required by client to access the service (NULL if not needed). This translates to:
  - Wi-Fi password when provisioning mode is softAP
  - ignored when provisioning mode is BLE

**Returns**

- ESP_OK: Provisioning started successfully
- ESP_FAIL: Failed to start provisioning service
- ESP_ERR_INVALID_STATE: Provisioning manager not initialized or already started

```c
void wifi_prov_mgr_stop_provisioning (void)
```

Stop provisioning service.

If provisioning service is active, this API will initiate a process to stop the service and return. Once the service actually stops, the event WIFI_PROV_END will be emitted.

If wifi_prov_mgr_deinit() is called without calling this API first, it will automatically stop the provisioning service and emit the WIFI_PROV_END, followed by WIFI_PROV_DEINIT, before returning.

This API will generally be used along with wifi_prov_mgr_disable_auto_stop() in the scenario when the main application has registered its own endpoints, and wishes that the provisioning service is stopped only when some protocomm command from the client side application is received.

Calling this API inside an endpoint handler, with sufficient cleanup_delay, will allow the response / acknowledgment to be sent successfully before the underlying protocomm service is stopped.

Cleanup delay is set when calling wifi_prov_mgr_disable_auto_stop(). If not specified, it defaults to 1000ms.

For straightforward cases, using this API is usually not necessary as provisioning is stopped automatically once WIFI_PROV_CRED_SUCCESS is emitted. Stopping is delayed (maximum 30 seconds) thus allowing the client side application to query for Wi-Fi state, i.e. after receiving the first query and sending Wi-Fi state connected response the service is stopped immediately.

```c
void wifi_prov_mgr_wait (void)
```

Wait for provisioning service to finish.

Calling this API will block until provisioning service is stopped i.e. till event WIFI_PROV_END is emitted.

This will not block if provisioning is not started or not initialized.

```c
esp_err_t wifi_prov_mgr_disable_auto_stop (uint32_t cleanup_delay)
```

Disable auto stopping of provisioning service upon completion.

By default, once provisioning is complete, the provisioning service is automatically stopped, and all endpoints (along with those registered by main application) are deactivated.

This API is useful in the case when main application wishes to close provisioning service only after it receives some protocomm command from the client side app. For example, after connecting to Wi-Fi, the device may want to connect to the cloud, and only once that is successfully, the device is said to be fully configured. But,
then it is up to the main application to explicitly call `wifi_prov_mgr_stop_provisioning()` later when the device is fully configured and the provisioning service is no longer required.

**Note:** This must be called before executing `wifi_prov_mgr_start_provisioning()`

**Parameters**

**cleanup_delay** - [in] Sets the delay after which the actual cleanup of transport related resources is done after a call to `wifi_prov_mgr_stop_provisioning()` returns. Minimum allowed value is 100ms. If not specified, this will default to 1000ms.

**Returns**

- `ESP_OK`: Success
- `ESP_ERR_INVALID_STATE`: Manager not initialized or provisioning service already started

```c
esp_err_t wifi_prov_mgr_set_app_info (const char* label, const char* version, const char** capabilities, size_t total_capabilities)
```

Set application version and capabilities in the JSON data returned by proto-ver endpoint.

This function can be called multiple times, to specify information about the various application specific services running on the device, identified by unique labels.

The provisioning service itself registers an entry in the JSON data, by the label “prov”, containing only provisioning service version and capabilities. Application services should use a label other than “prov” so as not to overwrite this.

**Note:** This must be called before executing `wifi_prov_mgr_start_provisioning()`

**Parameters**

- `label` - [in] String indicating the application name.
- `version` - [in] String indicating the application version. There is no constraint on format.
- `capabilities` - [in] Array of strings with capabilities. These could be used by the client side app to know the application registered endpoint capabilities
- `total_capabilities` - [in] Size of capabilities array

**Returns**

- `ESP_OK`: Success
- `ESP_ERR_INVALID_STATE`: Manager not initialized or provisioning service already started
- `ESP_ERR_NO_MEM`: Failed to allocate memory for version string
- `ESP_ERR_INVALID_ARG`: Null argument

```c
esp_err_t wifi_prov_mgr_endpoint_create (const char *ep_name)
```

Create an additional endpoint and allocate internal resources for it.

This API is to be called by the application if it wants to create an additional endpoint. All additional endpoints will be assigned UUIDs starting from 0xFF54 and so on in the order of execution.

The `protocomm` handler for the created endpoint is to be registered later using `wifi_prov_mgr_endpoint_register()` after provisioning has started.

**Note:** This API can only be called BEFORE provisioning is started

**Note:** Additional endpoints can be used for configuring client provided parameters other than Wi-Fi credentials, that are necessary for the main application and hence must be set prior to starting the application.
Note: After session establishment, the additional endpoints must be targeted first by the client side application before sending Wi-Fi configuration, because once Wi-Fi configuration finishes the provisioning service is stopped and hence all endpoints are unregistered.

Parameters
- `ep_name` [in] unique name of the endpoint

Returns
- ESP_OK: Success
- ESP_FAIL: Failure

```c
esp_err_t wifi_prov_mgr_endpoint_register
(const char *ep_name, protocomm_req_handler_t
handler, void *user_ctx)
```

Register a handler for the previously created endpoint.

This API can be called by the application to register a protocomm handler to any endpoint that was created using `wifi_prov_mgr_endpoint_create()`.

Note: This API can only be called AFTER provisioning has started

Note: Additional endpoints can be used for configuring client provided parameters other than Wi-Fi credentials, that are necessary for the main application and hence must be set prior to starting the application.

Note: After session establishment, the additional endpoints must be targeted first by the client side application before sending Wi-Fi configuration, because once Wi-Fi configuration finishes the provisioning service is stopped and hence all endpoints are unregistered.

Parameters
- `ep_name` [in] Name of the endpoint
- `handler` [in] Endpoint handler function
- `user_ctx` [in] User data

Returns
- ESP_OK: Success
- ESP_FAIL: Failure

```c
void wifi_prov_mgr_endpoint_unregister(const char *ep_name)
```

Unregister the handler for an endpoint.

This API can be called if the application wants to selectively unregister the handler of an endpoint while the provisioning is still in progress.

All the endpoint handlers are unregistered automatically when the provisioning stops.

```c
esp_err_t wifi_prov_mgr_get_wifi_state(wifi_prov_sta_state_t *state)
```

Get state of Wi-Fi Station during provisioning.

Parameters `state` [out] Pointer to `wifi_prov_sta_state_t` variable to be filled

Returns
- ESP_OK: Successfully retrieved Wi-Fi state
- ESP_FAIL: Provisioning app not running

```c
esp_err_t wifi_prov_mgr_get_wifi_disconnect_reason(wifi_prov_sta_fail_reason_t *reason)
```

Get reason code in case of Wi-Fi station disconnection during provisioning.

Parameters `reason` [out] Pointer to `wifi_prov_sta_fail_reason_t` variable to be filled
**Chapter 2. API Reference**

**Returns**
- ESP_OK : Successfully retrieved Wi-Fi disconnect reason
- ESP_FAIL : Provisioning app not running

`esp_err_t wifi_prov_mgr_configure_sta(wifi_config_t *wifi_cfg)`
Runs Wi-Fi as Station with the supplied configuration.

Configures the Wi-Fi station mode to connect to the AP with SSID and password specified in config structure and sets Wi-Fi to run as station.

This is automatically called by provisioning service upon receiving new credentials.

If credentials are to be supplied to the manager via a different mode other than through protocomm, then this API needs to be called.

Event WIFI_PROV_CRED_RECV is emitted after credentials have been applied and Wi-Fi station started

**Parameters**
- `wifi_cfg` - [in] Pointer to Wi-Fi configuration structure

**Returns**
- ESP_OK : Wi-Fi configured and started successfully
- ESP_FAIL : Failed to set configuration

`esp_err_t wifi_prov_mgr_reset_provisioning(void)`
Reset Wi-Fi provisioning config.

Calling this API will restore WiFi stack persistent settings to default values.

**Returns**
- ESP_OK : Reset provisioning config successfully
- ESP_FAIL : Failed to reset provisioning config
- ESP_ERR_INVALID_STATE : Manager not initialized

`esp_err_t wifi_prov_mgr_reset_sm_state_on_failure(void)`
Reset internal state machine and clear provisioned credentials.

This API should be used to restart provisioning ONLY in the case of provisioning failures without rebooting the device.

**Returns**
- ESP_OK : Reset provisioning state machine successfully
- ESP_FAIL : Failed to reset provisioning state machine
- ESP_ERR_INVALID_STATE : Manager not initialized

`esp_err_t wifi_prov_mgr_reset_sm_state_for_reprovision(void)`
Reset internal state machine and clear provisioned credentials.

This API can be used to restart provisioning ONLY in case the device is to be provisioned again for new credentials after a previous successful provisioning without rebooting the device.

**Note:** This API can be used only if provisioning auto-stop has been disabled using `wifi_prov_mgr_disable_auto_stop()`

**Returns**
- ESP_OK : Reset provisioning state machine successfully
- ESP_FAIL : Failed to reset provisioning state machine
- ESP_ERR_INVALID_STATE : Manager not initialized

**Structures**

`struct wifi_prov_event_handler_t`  
Event handler that is used by the manager while provisioning service is active.
Public Members

`wifi_prov_cb_func_t event_cb`
Callback function to be executed on provisioning events

`void *user_data`
User context data to pass as parameter to callback function

`struct wifi_prov_scheme`
Structure for specifying the provisioning scheme to be followed by the manager.

**Note:** Ready to use schemes are available:
- `wifi_prov_scheme_ble`: for provisioning over BLE transport + GATT server
- `wifi_prov_scheme_softap`: for provisioning over SoftAP transport + HTTP server
- `wifi_prov_scheme_console`: for provisioning over Serial UART transport + Console (for debugging)

Public Members

`esp_err_t (*prov_start)(protocomm_t *pc, void *config)`
Function which is to be called by the manager when it is to start the provisioning service associated with a protocomm instance and a scheme specific configuration

`esp_err_t (*prov_stop)(protocomm_t *pc)`
Function which is to be called by the manager to stop the provisioning service previously associated with a protocomm instance

`void *(new_config)(void)`
Function which is to be called by the manager to generate a new configuration for the provisioning service, that is to be passed to `prov_start()`

`void *(delete_config)(void *config)`
Function which is to be called by the manager to delete a configuration generated using `new_config()`

`esp_err_t (*set_config_service)(void *config, const char *service_name, const char *service_key)`
Function which is to be called by the manager to set the service name and key values in the configuration structure

`esp_err_t (*set_config_endpoint)(void *config, const char *endpoint_name, uint16_t uuid)`
Function which is to be called by the manager to set a protocomm endpoint with an identifying name and UUID in the configuration structure

`wifi_mode_t wifi_mode`
Sets mode of operation of Wi-Fi during provisioning. This is set to:
- WIFI_MODE_APSTA for SoftAP transport
- WIFI_MODE_STA for BLE transport

`struct wifi_prov_mgr_config_t`
Structure for specifying the manager configuration.
Public Members

**wifi_prov_scheme_t scheme**

Provisioning scheme to use. Following schemes are already available:

- `wifi_prov_scheme_ble`: for provisioning over BLE transport + GATT server
- `wifi_prov_scheme_softap`: for provisioning over SoftAP transport + HTTP server + mDNS (optional)
- `wifi_prov_scheme_console`: for provisioning over Serial UART transport + Console (for debugging)

**wifi_prov_event_handler_t scheme_event_handler**

Event handler required by the scheme for incorporating scheme specific behavior while provisioning manager is running. Various options may be provided by the scheme for setting this field. Use `WIFI_PROV_EVENT_HANDLER_NONE` when not used. When using scheme `wifi_prov_scheme_ble`, the following options are available:

- `WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BTDM`
- `WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BLE`
- `WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BT`

**wifi_prov_event_handler_t app_event_handler**

Event handler that can be set for the purpose of incorporating application specific behavior. Use `WIFI_PROV_EVENT_HANDLER_NONE` when not used.

Macros

**WIFI_PROV_EVENT_HANDLER_NONE**

Event handler can be set to none if not used.

Type Definitions

typedef void (*wifi_prov_cb_func_t)(void *user_data, wifi_prov_cb_event_t event, void *event_data)

typedef struct wifi_prov_scheme wifi_prov_scheme_t

Structure for specifying the provisioning scheme to be followed by the manager.

Note: Ready to use schemes are available:

- `wifi_prov_scheme_ble`: for provisioning over BLE transport + GATT server
- `wifi_prov_scheme_softap`: for provisioning over SoftAP transport + HTTP server
- `wifi_prov_scheme_console`: for provisioning over Serial UART transport + Console (for debugging)

typedef enum wifi_prov_security wifi_prov_security_t

Security modes supported by the Provisioning Manager.

These are same as the security modes provided by protocomm

typedef protocomm_security2_params_t wifi_prov_security2_params_t

Security 2 params structure This needs to be passed when using WIFI_PROV_SECURITY_2.

Enumerations
Chapter 2. API Reference

enum wifi_prov_cb_event_t

Events generated by manager.

These events are generated in order of declaration and, for the stretch of time between initialization and de-initialization of the manager, each event is signaled only once.

Values:

enumerator WIFI_PROV_INIT

Emitted when the manager is initialized.

enumerator WIFI_PROV_START

Indicates that provisioning has started.

enumerator WIFI_PROV_CRED_RECV

Emitted when Wi-Fi AP credentials are received via `protocomm` endpoint `wifi_config`. The event data in this case is a pointer to the corresponding `wifi_sta_config_t` structure.

enumerator WIFI_PROV_CRED_FAIL

Emitted when device fails to connect to the AP of which the credentials were received earlier on event `WIFI_PROV_CRED_RECV`. The event data in this case is a pointer to the disconnection reason code with type `wifi_prov_sta_fail_reason_t`.

enumerator WIFI_PROV_CRED_SUCCESS

Emitted when device successfully connects to the AP of which the credentials were received earlier on event `WIFI_PROV_CRED_RECV`.

enumerator WIFI_PROV_END

Signals that provisioning service has stopped.

enumerator WIFI_PROV_DEINIT

Signals that manager has been de-initialized.

enum wifi_prov_security

Security modes supported by the Provisioning Manager.

These are same as the security modes provided by `protocomm`.

Values:

enumerator WIFI_PROV_SECURITY_0

No security (plain-text communication).

enumerator WIFI_PROV_SECURITY_1

This secure communication mode consists of X25519 key exchange

- proof of possession (pop) based authentication
- AES-CTR encryption

enumerator WIFI_PROV_SECURITY_2

This secure communication mode consists of SRP6a based authentication and key exchange

- AES-GCM encryption/decryption
Header File

- components/wifi_provisioning/include/wifi_provisioning/scheme_ble.h

Functions

void wifi_prov_scheme_ble_event_cb_free_btdm (void *user_data, wifi_prov_cb_event_t event, void *event_data)

void wifi_prov_scheme_ble_event_cb_free_ble (void *user_data, wifi_prov_cb_event_t event, void *event_data)

void wifi_prov_scheme_ble_event_cb_free_bt (void *user_data, wifi_prov_cb_event_t event, void *event_data)

esp_err_t wifi_prov_scheme_ble_set_service_uuid (uint8_t *uuid128)

Set the 128 bit GATT service UUID used for provisioning.

This API is used to override the default 128 bit provisioning service UUID, which is 0000fff-0000-1000-8000-00805f9b34fb.

This must be called before starting provisioning, i.e. before making a call to wifi_prov_mgr_start_provisioning(), otherwise the default UUID will be used.

Note: The data being pointed to by the argument must be valid at least till provisioning is started. Upon start, the manager will store an internal copy of this UUID, and this data can be freed or invalidated afterwards.

Parameters

- uuid128 [in] A custom 128 bit UUID

Returns

- ESP_OK : Success
- ESP_ERR_INVALID_ARG : Null argument

esp_err_t wifi_prov_scheme_ble_set_mfg_data (uint8_t *mfg_data, ssize_t mfg_data_len)

Set manufacturer specific data in scan response.

This must be called before starting provisioning, i.e. before making a call to wifi_prov_mgr_start_provisioning().

Note: It is important to understand that length of custom manufacturer data should be within limits. The manufacturer data goes into scan response along with BLE device name. By default, BLE device name length is of 11 Bytes, however it can vary as per application use case. So, one has to honour the scan response data size limits i.e. (mfg_data_len + 2) < 31 - (device_name_length + 2). If the mfg_data length exceeds this limit, the length will be truncated.

Parameters

- mfg_data [in] Custom manufacturer data
- mfg_data_len [in] Manufacturer data length

Returns

- ESP_OK : Success
- ESP_ERR_INVALID_ARG : Null argument

Macros

WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BTDM

WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BLE
**WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BT**

**Header File**

- components/wifi_provisioning/include/wifi_provisioning/scheme_softap.h

**Functions**

`void wifi_prov_scheme_softap_set_httpd_handle(void* handle)`

Provide HTTPD Server handle externally.

Useful in cases wherein applications need the webserver for some different operations, and do not want the wifi provisioning component to start/stop a new instance.

**Note:** This API should be called before wifi_prov_mgr_start_provisioning()

**Parameters**

`handle` - [in] Handle to HTTPD server instance

**Header File**

- components/wifi_provisioning/include/wifi_provisioning/scheme_console.h

**Header File**

- components/wifi_provisioning/include/wifi_provisioning/wifi_config.h

**Functions**

`esp_err_t wifi_prov_config_data_handler(uint32_t session_id, const uint8_t* inbuf, ssize_t inlen, uint8_t** outbuf, ssize_t* outlen, void* priv_data)`

Handler for receiving and responding to requests from master.

This is to be registered as the `wifi_config` endpoint handler (protocomm proto-comm_req_handler_t) using protocomm_add_endpoint()

**Structures**

`struct wifi_prov_sta_conn_info_t`

WiFi STA connected status information.

**Public Members**

- `char ip_addr[IP4ADDR_STRLEN_MAX]`
  
  IP Address received by station

- `char bssid[6]`
  
  BSSID of the AP to which connection was established

- `char ssid[33]`
  
  SSID of the to which connection was established
Chapter 2. API Reference

```c
uint8_t channel
Channel of the AP

uint8_t auth_mode
Authorization mode of the AP
```

```c
t struct wifi_prov_config_get_data_t
WiFi status data to be sent in response to get_status request from master.
```

Public Members

```c
wifi_prov_sta_state_t wifi_state
WiFi state of the station

wifi_prov_sta_fail_reason_t fail_reason
Reason for disconnection (valid only when wifi_state is WIFI_STATION_DISCONNECTED)

wifi_prov_sta_conn_info_t conn_info
Connection information (valid only when wifi_state is WIFI_STATION_CONNECTED)
```

```c
 struct wifi_prov_config_set_data_t
WiFi config data received by slave during set_config request from master.
```

Public Members

```c
char ssid[33]
SSID of the AP to which the slave is to be connected

char password[64]
Password of the AP

char bssid[6]
BSSID of the AP

uint8_t channel
Channel of the AP
```

```c
struct wifi_prov_config_handlers
Internal handlers for receiving and responding to protocomm requests from master.

This is to be passed as priv_data for protocomm request handler (refer to
wifi_prov_config_data_handler()) when calling protocomm_add_endpoint().
```

Public Members

```c
esp_err_t (*get_status_handler)(wifi_prov_config_get_data_t *resp_data, wifi_prov_ctx_t **ctx)
Handler function called when connection status of the slave (in WiFi station mode) is requested
```
esp_err_t (*set_config_handler)(const wifi_prov_config_set_data_t *req_data, wifi_prov_ctx_t **ctx)
Handler function called when WiFi connection configuration (e.g., AP SSID, password, etc.) of the slave (in WiFi station mode) is to be set to user provided values

esp_err_t (*apply_config_handler)(wifi_prov_ctx_t **ctx)
Handler function for applying the configuration that was set in set_config_handler. After applying the station may get connected to the AP or may fail to connect. The slave must be ready to convey the updated connection status information when get_status_handler is invoked again by the master.

wifi_prov_ctx_t *ctx
Context pointer to be passed to above handler functions upon invocation

Type Definitions
typedef struct wifi_prov_ctx wifi_prov_ctx_t
Type of context data passed to each get/set/apply handler function set in wifi_prov_config_handlers structure.
This is passed as an opaque pointer, thereby allowing it to be defined later in application code as per requirements.
typedef struct wifi_prov_config_handlers wifiProv_config_handlers_t
Internal handlers for receiving and responding to protocomm requests from master.
This is to be passed as priv_data for protocomm request handler (refer to wifi_prov_config_data_handler()) when calling protocomm_add_endpoint().

Enumerations
eenum wifi_prov_sta_state_t
WiFi STA status for conveying back to the provisioning master.
Values:

erenumerator WIFI_PROV_STA_CONNECTING

erenumerator WIFI_PROV_STA_CONNECTED

erenumerator WIFI_PROV_STA_DISCONNECTED

eenum wifi_prov_sta_fail_reason_t
WiFi STA connection fail reason.
Values:

erenumerator WIFI_PROV_STA_AUTH_ERROR

erenumerator WIFI_PROV_STA_AP_NOT_FOUND
Code examples for above API are provided in the provisioning directory of ESP-IDF examples.
Code example for above API is provided in wifi/smart_config.
Code example for above API is provided in wifi/wifi_easy_connect/dpp-enrollee.
Chapter 2. API Reference

2.9 Storage API

This section contains reference of the high-level storage APIs. They are based on low-level drivers such as SPI Flash, SD/MMC.

- **Partitions API** allow block based access to SPI Flash according to the Partition Table.
- **Non-Volatile Storage library (NVS)** implements a fault-tolerant wear-levelled key-value storage in SPI NOR Flash.
- **Virtual File System (VFS)** library provides an interface for registration of file system drivers. SPIFFS, FAT and various other file system libraries are based on the VFS.
- **SPIFFS** is a wear-levelled file system optimized for SPI NOR Flash, well suited for small partition sizes and low throughput
- **FAT** is a standard file system which can be used in SPI Flash or on SD/MMC cards
- **Wear Levelling** library implements a flash translation layer (FTL) suitable for SPI NOR Flash. It is used as a container for FAT partitions in Flash.

**Note:** It is suggested to use high-level APIs (`esp_partition` or file system) instead of low-level driver APIs to access the SPI NOR Flash.

Due to the restriction of NOR Flash and ESP hardware, accessing the main flash will affect the performance of the whole system. See *SPI Flash Documents* to learn more about the limitations.

2.9.1 FAT Filesystem Support

ESP-IDF uses the FatFs library to work with FAT filesystems. FatFs resides in the fatfs component. Although the library can be used directly, many of its features can be accessed via VFS using the C standard library and POSIX API functions.

Additionally, FatFs has been modified to support the runtime pluggable disk I/O layer. This allows mapping of FatFs drives to physical disks at runtime.

**Using FatFs with VFS**

The header file `fatfs/vfs/esp_vfs_fat.h` defines the functions for connecting FatFs and VFS.

The function `esp_vfs_fat_register()` allocates a FATFS structure and registers a given path prefix in VFS. Subsequent operations on files starting with this prefix are forwarded to FatFs APIs.

The function `esp_vfs_fat_unregister_path()` deletes the registration with VFS, and frees the FATFS structure.

Most applications use the following workflow when working with `esp_vfs_fat_` functions:

1. **Call `esp_vfs_fat_register()` to specify:**
   - Path prefix where to mount the filesystem (e.g., "/sdcard", "/spiflash")
   - FatFs drive number
   - A variable which will receive the pointer to the FATFS structure
2. **Call `ff_diskio_register()` to register the disk I/O driver for the drive number used in Step 1.
3. **Call the FatFs function `f_mount`, and optionally `f_fdisk`, `f_mkfs`, to mount the filesystem using the same drive number which was passed to `esp_vfs_fat_register()`**. For more information, see FatFs documentation.
4. **Call the C standard library and POSIX API functions to perform such actions on files as open, read, write, erase, copy, etc.** Use paths starting with the path prefix passed to `esp_vfs_register()` (for example, "/sdcard/hello.txt"). The filesystem uses 8.3 filenames format (SFN) by default. If you need to use
long filenames (LFN), enable the `CONFIG_FATFS_LONG_FILENAMES` option. More details on the FatFs filenames are available here.

5. Optionally, by enabling the option `CONFIG_FATFS_USE_FASTSEEK`, you can use the POSIX `seek` function to perform it faster. The fast seek will not work for files in write mode, so to take advantage of fast seek, you should open (or close and then reopen) the file in read-only mode.

6. Optionally, call the FatFs library functions directly. In this case, use paths without a VFS prefix (for example, "/hello.txt").

7. Close all open files.

8. Call the FatFs function `f_mount` for the same drive number with NULL `FATFS*` argument to unmount the filesystem.

9. Call the FatFs function `ff_diskio_register()` with NULL `ff_diskio_impl_t*` argument and the same drive number to unregister the disk I/O driver.

10. Call `esp_vfsFat_unregister_path()` with the path where the file system is mounted to remove FatFs from VFS, and free the FATFS structure allocated in Step 1.

The convenience functions `esp_vfsFat_sdmmc_mount()`, `esp_vfsFat_sdspi_mount()`, and `esp_vfsFat_sdcardUnmount()` wrap the steps described above and also handle SD card initialization. These functions are described in the next section.

Using FatFs with VFS and SD Cards

The header file `fatfs/vfs/esp_vfsFat.h` defines convenience functions `esp_vfsFat_sdmmc_mount()`, `esp_vfsFat_sdspi_mount()`, and `esp_vfsFat_sdcardUnmount()`. These functions perform Steps 1–3 and 7–9 respectively and handle SD card initialization, but provide only limited error handling. Developers are encouraged to check its source code and incorporate more advanced features into production applications.

The convenience function `esp_vfsFat_sdmmcUnmount()` unmounts the filesystem and releases the resources acquired by `esp_vfsFat_sdmmcMount()`.

Using FatFs with VFS in Read-Only Mode

The header file `fatfs/vfs/esp_vfsFat.h` also defines the convenience functions `esp_vfsFat_spiflash_mount_ro()` and `esp_vfsFat_spiflashUnmount_ro()`. These functions perform Steps 1-3 and 7-9 respectively for read-only FAT partitions. These are particularly helpful for data partitions written only once during factory provisioning which will not be changed by production application throughout the lifetime of the hardware.

FatFS Disk IO Layer

FatFs has been extended with API functions that register the disk I/O driver at runtime.

These APIs provide implementation of disk I/O functions for SD/MMC cards and can be registered for the given FatFs drive number using the function `ff_diskio_register_sdmmc()`.

```c
void ff_diskio_register (BYTE pdrv, const ff_diskio_impl_t *discio_impl)
{
    Register or unregister diskio driver for given drive number.

    When FATFS library calls one of disk_xxx functions for driver number pdrv, corresponding function in discio_impl for given pdrv will be called.

    Parameters
    • pdrv - drive number
    • discio_impl - pointer to ff_diskio_impl_t structure with diskio functions or NULL to unregister and free previously registered drive

    struct ff_diskio_impl_t
    Structure of pointers to disk IO driver functions.

    See FatFs documentation for details about these functions
```
Public Members

DSTATUS (*init)(unsigned char pdrv)
    disk initialization function

DSTATUS (*status)(unsigned char pdrv)
    disk status check function

DRESULT (*read)(unsigned char pdrv, unsigned char *buff, uint32_t sector, unsigned count)
    sector read function

DRESULT (*write)(unsigned char pdrv, const unsigned char *buff, uint32_t sector, unsigned count)
    sector write function

DRESULT (*ioctl)(unsigned char pdrv, unsigned char cmd, void *buff)
    function to get info about disk and do some misc operations

void ff_diskio_register_sdmmc (unsigned char pdrv, sdmmc_card_t *card)
    Register SD/MMC diskio driver

Parameters

• pdrv  - drive number
• card   - pointer to sdmmc_card_t structure describing a card; card should be initialized before calling f_mount.

esp_err_t ff_diskio_register_wl_partition (unsigned char pdrv, wl_handle_t flash_handle)
    Register spi flash partition

Parameters

• pdrv  - drive number
• flash_handle  - handle of the wear levelling partition.

esp_err_t ff_diskio_register_raw_partition (unsigned char pdrv, const esp_partition_t *part_handle)
    Register spi flash partition

Parameters

• pdrv  - drive number
• part_handle - pointer to raw flash partition.

FatFs Partition Generator

We provide a partition generator for FatFs (wl_fatfsgen.py) which is integrated into the build system and could be easily used in the user project.

The tool is used to create filesystem images on a host and populate it with content of the specified host folder.

The script is based on the partition generator (fatfsgen.py). Apart from generating partition, it can also initialize wear levelling.

The latest version supports both short and long file names, FAT12 and FAT16. The long file names are limited to 255 characters and can contain multiple periods (.) characters within the filename and additional characters +, , ;, =, [ and ].
**Build System Integration with FatFs Partition Generator**  
It is possible to invoke FatFs generator directly from the CMake build system by calling `fatfs_create_spiflash_image`:

```c
fatfs_create_spiflash_image(<partition> <base_dir> [FLASH_IN_PROJECT])
```

If you prefer generating partition without wear levelling support, you can use `fatfs_create_rawflash_image`:

```c
fatfs_create_rawflash_image(<partition> <base_dir> [FLASH_IN_PROJECT])
```

`fatfs_create_spiflash_image` respectively `fatfs_create_rawflash_image` must be called from project’s CMakeLists.txt.

If you decide for any reason to use `fatfs_create_rawflash_image` (without wear levelling support), beware that it supports mounting only in read-only mode in the device.

The arguments of the function are as follows:

1. **partition** - the name of the partition as defined in the partition table (e.g. `storage/fatfsgen/partitions_example.csv`).
2. **base_dir** - the directory that will be encoded to FatFs partition and optionally flashed into the device. Beware that you have to specify the suitable size of the partition in the partition table.
3. **flag FLASH_IN_PROJECT** - optionally, users can have the image automatically flashed together with the app binaries, partition tables, etc. on `idf.py flash -p <PORT>` by specifying `FLASH_IN_PROJECT`.
4. **flag PRESERVE_TIME** - optionally, users can force preserving the timestamps from the source folder to the target image. Without preserving the time, every timestamp will be set to the FATFS default initial time (1st January 1980).

For example:

```c
fatfs_create_spiflash_image(my_fatfs_partition my_folder FLASH_IN_PROJECT)
```

If `FLASH_IN_PROJECT` is not specified, the image will still be generated, but you will have to flash it manually using `esptool.py` or a custom build system target.

For an example, see `storage/fatfsgen`.

**FatFs Partition Analyzer**

(`fatfsparse.py`) is a partition analyzing tool for FatFs.

It is a reverse tool of (`fatfsgen.py`), i.e. it can generate the folder structure on the host based on the FatFs image.

Usage:

```
./fatfsparse.py [-h] [.--wl-layer {detect,enabled,disabled}] fatfs_image.img
```

**High-level API Reference**

**Header File**

- `components/fatfs/vfs/esp_vfs_fat.h`

**Functions**

`esp_err_t esp_vfs_fat_register` (const char *base_path, const char *fat_drive, size_t max_files, FATFS **out_fs)

Register FATFs with VFS component.

This function registers given FAT drive in VFS, at the specified base path. If only one drive is used, fat_drive argument can be an empty string. Refer to FATFS library documentation on how to specify FAT drive. This function also allocates FATFS structure which should be used for f_mount call.
Note: This function doesn’t mount the drive into FATFS, it just connects POSIX and C standard library IO function with FATFS. You need to mount desired drive into FATFS separately.

Parameters
- **base_path** — path prefix where FATFS should be registered
- **fat_drive** — FATFS drive specification; if only one drive is used, can be an empty string
- **max_files** — maximum number of files which can be open at the same time
- **out_fs** [out] pointer to FATFS structure which can be used for FATFS f_mount call is returned via this argument.

Returns
- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_register was already called
- ESP_ERR_NO_MEM if not enough memory or too many VFSes already registered

```c
esp_err_t esp_vfs_fat_unregister_path (const char *base_path)
```
Un-register FATFS from VFS.

Note: FATFS structure returned by esp_vfs_fat_register is destroyed after this call. Make sure to call f_mount function to unmount it before calling esp_vfs_fat_unregister_ctx. Difference between this function and the one above is that this one will release the correct drive, while the one above will release the last registered one.

Parameters **base_path** — path prefix where FATFS is registered. This is the same used when esp_vfs_fat_register was called

Returns
- ESP_OK on success
- ESP_ERR_INVALID_STATE if FATFS is not registered in VFS

```c
esp_err_t esp_vfs_fat_sdmmc_mount (const char *base_path, const sdmmc_host_t *host_config, const void *slot_config, const esp_vfs_fat_mount_config_t *mount_config, sdmmc_card_t **out_card)
```
Convenience function to get FAT filesystem on SD card registered in VFS.

This is an all-in-one function which does the following:
- Initializes SDMMC driver or SPI driver with configuration in host_config
- Initializes SD card with configuration in slot_config
- Mounts FAT partition on SD card using FATFS library, with configuration in mount_config
- Registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact. For real world applications, developers should implement the logic of probing SD card, locating and mounting partition, and registering FATFS in VFS, with proper error checking and handling of exceptional conditions.

Note: Use this API to mount a card through SDSPI is deprecated. Please call esp_vfs_fat_sdspi_mount() instead for that case.

Parameters
- **base_path** — path where partition should be registered (e.g. “/sdcard”)
- **host_config** — Pointer to structure describing SDMMC host. When using SDMMC peripheral, this structure can be initialized using SDMMC_HOST_DEFAULT() macro. When using SPI peripheral, this structure can be initialized using SD_SPI_HOST_DEFAULT() macro.
- **slot_config** — Pointer to structure with slot configuration. For SDMMC peripheral, pass a pointer to sdmmc_slot_config_t structure initialized using SDMMC_SLOT_CONFIG_DEFAULT.
• **mount_config** — pointer to structure with extra parameters for mounting FATFS
• **out_card** `[out]` if not NULL, pointer to the card information structure will be returned via this argument

**Returns**
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_sdspi_mount was already called
• ESP_ERR_NO_MEM if memory can not be allocated
• ESP_FAIL if partition can not be mounted
• other error codes from SDMMC or SPI drivers, SDMMC protocol, or FATFS drivers

```c
esp_err_t esp_vfs_fat_sdspi_mount(const char* base_path, const sdmmc_host_t *host_config_input,
                                 const sdspi_device_config_t *slot_config,
                                 const esp_vfs_fat_mount_config_t *mount_config,
                                 sdmmc_card_t **out_card)
```

Convenience function to get FAT filesystem on SD card registered in VFS.

This is an all-in-one function which does the following:

• initializes an SPI Master device based on the SPI Master driver with configuration in slot_config, and attach it to an initialized SPI bus.
• initializes SD card with configuration in host_config_input
• mounts FAT partition on SD card using FATFS library, with configuration in mount_config
• registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact. For real world applications, developers should implement the logic of probing SD card, locating and mounting partition, and registering FATFS in VFS, with proper error checking and handling of exceptional conditions.

**Note:** This function try to attach the new SD SPI device to the bus specified in host_config. Make sure the SPI bus specified in host_config->slot have been initialized by `spi_bus_initialize()` before.

**Parameters**
• **base_path** — path where partition should be registered (e.g. “/sdcard”)
• **host_config_input** — Pointer to structure describing SDMMC host. This structure can be initialized using `SDSPI_HOST_DEFAULT()` macro.
• **slot_config** — Pointer to structure with slot configuration. For SPI peripheral, pass a pointer to `sdspi_device_config_t` structure initialized using `SDSPI_DEVICE_CONFIG_DEFAULT()`.
• **mount_config** — pointer to structure with extra parameters for mounting FATFS
• **out_card** `[out]` If not NULL, pointer to the card information structure will be returned via this argument. It is suggested to hold this handle and use it to unmount the card later if needed. Otherwise it’s not suggested to use more than one card at the same time and unmount one of them in your application.

**Returns**
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_sdspi_mount was already called
• ESP_ERR_NO_MEM if memory can not be allocated
• ESP_FAIL if partition can not be mounted
• other error codes from SDMMC or SPI drivers, SDMMC protocol, or FATFS drivers

```c
esp_err_t esp_vfs_fat_sdmmcUnmount(void)
```

Unmount FAT filesystem and release resources acquired using esp_vfs_fat_sdmmc_mount.

**Deprecated:**
Use `esp_vfs_fat_sdcardUnmount()` instead.
## Returns

- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_sdmmc_mount hasn’t been called

### esp_err_t esp_vfs_fat_sdcard_unmount (const char *base_path, sdmmc_card_t *card)

Unmount an SD card from the FAT filesystem and release resources acquired using esp_vfs_fat_sdmmc_mount() or esp_vfs_fat_sdspi_mount().

### Returns

- ESP_OK on success
- ESP_ERR_INVALID_ARG if the card argument is unregistered
- ESP_ERR_INVALID_STATE if esp_vfs_fat_sdmmc_mount hasn’t been called

### esp_err_t esp_vfs_fat_sdcard_format (const char *base_path, sdmmc_card_t *card)

Format FAT filesystem.

### Note:
This API should be only called when the FAT is already mounted.

## Parameters

- **base_path** – Path where partition should be registered (e.g. “/sdcard”)
- **card** – Pointer to the card handle, which should be initialised by calling esp_vfs_fat_sdspi_mount first

### Returns

- ESP_OK
- ESP_ERR_INVALID_STATE: FAT partition isn’t mounted, call esp_vfs_fat_sdmmc_mount or esp_vfs_fat_sdspi_mount first
- ESP_ERR_NO_MEM: if memory cannot be allocated
- ESP_FAIL: fail to format it, or fail to mount back

### esp_err_t esp_vfs_fat_spiflash_mount_rw_wl (const char *base_path, const char *partition_label, const esp_vfs_fat_mount_config_t *mount_config, wl_handle_t *wl_handle)

Convenience function to initialize FAT filesystem in SPI flash and register it in VFS. This is an all-in-one function which does the following:

- finds the partition with defined partition_label. Partition label should be configured in the partition table.
- initializes flash wear levelling library on top of the given partition
- mounts FAT partition using FATFS library on top of flash wear levelling library
- registers FATFS library with VFS, with prefix given by base_prefix variable

This function is intended to make example code more compact.

### Parameters

- **base_path** – path where FATFS partition should be mounted (e.g. “/spiflash”)
- **partition_label** – label of the partition which should be used
- **mount_config** – pointer to structure with extra parameters for mounting FATFS
- **wl_handle** – [out] wear levelling driver handle

### Returns

- ESP_OK on success
- ESP_ERR_NOT_FOUND if the partition table does not contain FATFS partition with given label
- ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount_rw_wl was already called
- ESP_ERR_NO_MEM if memory cannot be allocated
- ESP_FAIL if partition cannot be mounted
- other error codes from wear levelling library, SPI flash driver, or FATFS drivers
**Chapter 2. API Reference**

```c
esp_err_t esp_vfs_fat_spiflash_unmount_rw_wl(const char* base_path, wl_handle_t wl_handle)
```

Unmount FAT filesystem and release resources acquired using esp_vfs_fat_spiflash_mount_rw_wl.

**Parameters**
- `base_path` – path where partition should be registered (e.g. “/spiflash”)
- `wl_handle` – wear levelling driver handle returned by esp_vfs_fat_spiflash_mount_rw_wl

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount_rw_wl hasn’t been called

```c
esp_err_t esp_vfs_fat_spiflash_format_rw_wl(const char* base_path, const char* partition_label)
```

Format FAT filesystem.

**Note:** This API can be called when the FAT is mounted / not mounted. If this API is called when the FAT isn’t mounted (by calling esp_vfs_fat_spiflash_mount_rw_wl), this API will first mount the FAT then format it, then restore back to the original state.

**Parameters**
- `base_path` – Path where partition should be registered (e.g. “/spiflash”)
- `partition_label` – Label of the partition which should be used

**Returns**
- ESP_OK
- ESP_ERR_NO_MEM: if memory cannot be allocated
- Other errors from esp_vfs_fat_spiflash_mount_rw_wl

```c
esp_err_t esp_vfs_fat_spiflash_mount_ro(const char* base_path, const char* partition_label, const esp_vfs_fat_mount_config_t* mount_config)
```

Convenience function to initialize read-only FAT filesystem and register it in VFS.

This is an all-in-one function which does the following:

- finds the partition with defined partition_label. Partition label should be configured in the partition table.
- mounts FAT partition using FATFS library
- registers FATFS library with VFS, with prefix given by base_prefix variable

**Note:** Wear levelling is not used when FAT is mounted in read-only mode using this function.

**Parameters**
- `base_path` – path where FATFS partition should be mounted (e.g. “/spiflash”)
- `partition_label` – label of the partition which should be used
- `mount_config` – pointer to structure with extra parameters for mounting FATFS

**Returns**
- ESP_OK on success
- ESP_ERR_NOT_FOUND if the partition table does not contain FATFS partition with given label
- ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount_ro was already called for the same partition
- ESP_ERR_NO_MEM if memory can not be allocated
- ESP_FAIL if partition can not be mounted
- other error codes from SPI flash driver, or FATFS drivers

```c
esp_err_t esp_vfs_fat_spiflash_unmount_ro(const char* base_path, const char* partition_label)
```

Unmount FAT filesystem and release resources acquired using esp_vfs_fat_spiflash_mount_ro.
Parameters

- **base_path** - path where partition should be registered (e.g. “/spiflash”)
- **partition_label** - label of partition to be unmounted

Returns

- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount_ro hasn’t been called

```c
esp_err_t esp_vfs_fat_info (const char* base_path, uint64_t* out_total_bytes, uint64_t* out_free_bytes)
```

Get information for FATFS partition.

Parameters

- **base_path** - Base path of the partition examined (e.g. “/spiflash”)
- **out_total_bytes** - [out] Size of the file system
- **out_free_bytes** - [out] Free bytes available in the file system

Returns

- ESP_OK on success
- ESP_ERR_INVALID_STATE if partition not found
- ESP_FAIL if another FRESULT error (saved in errno)

Structures

```c
struct esp_vfs_fat_mount_config_t
```

Configuration arguments for esp_vfs_fat_sdmmc_mount and esp_vfs_fat_spiflash_mount_rw_wl functions.

Public Members

```c
bool format_if_mount_failed
```

If FAT partition can not be mounted, and this parameter is true, create partition table and format the filesystem.

```c
int max_files
```

Max number of open files.

```c
size_t allocation_unit_size
```

If format_if_mount_failed is set, and mount fails, format the card with given allocation unit size. Must be a power of 2, between sector size and 128 * sector size. For SD cards, sector size is always 512 bytes. For wear levelling, sector size is determined by CONFIG_WL_SECTOR_SIZE option.

Using larger allocation unit size will result in higher read/write performance and higher overhead when storing small files.

Setting this field to 0 will result in allocation unit set to the sector size.

```c
bool disk_status_check_enable
```

Enables real ff_disk_status function implementation for SD cards (ff_sdmmc_status). Possibly slows down IO performance.

Try to enable if you need to handle situations when SD cards are not unmounted properly before physical removal or you are experiencing issues with SD cards.

Doesn’t do anything for other memory storage media.

Type Definitions

```c
typedef esp_vfs_fat_mount_config_t esp_vfsFat_sdmmc_mount_config_t
```

Espressif Systems 1811 Release v5.1.2

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2.9.2 Manufacturing Utility

Introduction

This utility is designed to create instances of factory NVS partition images on a per-device basis for mass manufacturing purposes. The NVS partition images are created from CSV files containing user-provided configurations and values.

Please note that this utility only creates manufacturing binary images which then need to be flashed onto your devices using:

- `esptool.py`
- `Flash Download tool` (available on Windows only). Just download it, unzip, and follow the instructions inside the `doc` folder.
- Direct flash programming using custom production tools.

Prerequisites

This utility is dependent on esp-idf’s NVS partition utility.

- **Operating System requirements:**
  - Linux / MacOS / Windows (standard distributions)
- **The following packages are needed to use this utility:**
  - Python

*Note:*

Before using this utility, please make sure that:

- The path to Python is added to the PATH environment variable.
- You have installed the packages from `requirement.txt`, the file in the root of the esp-idf directory.

Workflow

CSV Configuration file  →  Master Value CSV file  →  Binary files

CSV Configuration File

This file contains the configuration of the device to be flashed.

The data in the configuration file has the following format (the `REPEAT` tag is optional):

```plaintext
name1,namespace,  <-- First entry should be of type "namespace"
key1,type1,encoding1
key2,type2,encoding2,REPEAT
name2,namespace,
key3,type3,encoding3
key4,type4,encoding4
```
Note: The first line in this file should always be the namespace entry.

Each line should have three parameters: key, type, encoding, separated by a comma. If the REPEAT tag is present, the value corresponding to this key in the master value CSV file will be the same for all devices.

Please refer to README of the NVS Partition Generator utility for detailed description of each parameter.

Below is a sample example of such a configuration file:

```txt
app,namespace,
firmware_key,data,hex2bin
serial_no,data,string,REPEAT
device_no,data,i32
```

Note:

Make sure there are no spaces:

- before and after `,,'
- at the end of each line in a CSV file

Master Value CSV File

This file contains details of the devices to be flashed. Each line in this file corresponds to a device instance.

The data in the master value CSV file has the following format:

```txt
key1,key2,key3,......
value1,value2,value3,....
```

Note: The first line in the file should always contain the key names. All the keys from the configuration file should be present here in the same order. This file can have additional columns (keys). The additional keys will be treated as metadata and would not be part of the final binary files.

Each line should contain the value of the corresponding keys, separated by a comma. If the key has the REPEAT tag, its corresponding value must be entered in the second line only. Keep the entry empty for this value in the following lines.

The description of this parameter is as follows:

value Data value

Data value is the value of data corresponding to the key.

Below is a sample example of a master value CSV file:

```txt
id,firmware_key,serial_no,device_no
1,1a2b3c4d5e6faabb,A1,101
2,1a2b3c4d5e6fcddd,,102
3,1a2b3c4d5e6feeff,,103
```

Note: If the ‘REPEAT’ tag is present, a new master value CSV file will be created in the same folder as the input Master CSV File with the values inserted at each line for the key with the ‘REPEAT’ tag.

This utility creates intermediate CSV files which are used as input for the NVS partition utility to generate the binary files.

The format of this intermediate CSV file is as follows:
An instance of an intermediate CSV file will be created for each device on an individual basis.

**Running the utility**

**Usage:**

```
python mfg_gen.py [-h] {generate,generate-key} ...
```

**Optional Arguments:**

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
</tbody>
</table>

**Commands:**

Run `mfg_gen.py {command} -h` for additional help

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>generate</td>
<td>Generate NVS partition</td>
</tr>
<tr>
<td>2</td>
<td>generate-key</td>
<td>Generate keys for encryption</td>
</tr>
</tbody>
</table>

To generate factory images for each device (Default):

**Usage:**

```
python mfg_gen.py generate [-h] [--fileid FILEID] [--version {1,2}] [--keygen] [--keyfile KEYFILE] [--inputkey INPUTKEY] [--outdir OUTDIR]
cnf values prefix size
```

**Positional Arguments:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>conf</td>
<td>Path to configuration csv file to parse</td>
</tr>
<tr>
<td>values</td>
<td>Path to values csv file to parse</td>
</tr>
<tr>
<td>prefix</td>
<td>Unique name for each output filename prefix</td>
</tr>
<tr>
<td>size</td>
<td>Size of NVS partition in bytes (must be multiple of 4096)</td>
</tr>
</tbody>
</table>

**Optional Arguments:**
### Chapter 2. API Reference

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-h</code>, <code>--help</code></td>
<td>show this help message and exit</td>
</tr>
<tr>
<td><code>fileid</code></td>
<td>Unique file identifier (any key in values file) for each filename suffix</td>
</tr>
<tr>
<td><code>FILEID</code></td>
<td>(Default: numeric value(1,2,3,...))</td>
</tr>
<tr>
<td><code>{1,2}</code></td>
<td>Version 2 - Multipage blob support enabled.</td>
</tr>
<tr>
<td><code>keygen</code></td>
<td>Generates key for encrypting NVS partition</td>
</tr>
<tr>
<td><code>inputkey</code></td>
<td>File having key for encrypting NVS partition</td>
</tr>
<tr>
<td><code>outdir</code></td>
<td>Output directory to store files created (Default: current directory)</td>
</tr>
</tbody>
</table>

You can run the utility to generate factory images for each device using the command below. A sample CSV file is provided with the utility:

```bash
python mfg_gen.py generate samples/sample_config.csv samples/sample_values_-singlepage_blob.csv Sample 0x3000
```

The master value CSV file should have the path in the file type relative to the directory from which you are running the utility.

**To generate encrypted factory images for each device:**

You can run the utility to encrypt factory images for each device using the command below. A sample CSV file is provided with the utility:

- Encrypt by allowing the utility to generate encryption keys:

  ```bash
  python mfg_gen.py generate samples/sample_config.csv samples/sample_values_-singlepage_blob.csv Sample 0x3000 --keygen
  ```

  **Note:** Encryption key of the following format `<outdir>/keys/keys-<prefix>-<fileid>.bin` is created. This newly created file having encryption keys in `keys/` directory is compatible with NVS key-partition structure. Refer to *NVS Key Partition* for more details.

- Encrypt by providing the encryption keys as input binary file:

  ```bash
  python mfg_gen.py generate samples/sample_config.csv samples/sample_values_-singlepage_blob.csv Sample 0x3000 --inputkey keys/sample_keys.bin
  ```

**To generate only encryption keys:**

**Usage:** python mfg_gen.py generate-key [-h] [-keyfile KEYFILE] [-outdir OUTDIR]

**Optional Arguments:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>-h</code>, <code>--help</code></td>
<td>show this help message and exit</td>
</tr>
<tr>
<td><code>keyfile</code></td>
<td>Path to output encryption keys file</td>
</tr>
<tr>
<td><code>outdir</code></td>
<td>Output directory to store files created. (Default: current directory)</td>
</tr>
</tbody>
</table>

You can run the utility to generate only encryption keys using the command below:

```bash
python mfg_gen.py generate-key
```

**Note:** Encryption key of the following format `<outdir>/keys/keys-<timestamp>.bin` is created. Timestamp format is: `%m-%d_%H-%M`. To provide custom target filename use the `--keyfile` argument.

Generated encryption key binary file can further be used to encrypt factory images created on the per device basis.
The default numeric value: 1,2,3 of the fileid argument corresponds to each line bearing device instance values in the master value CSV file.

While running the manufacturing utility, the following folders will be created in the specified outdir directory:

- **bin/** for storing the generated binary files
- **csv/** for storing the generated intermediate CSV files
- **keys/** for storing encryption keys (when generating encrypted factory images)

## 2.9.3 Non-volatile Storage Library

### Introduction

Non-volatile storage (NVS) library is designed to store key-value pairs in flash. This section introduces some concepts used by NVS.

**Underlying Storage**  Currently, NVS uses a portion of main flash memory through the *esp_partition* API. The library uses all the partitions with *data* type and *nvs* subtype. The application can choose to use the partition with the label *nvs* through the *nvs_open()* API function or any other partition by specifying its name using the *nvs_open_from_partition()* API function.

Future versions of this library may have other storage backends to keep data in another flash chip (SPI or I2C), RTC, FRAM, etc.

**Note:** if an NVS partition is truncated (for example, when the partition table layout is changed), its contents should be erased. ESP-IDF build system provides [idf.py erase-flash](https://docs.espressif.com/projects/idf/en/latest/boards/components/esp_partition.html) target to erase all contents of the flash chip.

**Note:** NVS works best for storing many small values, rather than a few large values of the type ‘string’ and ‘blob’. If you need to store large blobs or strings, consider using the facilities provided by the FAT filesystem on top of the wear levelling library.

**Keys and Values**  NVS operates on key-value pairs. Keys are ASCII strings; the maximum key length is currently 15 characters. Values can have one of the following types:

- integer types: `uint8_t, int8_t, uint16_t, int16_t, uint32_t, int32_t, uint64_t, int64_t`
- zero-terminated string
- variable length binary data (blob)

**Note:** String values are currently limited to 4000 bytes. This includes the null terminator. Blob values are limited to 508,000 bytes or 97.6% of the partition size - 4000 bytes, whichever is lower.

Additional types, such as `float` and `double` might be added later.

Keys are required to be unique. Assigning a new value to an existing key works as follows:

- If the new value is of the same type as the old one, value is updated.
- If the new value has a different data type, an error is returned.

Data type check is also performed when reading a value. An error is returned if the data type of the read operation does not match the data type of the value.
Namespaces   To mitigate potential conflicts in key names between different components, NVS assigns each key-value pair to one of namespaces. Namespace names follow the same rules as key names, i.e., the maximum length is 15 characters. Furthermore, there can be no more than 254 different namespaces in one NVS partition. Namespace name is specified in the `nvs_open()` or `nvs_open_from_partition` call. This call returns an opaque handle, which is used in subsequent calls to the `nvs_get_*`, `nvs_set_*`, and `nvs_commit()` functions. This way, a handle is associated with a namespace, and key names will not collide with same names in other namespaces. Please note that the namespaces with the same name in different NVS partitions are considered as separate namespaces.

NVS Iterators   Iterators allow to list key-value pairs stored in NVS, based on specified partition name, namespace, and data type. There are the following functions available:

- `nvs_entry_find()` creates an opaque handle, which is used in subsequent calls to the `nvs_entry_next()` and `nvs_entry_info()` functions.
- `nvs_entry_next()` advances an iterator to the next key-value pair.
- `nvs_entry_info()` returns information about each key-value pair.

In general, all iterators obtained via `nvs_entry_find()` have to be released using `nvs_release_iterator()`, which also tolerates NULL iterators. `nvs_entry_find()` and `nvs_entry_next()` will set the given iterator to NULL or a valid iterator in all cases except a parameter error occurred (i.e., return ESP_ERR_NVS_NOT_FOUND). In case of a parameter error, the given iterator will not be modified. Hence, it is best practice to initialize the iterator to NULL before calling `nvs_entry_find()` to avoid complicated error checking before releasing the iterator.

Security, Tampering, and Robustness   NVS is not directly compatible with the ESP32 flash encryption system. However, data can still be stored in encrypted form if NVS encryption is used together with ESP32 flash encryption. Please refer to NVS Encryption for more details.

If NVS encryption is not used, it is possible for anyone with physical access to the flash chip to alter, erase, or add key-value pairs. With NVS encryption enabled, it is not possible to alter or add a key-value pair and get recognized as a valid pair without knowing corresponding NVS encryption keys. However, there is no tamper-resistance against the erase operation.

The library does try to recover from conditions when flash memory is in an inconsistent state. In particular, one should be able to power off the device at any point and time and then power it back on. This should not result in loss of data, except for the new key-value pair if it was being written at the moment of powering off. The library should also be able to initialize properly with any random data present in flash memory.

NVS Encryption

Data stored in NVS partitions can be encrypted using AES-XTS in the manner similar to the one mentioned in disk encryption standard IEEE P1619. For the purpose of encryption, each entry is treated as one sector and relative address of the entry (w.r.t. partition-start) is fed to the encryption algorithm as sector-number. The NVS Encryption can be enabled by enabling `CONFIG_NVS_ENCRYPTION`. The keys required for NVS encryption are stored in yet another partition, which is protected using Flash Encryption. Therefore, enabling Flash Encryption is a prerequisite for NVS encryption.

The NVS Encryption is enabled by default when Flash Encryption is enabled. This is done because Wi-Fi driver stores credentials (like SSID and passphrase) in the default NVS partition. It is important to encrypt them as default choice if platform level encryption is already enabled.

For using NVS encryption, the partition table must contain the NVS Key Partition. Two partition tables containing the NVS Key Partition are provided for NVS encryption under the partition table option (menuconfig > Partition Table). They can be selected with the project configuration menu (`idf.py menuconfig`). Please refer to the example security/flash_encryption for how to configure and use NVS encryption feature.
NVS Key Partition  An application requiring NVS encryption support needs to be compiled with a key-partition of the type data and subtype key. This partition should be marked as encrypted and its size should be the minimum partition size (4KB). Refer to Partition Tables for more details. Two additional partition tables which contain the NVS Key Partition are provided under the partition table option (menuconfig > Partition Table). They can be directly used for NVS Encryption. The structure of these partitions is depicted below.

| +-------------------------------------------------+       |
| | XTS encryption key (32) |       |
| +---------------------------------------------+       |
| | XTS tweak key (32) |       |
| +---------------------------------------------+       |
| | CRC32 (4) |       |
| +-------------------------------------------------+       |

The XTS encryption keys in the NVS Key Partition can be generated in one of the following two ways.

1. Generate the keys on the ESP chip:
   When NVS encryption is enabled the nvs_flash_init() API function can be used to initialize the encrypted default NVS partition. The API function internally generates the XTS encryption keys on the ESP chip. The API function finds the first NVS Key Partition. Then the API function automatically generates and stores the NVS keys in that partition by making use of the nvs_flash_generate_keys() API function provided by nvs_flash/include/nvs_flash.h. New keys are generated and stored only when the respective key partition is empty. The same key partition can then be used to read the security configurations for initializing a custom encrypted NVS partition with help of nvs_flash_secure_init_partition(). The API functions nvs_flash_secure_init() and nvs_flash_secure_init_partition() do not generate the keys internally. When these API functions are used for initializing encrypted NVS partitions, the keys can be generated after startup using the nvsflash_generate_keys() API function provided by nvs_flash.h. The API function will then write those keys onto the key-partition in encrypted form.

   **Note:** Please note that nvs_keys partition must be completely erased before you start the application in this approach. Otherwise the application may generate ESP_ERR_NVS_CORRUPT_KEY_PART error code assuming that nvs_keys partition is not empty and contains malformed data. You can use the following command for this:

   parttool.py --port PORT --partition-table-file=PARTITION_TABLE_FILE --partition-table-offset PARTITION_TABLE_OFFSET erase_partition --partition-type=data --partition-subtype=nvs_keys

2. Use pre-generated key partition:
   This option will be required by the user when keys in the NVS Key Partition are not generated by the application. The NVS Key Partition containing the XTS encryption keys can be generated with the help of NVS Partition Generator Utility. Then the user can store the pre generated key partition on the flash with help of the following two commands:
   i) Build and flash the partition table

   ```
   idf.py partition-table partition-table-flash
   ```
   ii) Store the keys in the NVS Key Partition (on the flash) with the help of parttool.py (see Partition Tool section in partition-tables for more details)

   ```
   parttool.py --port PORT --partition-table-offset PARTITION_TABLE_OFFSET write_partition --partition-name="name of nvs_key partition" --input NVS_KEY_PARTITION_FILE
   ```

   **Note:** If the device is encrypted in flash encryption development mode and you want to renew the NVS key partition, you need to tell parttool.py to encrypt the NVS key partition and you also need to give it a pointer to the unencrypted partition table in your build directory (build/partition_table) since the partition table on the device is encrypted, too. You can use the following command:
Since the key partition is marked as *encrypted* and *Flash Encryption* is enabled, the bootloader will encrypt this partition using flash encryption key on the first boot.

It is possible for an application to use different keys for different NVS partitions and thereby have multiple key-partitions. However, it is a responsibility of the application to provide correct key-partition/keys for the purpose of encryption/decryption.

**Encrypted Read/Write**  The same NVS API functions `nvs_get_*` or `nvs_set_*` can be used for reading of, and writing to an encrypted nvs partition as well.

**Encrypt the default NVS partition**: To enable encryption for the default NVS partition no additional steps are necessary. When `CONFIG_NVS_ENCRYPTION` is enabled, the `nvs_flash_init()` API function internally performs some additional steps using the first NVS Key Partition found to enable encryption for the default NVS partition (refer to the API documentation for more details). Alternatively, `nvs_flash_secure_init()` API function can also be used to enable encryption for the default NVS partition.

**Encrypt a custom NVS partition**: To enable encryption for a custom NVS partition, `nvs_flash_secure_init_partition()` API function is used instead of `nvs_flash_init_partition()`.

When `nvs_flash_secure_init()` and `nvs_flash_secure_init_partition()` API functions are used, the applications are expected to follow the steps below in order to perform NVS read/write operations with encryption enabled.

1. Find key partition and NVS data partition using `esp_partition_find_*` API functions.
2. Populate the `nvs_sec_cfg_t` struct using the `nvs_flash_read_security_cfg()` or `nvs_flash_generate_keys()` API functions.
3. Initialise NVS flash partition using the `nvs_flash_secure_init()` or `nvs_flash_secure_init_partition()` API functions.
4. Open a namespace using the `nvs_open()` or `nvs_open_from_partition()` API functions.
5. Perform NVS read/write operations using `nvs_get_*` or `nvs_set_*`.
6. Deinitialise an NVS partition using `nvs_flash_deinit()`.

**NVS Partition Generator Utility**

This utility helps generate NVS partition binary files which can be flashed separately on a dedicated partition via a flashing utility. Key-value pairs to be flashed onto the partition can be provided via a CSV file. For more details, please refer to *NVS Partition Generator Utility*.

**Application Example**

You can find code examples in the `storage` directory of ESP-IDF examples:

- **storage/nvs_rw_value**
  
  Demonstrates how to read a single integer value from, and write it to NVS.
  
  The value checked in this example holds the number of the ESP32 module restarts. The value’s function as a counter is only possible due to its storing in NVS.
  
  The example also shows how to check if a read / write operation was successful, or if a certain value has not been initialized in NVS. The diagnostic procedure is provided in plain text to help you track the program flow and capture any issues on the way.

- **storage/nvs_rw_blob**
Chapter 2. API Reference

Demonstrates how to read a single integer value and a blob (binary large object), and write them to NVS to preserve this value between ESP32 module restarts.

- value - tracks the number of the ESP32 module soft and hard restarts.
- blob - contains a table with module run times. The table is read from NVS to dynamically allocated RAM. A new run time is added to the table on each manually triggered soft restart, and then the added run time is written to NVS. Triggering is done by pulling down GPIO0.

The example also shows how to implement the diagnostic procedure to check if the read / write operation was successful.

storage/nvs_rw_value_cxx

This example does exactly the same as storage/nvs_rw_value, except that it uses the C++ NVS handle class.

Internals

**Log of Key-Value Pairs** NVS stores key-value pairs sequentially, with new key-value pairs being added at the end. When a value of any given key has to be updated, a new key-value pair is added at the end of the log and the old key-value pair is marked as erased.

**Pages and Entries** NVS library uses two main entities in its operation: pages and entries. Page is a logical structure which stores a portion of the overall log. Logical page corresponds to one physical sector of flash memory. Pages which are in use have a sequence number associated with them. Sequence numbers impose an ordering on pages. Higher sequence numbers correspond to pages which were created later. Each page can be in one of the following states:

- **Empty/uninitialized** Flash storage for the page is empty (all bytes are \(0xff\)). Page is not used to store any data at this point and does not have a sequence number.
- **Active** Flash storage is initialized, page header has been written to flash, page has a valid sequence number. Page has some empty entries and data can be written there. No more than one page can be in this state at any given moment.
- **Full** Flash storage is in a consistent state and is filled with key-value pairs. Writing new key-value pairs into this page is not possible. It is still possible to mark some key-value pairs as erased.
- **Erasing** Non-erased key-value pairs are being moved into another page so that the current page can be erased. This is a transient state, i.e., page should never stay in this state at the time when any API call returns. In case of a sudden power off, the move-and-erase process will be completed upon the next power-on.
- **Corrupted** Page header contains invalid data, and further parsing of page data was canceled. Any items previously written into this page will not be accessible. The corresponding flash sector will not be erased immediately and will be kept along with sectors in uninitialized state for later use. This may be useful for debugging.

Mapping from flash sectors to logical pages does not have any particular order. The library will inspect sequence numbers of pages found in each flash sector and organize pages in a list based on these numbers.

| +----------+ | +----------+ | +----------+ | +----------+ |
| Page 1 | Page 2 | Page 3 | Page 4 |
| Full | Full | Active | Empty |
| #11 | #12 | #14 | |
| +----------+ | +----------+ | +----------+ |
| | | |
| +----------+ | +----------+ | +----------+ | +----------+ |
| | | | |
| | | | |
| Sector 3 | Sector 0 | Sector 2 | Sector 1 |
| +----------+ | +----------+ | +----------+ |

**Structure of a Page** For now, we assume that flash sector size is 4096 bytes and that ESP32 flash encryption hardware operates on 32-byte blocks. It is possible to introduce some settings configurable at compile-time (e.g., via...
menuconfig) to accommodate flash chips with different sector sizes (although it is not clear if other components in the system, e.g., SPI flash driver and SPI flash cache can support these other sizes).

Page consists of three parts: header, entry state bitmap, and entries themselves. To be compatible with ESP32 flash encryption, the entry size is 32 bytes. For integer types, an entry holds one key-value pair. For strings and blobs, an entry holds part of key-value pair (more on that in the entry structure description).

The following diagram illustrates the page structure. Numbers in parentheses indicate the size of each part in bytes.

![Diagram of page structure](image)

Page header and entry state bitmap are always written to flash unencrypted. Entries are encrypted if flash encryption feature of ESP32 is used.

Page state values are defined in such a way that changing state is possible by writing 0 into some of the bits. Therefore it is not necessary to erase the page to change its state unless that is a change to the erased state.

The version field in the header reflects the NVS format version used. For backward compatibility reasons, it is decremented for every version upgrade starting at 0xff (i.e., 0xff for version-1, 0xfe for version-2 and so on).

CRC32 value in the header is calculated over the part which does not include a state value (bytes 4 to 28). The unused part is currently filled with 0xff bytes.

The following sections describe the structure of entry state bitmap and entry itself.

**Entry and Entry State Bitmap** Each entry can be in one of the following three states represented with two bits in the entry state bitmap. The final four bits in the bitmap (256 - 2 * 126) are not used.

- **Empty** (2'b11) Nothing is written into the specific entry yet. It is in an uninitialized state (all bytes are 0xff).
- **Written** (2'b10) A key-value pair (or part of key-value pair which spans multiple entries) has been written into the entry.
- **Erased** (2'b00) A key-value pair in this entry has been discarded. Contents of this entry will not be parsed anymore.

**Structure of Entry** For values of primitive types (currently integers from 1 to 8 bytes long), entry holds one key-value pair. For string and blob types, entry holds part of the whole key-value pair. For strings, in case when a key-value pair spans multiple entries, all entries are stored in the same page. Blobs are allowed to span over multiple pages by dividing them into smaller chunks. For tracking these chunks, an additional fixed length metadata entry is stored called “blob index”. Earlier formats of blobs are still supported (can be read and modified). However, once the blobs are modified, they are stored using the new format.
Individual fields in entry structure have the following meanings:

**NS**  Namespace index for this entry. For more information on this value, see the section on namespaces implementation.

**Type**  One byte indicating the value data type. See the `ItemType` enumeration in `nvs_flash/include/nvs_handle.hpp` for possible values.

**Span**  Number of entries used by this key-value pair. For integer types, this is equal to 1. For strings and blobs, this depends on value length.

**ChunkIndex**  Used to store the index of a blob-data chunk for blob types. For other types, this should be `0xff`.

**CRC32**  Checksum calculated over all the bytes in this entry, except for the CRC32 field itself.

**Key**  Zero-terminated ASCII string containing a key name. Maximum string length is 15 bytes, excluding a zero terminator.

**Data**  For integer types, this field contains the value itself. If the value itself is shorter than 8 bytes, it is padded to the right, with unused bytes filled with `0xff`.

For “blob index” entry, these 8 bytes hold the following information about data-chunks:

- **Size**  (Only for blob index.) Size, in bytes, of complete blob data.
- **ChunkCount**  (Only for blob index.) Total number of blob-data chunks into which the blob was divided during storage.
- **ChunkStart**  (Only for blob index.) ChunkIndex of the first blob-data chunk of this blob. Subsequent chunks have chunkIndex incrementally allocated (step of 1).

For string and blob data chunks, these 8 bytes hold additional data about the value, which are described below:

- **Size**  (Only for strings and blobs.) Size, in bytes, of actual data. For strings, this includes zero terminators.
- **CRC32**  (Only for strings and blobs.) Checksum calculated over all bytes of data.

Variable length values (strings and blobs) are written into subsequent entries, 32 bytes per entry. The **Span** field of the first entry indicates how many entries are used.

**Namespaces**  As mentioned above, each key-value pair belongs to one of the namespaces. Namespace identifiers (strings) are stored as keys of key-value pairs in namespace with index 0. Values corresponding to these keys are indexes of these namespaces.
Item Hash List  To reduce the number of reads from flash memory, each member of the Page class maintains a list of pairs: item index; item hash. This list makes searches much quicker. Instead of iterating over all entries, reading them from flash one at a time, Page::findItem first performs a search for the item hash in the hash list. This gives the item index within the page if such an item exists. Due to a hash collision, it is possible that a different item will be found. This is handled by falling back to iteration over items in flash.

Each node in the hash list contains a 24-bit hash and 8-bit item index. Hash is calculated based on item namespace, key name, and ChunkIndex. CRC32 is used for calculation; the result is truncated to 24 bits. To reduce the overhead for storing 32-bit entries in a linked list, the list is implemented as a double-linked list of arrays. Each array holds 29 entries, for the total size of 128 bytes, together with linked list pointers and a 32-bit count field. The minimum amount of extra RAM usage per page is therefore 128 bytes; maximum is 640 bytes.

API Reference

Header File

- components/nvs_flash/include/nvs_flash.h

Functions

`esp_err_t nvs_flash_init (void)`

Initialize the default NVS partition.

This API initialises the default NVS partition. The default NVS partition is the one that is labeled “nvs” in the partition table.

When “NVS_ENCRYPTION” is enabled in the menuconfig, this API enables the NVS encryption for the default NVS partition as follows:

a. Read security configurations from the first NVS key partition listed in the partition table. (NVS key partition is any “data” type partition which has the subtype value set to “nvs_keys”)
b. If the NVS key partition obtained in the previous step is empty, generate and store new keys in that NVS key partition.
c. Internally call “nvs_flash_secure_init()” with the security configurations obtained/generated in the previous steps.

Post initialization NVS read/write APIs remain the same irrespective of NVS encryption.

Returns

- ESP_OK if storage was successfully initialized.
- ESP_ERR_NVS_NO_FREE_PAGES if the NVS storage contains no empty pages (which may happen if NVS partition was truncated)
- ESP_ERR_NOT_FOUND if no partition with label “nvs” is found in the partition table
- ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
- one of the error codes from the underlying flash storage driver
- error codes from nvs_flash_read_security_cfg API (when “NVS_ENCRYPTION” is enabled).
- error codes from nvs_flash_generate_keys API (when “NVS_ENCRYPTION” is enabled).
- error codes from nvs_flash_secure_init_partition API (when “NVS_ENCRYPTION” is enabled).

`esp_err_t nvs_flash_init_partition (const char *partition_label)`

Initialize NVS flash storage for the specified partition.

Parameters `partition_label`  [in] Label of the partition. Must be no longer than 16 characters.

Returns

- ESP_OK if storage was successfully initialized.
- ESP_ERR_NVS_NO_FREE_PAGES if the NVS storage contains no empty pages (which may happen if NVS partition was truncated)
- ESP_ERR_NOT_FOUND if specified partition is not found in the partition table

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• ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
• one of the error codes from the underlying flash storage driver

\texttt{esp_err_t nvs\_flash\_init\_partition\_ptr} (\texttt{const esp\_partition\_t *partition})

Initialize NVS flash storage for the partition specified by partition pointer.

\textbf{Parameters} \textit{partition} \texttt{-[in]} pointer to a partition obtained by the ESP partition API.

\textbf{Returns}
• ESP_OK if storage was successfully initialized
• ESP_ERR_NVS_NO_FREE_PAGES if the NVS storage contains no empty pages (which may happen if NVS partition was truncated)
• ESP_ERR_INVALID_ARG in case partition is NULL
• ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
• one of the error codes from the underlying flash storage driver

\texttt{esp_err_t nvs\_flash\_deinit} (\texttt{void})

Deinitialize NVS storage for the default NVS partition.

Default NVS partition is the partition with “nvs” label in the partition table.

\textbf{Returns}
• ESP_OK on success (storage was deinitialized)
• ESP_ERR_NVS_NOT_INITIALIZED if the storage was not initialized prior to this call

\texttt{esp_err_t nvs\_flash\_deinit\_partition} (\texttt{const char *partition\_label})

Deinitialize NVS storage for the given NVS partition.

\textbf{Parameters} \textit{partition\_label} \texttt{-[in]} Label of the partition

\textbf{Returns}
• ESP_OK on success
• ESP_ERR_NVS_NOT_INITIALIZED if the storage for given partition was not initialized prior to this call

\texttt{esp_err_t nvs\_flash\_erase} (\texttt{void})

Erase the default NVS partition.

Erases all contents of the default NVS partition (one with label “nvs”).

\textbf{Note:} If the partition is initialized, this function first de-initializes it. Afterwards, the partition has to be initialized again to be used.

\textbf{Returns}
• ESP_OK on success
• ESP_ERR_NOT_FOUND if there is no NVS partition labeled “nvs” in the partition table
• different error in case de-initialization fails (shouldn’t happen)

\texttt{esp_err_t nvs\_flash\_erase\_partition} (\texttt{const char *part\_name})

Erase specified NVS partition.

Erase all content of a specified NVS partition

\textbf{Note:} If the partition is initialized, this function first de-initializes it. Afterwards, the partition has to be initialized again to be used.

\textbf{Parameters} \textit{part\_name} \texttt{-[in]} Name (label) of the partition which should be erased

\textbf{Returns}
• ESP_OK on success
Chapter 2. API Reference

- ESP_ERR_NOT_FOUND if there is no NVS partition with the specified name in the partition table
- different error in case de-initialization fails (shouldn’t happen)

```c
esp_err_t nvs_flash_erase_partition_ptr (const esp_partition_t *partition)
```
Erase custom partition.
Erase all content of specified custom partition.

**Note:** If the partition is initialized, this function first de-initializes it. Afterwards, the partition has to be initialized again to be used.

**Parameters**
- `partition` - [in] pointer to a partition obtained by the ESP partition API.

**Returns**
- ESP_OK on success
- ESP_ERR_NOT_FOUND if there is no partition with the specified parameters in the partition table
- ESP_ERR_INVALID_ARG in case partition is NULL
- one of the error codes from the underlying flash storage driver

```c
esp_err_t nvs_flash_secure_init (nvs_sec_cfg_t *cfg)
```
Initialize the default NVS partition.
This API initialises the default NVS partition. The default NVS partition is the one that is labeled “nvs” in the partition table.

**Parameters**
- `cfg` - [in] Security configuration (keys) to be used for NVS encryption/decryption. If `cfg` is NULL, no encryption is used.

**Returns**
- ESP_OK if storage has been initialized successfully.
- ESP_ERR_NVS_NO_FREE_PAGES if the NVS storage contains no empty pages (which may happen if NVS partition was truncated)
- ESP_ERR_NOT_FOUND if no partition with label “nvs” is found in the partition table
- ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
- one of the error codes from the underlying flash storage driver

```c
esp_err_t nvs_flash_secure_init_partition (const char* partition_label, nvs_sec_cfg_t *cfg)
```
Initialize NVS flash storage for the specified partition.

**Parameters**
- `partition_label` - [in] Label of the partition. Note that internally, a reference to passed value is kept and it should be accessible for future operations
- `cfg` - [in] Security configuration (keys) to be used for NVS encryption/decryption. If `cfg` is null, no encryption/decryption is used.

**Returns**
- ESP_OK if storage has been initialized successfully.
- ESP_ERR_NVS_NO_FREE_PAGES if the NVS storage contains no empty pages (which may happen if NVS partition was truncated)
- ESP_ERR_NOT_FOUND if specified partition is not found in the partition table
- ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
- one of the error codes from the underlying flash storage driver

```c
esp_err_t nvs_flash_generate_keys (const esp_partition_t *partition, nvs_sec_cfg_t *cfg)
```
Generate and store NVS keys in the provided esp partition.

**Parameters**
- `partition` - [in] Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
Chapter 2. API Reference

- **cfg** - [out] Pointer to nvs security configuration structure. Pointer must be non-NULL. Generated keys will be populated in this structure.

**Returns**
- ESP_OK, if cfg was read successfully; -ESP_INVALID_ARG, if partition or cfg; -or error codes from esp_partition_write/erase APIs.

```c
esp_err_t nvs_flash_read_security_cfg (const esp_partition_t *partition, nvs_sec_cfg_t *cfg)
```

Read NVS security configuration from a partition.

**Note:** Provided partition is assumed to be marked ‘encrypted’.

**Parameters**

- **partition** - [in] Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- **cfg** - [out] Pointer to nvs security configuration structure. Pointer must be non-NULL.

**Returns**
- ESP_OK, if cfg was read successfully; -ESP_INVALID_ARG, if partition or cfg; -ESP_ERR_NVS_KEYS_NOT_INITIALIZED, if the partition is not yet written with keys; -ESP_ERR_NVS_CORRUPT_KEY_PART, if the partition containing keys is found to be corrupt -or error codes from esp_partition_read API.

**Structures**

```c
struct nvs_sec_cfg_t
```

Key for encryption and decryption.

**Public Members**

- `uint8_t eky[NVS_KEY_SIZE]`  
  XTS encryption and decryption key
- `uint8_t tky[NVS_KEY_SIZE]`  
  XTS tweak key

**Macros**

- **NVS_KEY_SIZE**

**Header File**

- components/nvs_flash/include/nvs.h

**Functions**

```c
esp_err_t nvs_set_i8 (nvs_handle_t handle, const char *key, int8_t value)
```

Set int8_t value for given key

Set value for the key, given its name. Note that the actual storage will not be updated until nvs_commit is called.

**Parameters**

- **handle** - [in] Handle obtained from nvs_open function. Handles that were opened read only cannot be used.
- **key** - [in] Key name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- **value** - [in] The value to set.
Returns

- ESP_OK if value was set successfully
- ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
- ESP_ERR_NVS_READ_ONLY if storage handle was opened as read only
- ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
- ESP_ERR_NVS_NOT_ENOUGH_SPACE if there is not enough space in the underlying storage to save the value
- ESP_ERR_NVS_REMOVE_FAILED if the value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.

```c
esp_err_t nvs_set_u8 (nvs_handle_t handle, const char* key, uint8_t value)
```

set uint8_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_i16 (nvs_handle_t handle, const char* key, int16_t value)
```

set int16_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_u16 (nvs_handle_t handle, const char* key, uint16_t value)
```

set uint16_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_i32 (nvs_handle_t handle, const char* key, int32_t value)
```

set int32_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_u32 (nvs_handle_t handle, const char* key, uint32_t value)
```

set uint32_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_i64 (nvs_handle_t handle, const char* key, int64_t value)
```

set int64_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_u64 (nvs_handle_t handle, const char* key, uint64_t value)
```

set uint64_t value for given key

This function is the same as `nvs_set_i8` except for the data type.

```c
esp_err_t nvs_set_str (nvs_handle_t handle, const char* key, const char* value)
```

set string for given key

Set value for the key, given its name. Note that the actual storage will not be updated until `nvs_commit` is called.

Parameters

- handle -[in] Handle obtained from `nvs_open` function. Handles that were opened read only cannot be used.
- key -[in] Key name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- value -[in] The value to set. For strings, the maximum length (including null character) is 4000 bytes, if there is one complete page free for writing. This decreases, however, if the free space is fragmented.

Returns

- ESP_OK if value was set successfully
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
• ESP_ERR_NVS_READ_ONLY if storage handle was opened as read only
• ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
• ESP_ERR_NVS_NOT_ENOUGH_SPACE if there is not enough space in the underlying storage to save the value
• ESP_ERR_NVS_REMOVE_FAILED if the value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.
• ESP_ERR_NVS_VALUE_TOO_LONG if the string value is too long

```c
esp_err_t nvs_get_i8 (nvs_handle_t handle, const char* key, int8_t*out_value)
get int8_t value for given key

These functions retrieve value for the key, given its name. If key does not exist, or the requested variable type doesn’t match the type which was used when setting a value, an error is returned.

In case of any error, out_value is not modified.

out_value has to be a pointer to an already allocated variable of the given type.

// Example of using nvs_get_i32:
int32_t max_buffer_size = 4096; // default value
esp_err_t err = nvs_get_i32(my_handle, "max_buffer_size", &max_buffer_size);
assert(err == ESP_OK || err == ESP_ERR_NVS_NOT_FOUND);
// if ESP_ERR_NVS_NOT_FOUND was returned, max_buffer_size will still
// have its default value.
```

Parameters

• handle – [in] Handle obtained from nvs_open function.
• key – [in] Key name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
• out_value – Pointer to the output value. May be NULL for nvs_get_str and nvs_get_blob, in this case required length will be returned in length argument.

Returns

• ESP_OK if the value was retrieved successfully
• ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
• ESP_ERR_NVS_NOT_FOUND if the requested key doesn’t exist
• ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
• ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
• ESP_ERR_NVS_INVALID_LENGTH if length is not sufficient to store data

```c
esp_err_t nvs_get_u8 (nvs_handle_t handle, const char* key, uint8_t*out_value)
get uint8_t value for given key

This function is the same as nvs_get_i8 except for the data type.

esp_err_t nvs_get_i16 (nvs_handle_t handle, const char* key, int16_t*out_value)
get int16_t value for given key

This function is the same as nvs_get_i8 except for the data type.

esp_err_t nvs_get_u16 (nvs_handle_t handle, const char* key, uint16_t*out_value)
get uint16_t value for given key

This function is the same as nvs_get_i8 except for the data type.

esp_err_t nvs_get_i32 (nvs_handle_t handle, const char* key, int32_t*out_value)
get int32_t value for given key

This function is the same as nvs_get_i8 except for the data type.
```
Chapter 2. API Reference

```c
esp_err_t nvs_get_u32 (nvs_handle_t handle, const char* key, uint32_t*out_value)
get uint32_t value for given key

This function is the same as nvs_get_i8 except for the data type.
```

```c
esp_err_t nvs_get_i64 (nvs_handle_t handle, const char* key, int64_t*out_value)
get int64_t value for given key

This function is the same as nvs_get_i8 except for the data type.
```

```c
esp_err_t nvs_get_u64 (nvs_handle_t handle, const char* key, uint64_t*out_value)
get uint64_t value for given key

This function is the same as nvs_get_i8 except for the data type.
```

```c
esp_err_t nvs_get_str (nvs_handle_t handle, const char* key, char*out_value, size_t*length)
get string value for given key

These functions retrieve the data of an entry, given its key. If key does not exist, or the requested variable type doesn’t match the type which was used when setting a value, an error is returned.

In case of any error, out_value is not modified.

All functions expect out_value to be a pointer to an already allocated variable of the given type.

nvs_get_str and nvs_get_blob functions support WinAPI-style length queries. To get the size necessary to store the value, call nvs_get_str or nvs_get_blob with zero out_value and non-zero pointer to length. Variable pointed to by length argument will be set to the required length. For nvs_get_str, this length includes the zero terminator. When calling nvs_get_str and nvs_get_blob with non-zero out_value, length has to be non-zero and has to point to the length available in out_value. It is suggested that nvs_get/set_str is used for zero-terminated C strings, and nvs_get/set_blob used for arbitrary data structures.

```c
// Example (without error checking) of using nvs_get_str to get a string into dynamic array:
size_t required_size;
nvs_get_str(my_handle, "server_name", NULL, &required_size);
char* server_name = malloc(required_size);
nvs_get_str(my_handle, "server_name", server_name, &required_size);
```

```c
// Example (without error checking) of using nvs_get_blob to get a binary data into a static array:
uint8_t mac_addr[6];
size_t size = sizeof(mac_addr);
nvs_get_blob(my_handle, "dst_mac_addr", mac_addr, &size);
```

### Parameters

- **handle** [in] Handle obtained from nvs_open function.
- **key** [in] Key name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- **out_value** [out] Pointer to the output value. May be NULL for nvs_get_str and nvs_get_blob, in this case required length will be returned in length argument.
- **length** [inout] A non-zero pointer to the variable holding the length of out_value. In case out_value is zero, will be set to the length required to hold the value. In case out_value is not zero, will be set to the actual length of the value written. For nvs_get_str this includes zero terminator.

### Returns

- ESP_OK if the value was retrieved successfully
- ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
- ESP_ERR_NVS_NOT_FOUND if the requested key doesn’t exist
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
Chapter 2. API Reference

- ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
- ESP_ERR_NVS_INVALID_LENGTH if length is not sufficient to store data

```c
esp_err_t nvs_get_blob(nvs_handle_t handle, const char* key, void*out_value, size_t *length)
```

Get blob value for given key

This function behaves the same as nvs_get_str, except for the data type.

```c
esp_err_t nvs_open(const char* namespace_name, nvs_open_mode_t open_mode, nvs_handle_t*out_handle)
```

Open non-volatile storage with a given namespace from the default NVS partition.

Multiple internal ESP-IDF and third party application modules can store their key-value pairs in the NVS module. In order to reduce possible conflicts on key names, each module can use its own namespace. The default NVS partition is the one that is labelled “nvs” in the partition table.

**Parameters**
- namespace_name - [in] Namespace name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- open_mode - [in] NVS_READWRITE or NVS_READONLY. If NVS_READONLY, will open a handle for reading only. All write requests will be rejected for this handle.
- out_handle - [out] If successful (return code is zero), handle will be returned in this argument.

**Returns**
- ESP_OK if storage handle was opened successfully
- ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized
- ESP_ERR_NVS_PART_NOT_FOUND if the partition with label “nvs” is not found
- ESP_ERR_NVS_NOT_FOUND id namespace doesn’t exist yet and mode is NVS_READONLY
- ESP_ERR_NVS_INVALID_NAME if namespace name doesn’t satisfy constraints
- ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
- ESP_ERR_NVS_NOT_ENOUGH_SPACE if there is no space for a new entry or there are too many different namespaces (maximum allowed different namespaces: 254)
- other error codes from the underlying storage driver

```c
esp_err_t nvs_open_from_partition(const char* part_name, const char* namespace_name, nvs_open_mode_t open_mode, nvs_handle_t*out_handle)
```

Open non-volatile storage with a given namespace from specified partition.

The behaviour is same as nvs_open() API. However this API can operate on a specified NVS partition instead of default NVS partition. Note that the specified partition must be registered with NVS using nvs_flash_init_partition() API.

**Parameters**
- part_name - [in] Label (name) of the partition of interest for object read/write/erase
- namespace_name - [in] Namespace name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- open_mode - [in] NVS_READWRITE or NVS_READONLY. If NVS_READONLY, will open a handle for reading only. All write requests will be rejected for this handle.
- out_handle - [out] If successful (return code is zero), handle will be returned in this argument.

**Returns**
- ESP_OK if storage handle was opened successfully
- ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized
- ESP_ERR_NVS_PART_NOT_FOUND if the partition with specified name is not found
- ESP_ERR_NVS_NOT_FOUND id namespace doesn’t exist yet and mode is NVS_READONLY
- ESP_ERR_NVS_INVALID_NAME if namespace name doesn’t satisfy constraints
• ESP_ERR_NO_MEM in case memory could not be allocated for the internal structures
• ESP_ERR_NVS_NOT_ENOUGH_SPACE if there is no space for a new entry or there are too many different namespaces (maximum allowed different namespaces: 254)
• other error codes from the underlying storage driver

```c
esp_err_t nvs_set_blob(nvs_handle_t handle, const char *key, const void *value, size_t length)
```

set variable length binary value for given key

This family of functions set value for the key, given its name. Note that actual storage will not be updated until nvs_commit function is called.

**Parameters**
- **handle** - [in] Handle obtained from nvs_open function. Handles that were opened read only cannot be used.
- **key** - [in] Key name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- **value** - [in] The value to set.
- **length** - [in] length of binary value to set, in bytes; Maximum length is 508000 bytes or (97.6% of the partition size - 4000) bytes whichever is lower.

**Returns**
- ESP_OK if value was set successfully
- ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
- ESP_ERR_NVS_READ_ONLY if storage handle was opened as read only
- ESP_ERR_NVS_INVALID_NAME if key name doesn’t satisfy constraints
- ESP_ERR_NVS_NOT_ENOUGH_SPACE if there is not enough space in the underlying storage to save the value
- ESP_ERR_NVS_REMOVE_FAILED if the value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.
- ESP_ERR_NVS_VALUE_TOO_LONG if the value is too long

```c
esp_err_t nvs_erase_key(nvs_handle_t handle, const char *key)
```

Erase key-value pair with given key name.

Note that actual storage may not be updated until nvs_commit function is called.

**Parameters**
- **handle** - [in] Storage handle obtained with nvs_open. Handles that were opened read only cannot be used.
- **key** - [in] Key name. Maximum length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.

**Returns**
- ESP_OK if erase operation was successful
- ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
- ESP_ERR_NVS_READ_ONLY if handle was opened as read only
- ESP_ERR_NVS_NOT_FOUND if the requested key doesn’t exist
- other error codes from the underlying storage driver

```c
esp_err_t nvs_erase_all(nvs_handle_t handle)
```

Erase all key-value pairs in a namespace.

Note that actual storage may not be updated until nvs_commit function is called.

**Parameters**
- **handle** - [in] Storage handle obtained with nvs_open. Handles that were opened read only cannot be used.

**Returns**
- ESP_OK if erase operation was successful
• ESP_FAIL if there is an internal error; most likely due to corrupted NVS partition (only if NVS assertion checks are disabled)
• ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
• ESP_ERR_NVS_READ_ONLY if handle was opened as read only
• other error codes from the underlying storage driver

```c
esp_err_t nvs_commit (nvs_handle_t handle)
```

Write any pending changes to non-volatile storage.

After setting any values, nvs_commit() must be called to ensure changes are written to non-volatile storage. Individual implementations may write to storage at other times, but this is not guaranteed.

**Parameters**
- **handle** – [in] Storage handle obtained with nvs_open. Handles that were opened read only cannot be used.

**Returns**
- ESP_OK if the changes have been written successfully
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
- other error codes from the underlying storage driver

```c
void nvs_close (nvs_handle_t handle)
```

Close the storage handle and free any allocated resources.

This function should be called for each handle opened with nvs_open once the handle is not in use any more. Closing the handle may not automatically write the changes to nonvolatile storage. This has to be done explicitly using nvs_commit function. Once this function is called on a handle, the handle should no longer be used.

**Parameters**
- **handle** – [in] Storage handle to close

```c
esp_err_t nvs_get_stats (const char* part_name, nvs_stats_t *nvs_stats)
```

Fill structure `nvs_stats_t`. It provides info about used memory the partition.

This function calculates to runtime the number of used entries, free entries, total entries, and amount namespace in partition.

```c
// Example of nvs_get_stats() to get the number of used entries and free_entries:

nvs_stats_t nvs_stats;
if (nvs_get_stats(NULL, &nvs_stats)) {
    printf("Count: UsedEntries = (%d), FreeEntries = (%d), AllEntries = (%d)\n",
           nvs_stats.used_entries, nvs_stats.free_entries, nvs_stats.total_entries);
}
```

**Parameters**
- **part_name** – [in] Partition name NVS in the partition table. If pass a NULL than will use NVS_DEFAULT_PART_NAME ("nvs").
- **nvs_stats** – [out] Returns filled structure nvs_stats_t. It provides info about used memory the partition.

**Returns**
- ESP_OK if the changes have been written successfully. Return param nvs_stats will be filled.
- ESP_ERR_NVS_PART_NOT_FOUND if the partition with label “name” is not found. Return param nvs_stats will be filled 0.
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized. Return param nvs_stats will be filled 0.
- ESP_ERR_NVS_INVALID_ARG if nvs_stats equal to NULL.
- ESP_ERR_NVS_INVALID_STATE if there is page with the status of INVALID. Return param nvs_stats will be filled not with correct values because not all pages will be counted. Counting will be interrupted at the first INVALID page.
**esp_err_t** nvs_get_used_entry_count (nvs_handle_t handle, size_t* used_entries)

Calculate all entries in a namespace.

An entry represents the smallest storage unit in NVS. Strings and blobs may occupy more than one entry. Note that to find out the total number of entries occupied by the namespace, add one to the returned value used_entries (if err is equal to ESP_OK). Because the name space entry takes one entry.

```c
// Example of nvs_get_used_entry_count() to get amount of all key-value pairs... in one namespace:
void my_function() {
    nvs_handle_t handle;
    nvs_open("namespace1", NVS_READWRITE, &handle);
    ...
    size_t used_entries;
    size_t total_entries_namespace;
    if (nvs_get_used_entry_count(handle, &used_entries) == ESP_OK){
        // the total number of entries occupied by the namespace
        total_entries_namespace = used_entries + 1;
    }
}
```

**Parameters**
- **handle** - [in] Handle obtained from nvs_open function.
- **used_entries** - [out] Returns amount of used entries from a namespace.

**Returns**
- ESP_OK if the changes have been written successfully. Return param used_entries will be filled valid value.
- ESP_ERR_NVS_NOT_INITIALIZED if the storage driver is not initialized. Return param used_entries will be filled 0.
- ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL. Return param used_entries will be filled 0.
- ESP_ERR_NVS_INVALID_ARG if used_entries equal to NULL.
- Other error codes from the underlying storage driver. Return param used_entries will be filled 0.

**esp_err_t** nvs_entry_find (const char* part_name, const char* namespace_name, nvs_type_t type, nvs_iterator_t* output_iterator)

Create an iterator to enumerate NVS entries based on one or more parameters.

```c
// Example of listing all the key-value pairs of any type under specified... partition and namespace
nvs_iterator_t it = NULL;
esp_err_t res = nvs_entry_find(nvs_partition_name, <namespace>, NVS_TYPE_...ANY, &it);
while(res == ESP_OK) {
    nvs_entry_info_t info;
    nvs_entry_info(it, &info); // Can omit error check if parameters are... guaranteed to be non-NULL
    printf("key '%s', type '%d' \n", info.key, info.type);
    res = nvs_entry_next(&it);
}
```

**Parameters**
- **part_name** - [in] Partition name
- **namespace_name** - [in] Set this value if looking for entries with a specific namespace. Pass NULL otherwise.
- **type** - [in] One of nvs_type_t values.
output_iterator - [out] Set to a valid iterator to enumerate all the entries found. Set to NULL if no entry for specified criteria was found. If any other error except ESP_ERR_INVALID_ARG occurs, output_iterator is NULL, too. If ESP_ERR_INVALID_ARG occurs, output_iterator is not changed. If a valid iterator is obtained through this function, it has to be released using nvs_release_iterator when not used any more, unless ESP_ERR_INVALID_ARG is returned.

Returns
- ESP_OK if no internal error or programming error occurred.
- ESP_ERR_NVS_NOT_FOUND if no element of specified criteria has been found.
- ESP_ERR_NO_MEM if memory has been exhausted during allocation of internal structures.
- ESP_ERR_INVALID_ARG if any of the parameters is NULL. Note: don’t release output_iterator in case ESP_ERR_INVALID_ARG has been returned.

esp_err_t nvs_entry_next (nvs_iterator_t *iterator)

Advances the iterator to next item matching the iterator criteria.

Note that any copies of the iterator will be invalid after this call.

Parameters
- iterator - [inout] Iterator obtained from nvs_entry_find function. Must be non-NULL. If any error except ESP_ERR_INVALID_ARG occurs, iterator is set to NULL. If ESP_ERR_INVALID_ARG occurs, iterator is not changed.

Returns
- ESP_OK if no internal error or programming error occurred.
- ESP_ERR_NVS_NOT_FOUND if no next element matching the iterator criteria.
- ESP_ERR_INVALID_ARG if iterator is NULL.
- Possibly other errors in the future for internal programming or flash errors.

esp_err_t nvs_entry_info (const nvs_iterator_t iterator, nvs_entry_info_t *out_info)

Fills nvs_entry_info_t structure with information about entry pointed to by the iterator.

Parameters
- iterator - [in] Iterator obtained from nvs_entry_find function. Must be non-NULL.

Returns
- ESP_OK if all parameters are valid; current iterator data has been written to out_info
- ESP_ERR_INVALID_ARG if one of the parameters is NULL.

void nvs_release_iterator (nvs_iterator_t iterator)

Release iterator.

Parameters
- iterator - [in] Release iterator obtained from nvs_entry_find function. NULL argument is allowed.

Structures
struct nvs_entry_info_t

information about entry obtained from nvs_entry_info function

Public Members

char namespace_name[NVS_NS_NAME_MAX_SIZE]

Namespace to which key-value belong

char key[NVS_KEY_NAME_MAX_SIZE]

Key of stored key-value pair
Chapter 2. API Reference

*nvs_type_t* `type`

Type of stored key-value pair

`struct nvs_stats_t`

**Note:** Info about storage space NVS.

**Public Members**

`size_t used_entries`

Amount of used entries.

`size_t free_entries`

Amount of free entries.

`size_t total_entries`

Amount all available entries.

`size_t namespace_count`

Amount name space.

**Macros**

`ESP_ERR_NVS_BASE`

Starting number of error codes

`ESP_ERR_NVS_NOT_INITIALIZED`

The storage driver is not initialized

`ESP_ERR_NVS_NOT_FOUND`

A requested entry couldn’t be found or namespace doesn’t exist yet and mode is NVS_READONLY

`ESP_ERR_NVS_TYPE_MISMATCH`

The type of set or get operation doesn’t match the type of value stored in NVS

`ESP_ERR_NVS_READ_ONLY`

Storage handle was opened as read only

`ESP_ERR_NVS_NOT_ENOUGH_SPACE`

There is not enough space in the underlying storage to save the value

`ESP_ERR_NVS_INVALID_NAME`

Namespace name doesn’t satisfy constraints

`ESP_ERR_NVS_INVALID_HANDLE`

Handle has been closed or is NULL
**ESP_ERR_NVS_REMOVE_FAILED**

The value wasn’t updated because flash write operation has failed. The value was written however, and update will be finished after re-initialization of nvs, provided that flash operation doesn’t fail again.

**ESP_ERR_NVS_KEY_TOO_LONG**

Key name is too long

**ESP_ERR_NVS_PAGE_FULL**

Internal error; never returned by nvs API functions

**ESP_ERR_NVS_INVALID_STATE**

NVS is in an inconsistent state due to a previous error. Call nvs_flash_init and nvs_open again, then retry.

**ESP_ERR_NVS_INVALID_LENGTH**

String or blob length is not sufficient to store data

**ESP_ERR_NVS_NO_FREE_PAGES**

NVS partition doesn’t contain any empty pages. This may happen if NVS partition was truncated. Erase the whole partition and call nvs_flash_init again.

**ESP_ERR_NVS_VALUE_TOO_LONG**

Value doesn’t fit into the entry or string or blob length is longer than supported by the implementation

**ESP_ERR_NVS_PART_NOT_FOUND**

Partition with specified name is not found in the partition table

**ESP_ERR_NVS_NEW_VERSION_FOUND**

NVS partition contains data in new format and cannot be recognized by this version of code

**ESP_ERR_NVS_XTS_ENCR_FAILED**

XTS encryption failed while writing NVS entry

**ESP_ERR_NVS_XTS_DECRI_FAILED**

XTS decryption failed while reading NVS entry

**ESP_ERR_NVS_XTS_CFG FAILED**

XTS configuration setting failed

**ESP_ERR_NVS_XTS_CFG_NOT_FOUND**

XTS configuration not found

**ESP_ERR_NVS_ENCR_NOT_SUPPORTED**

NVS encryption is not supported in this version

**ESP_ERR_NVS_KEYS_NOT_INITIALIZED**

NVS key partition is uninitialized

**ESP_ERR_NVS_CORRUPT_KEY_PART**

NVS key partition is corrupt
Chapter 2. API Reference

ESP_ERR_NVS_WRONG_ENCRYPTION
NVS partition is marked as encrypted with generic flash encryption. This is forbidden since the NVS encryption works differently.

ESP_ERR_NVS_CONTENT_DIFFERS
Internal error; never returned by nvs API functions. NVS key is different in comparison

NVS_DEFAULT_PART_NAME
Default partition name of the NVS partition in the partition table

NVS_PART_NAME_MAX_SIZE
maximum length of partition name (excluding null terminator)

NVS_KEY_NAME_MAX_SIZE
Maximum length of NVS key name (including null terminator)

NVS_NS_NAME_MAX_SIZE
Maximum length of NVS namespace name (including null terminator)

Type Definitions
typedef uint32_t nvs_handle_t
Opaque pointer type representing non-volatile storage handle
typedef nvs_handle_t nvs_handle
typedef nvs_open_mode_t nvs_open_mode
typedef struct nvs_opaque_iterator_t *nvs_iterator_t
Opaque pointer type representing iterator to nvs entries

Enumerations
enum nvs_open_mode_t
Mode of opening the non-volatile storage.
Values:
	enumerator NVS_READONLY
Read only
tenumerator NVS_READWRITE
Read and write

enum nvs_type_t
Types of variables.
Values:
	enumerator NVS_TYPE_U8
Type uint8_t
enumerator NVS_TYPE_I8
    Type int8_t

enumerator NVS_TYPE_U16
    Type uint16_t

enumerator NVS_TYPE_I16
    Type int16_t

enumerator NVS_TYPE_U32
    Type uint32_t

enumerator NVS_TYPE_I32
    Type int32_t

enumerator NVS_TYPE_U64
    Type uint64_t

enumerator NVS_TYPE_I64
    Type int64_t

enumerator NVS_TYPE_STR
    Type string

enumerator NVS_TYPE_BLOB
    Type blob

enumerator NVS_TYPE_ANY
    Must be last

2.9.4 NVS Partition Generator Utility

Introduction

The utility nvs_flash/nvs_partition_generator/nvs_partition_gen.py creates a binary file based on key-value pairs provided in a CSV file. The binary file is compatible with NVS architecture defined in Non-Volatile Storage. This utility is ideally suited for generating a binary blob, containing data specific to ODM/OEM, which can be flashed externally at the time of device manufacturing. This allows manufacturers to generate many instances of the same application firmware with customized parameters for each device, such as a serial number.

Prerequisites

To use this utility in encryption mode, install the following packages:
   • cryptography package

All the required packages are included in requirements.txt in the root of the esp-idf directory.
CSV File Format

Each line of a CSV file should contain 4 parameters, separated by a comma. The table below provides the description for each of these parameters.

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Key</td>
<td>Key of the data. The data can be accessed later from an application using this key.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Type</td>
<td>Supported values are file, data, and namespace.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Encoding</td>
<td>Supported values are: u8, i8, u16, i16, u32, i32, u64, i64, string, hex2bin, base64, and binary. This specifies how actual data values are encoded in the resulting binary file. The difference between the string and binary encoding is that string data is terminated with a NULL character, whereas binary data is not.</td>
<td>As of now, for the file type, only hex2bin, base64, string, and binary encoding is supported.</td>
</tr>
<tr>
<td>4</td>
<td>Value</td>
<td>Data value</td>
<td>Encoding and Value cells for the namespace field type should be empty. Encoding and Value cells for namespace are fixed and are not configurable. Any values in these cells are ignored.</td>
</tr>
</tbody>
</table>

Note: The first line of the CSV file should always be the column header and it is not configurable.

Below is an example dump of such a CSV file:

```
key,type,encoding,value        <-- column header
namespace_name,namespace,,     <-- First entry should be of type "namespace"
key1,data,u8,1
key2,file,string,/path/to/file
```

Note:

Make sure there are no spaces:
- before and after ``,`
- at the end of each line in a CSV file

NVS Entry and Namespace Association

When a namespace entry is encountered in a CSV file, each following entry will be treated as part of that namespace until the next namespace entry is found. At this point, all the following entries will be treated as part of the new namespace.

Note: First entry in a CSV file should always be a namespace entry.
Multipage Blob Support

By default, binary blobs are allowed to span over multiple pages and are written in the format mentioned in Section Structure of Entry. If you intend to use an older format, the utility provides an option to disable this feature.

Encryption Support

The NVS Partition Generator utility also allows you to create an encrypted binary file. The utility uses the AES-XTS encryption. Please refer to NVS Encryption for more details.

Decryption Support

This utility allows you to decrypt an encrypted NVS binary file. The utility uses an NVS binary file encrypted using AES-XTS encryption. Please refer to NVS Encryption for more details.

Running the Utility

Usage:

```
python nvs_partition_gen.py [-h] {generate,generate-key,encrypt,decrypt} ...
```

Optional Arguments:

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-h, --help</td>
<td>Show this help message and exit</td>
</tr>
</tbody>
</table>

Commands:

Run `nvs_partition_gen.py {command} -h` for additional help

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>generate</td>
<td>Generate NVS partition</td>
</tr>
<tr>
<td>2</td>
<td>generate-key</td>
<td>Generate keys for encryption</td>
</tr>
<tr>
<td>3</td>
<td>encrypt</td>
<td>Generate NVS encrypted partition</td>
</tr>
<tr>
<td>4</td>
<td>decrypt</td>
<td>Decrypt NVS encrypted partition</td>
</tr>
</tbody>
</table>

To Generate NVS Partition (Default):

Usage:

```
python nvs_partition_gen.py generate [-h] [--version {1,2}] [--outdir OUTDIR] input output size
```

Positional Arguments:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>Path to CSV file to parse</td>
</tr>
<tr>
<td>output</td>
<td>Path to output NVS binary file</td>
</tr>
<tr>
<td>size</td>
<td>Size of NVS partition in bytes (must be multiple of 4096)</td>
</tr>
</tbody>
</table>

Optional Arguments:
To Generate Only Encryption Key Partition:  

Usage:

```
python nvs_partition_gen.py generate-key [-h] [--keyfile KEYFILE] [--outdir OUTDIR]
```

Optional Arguments:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>Show this help message and exit</td>
</tr>
<tr>
<td>--keyfile</td>
<td>Path to output encryption key partition file</td>
</tr>
<tr>
<td>--outdir</td>
<td>Output directory to store file created (Default: current directory)</td>
</tr>
</tbody>
</table>

You can run the utility to generate only the encryption key partition using the command below:

```
python nvs_partition_gen.py generate-key
```

To Generate Encrypted NVS Partition:  

Usage:

```
python nvs_partition_gen.py encrypt [-h] [--version {1,2}] [--keygen] [--keyfile KEYFILE] [--inputkey INPUTKEY] [--outdir OUTDIR] input output size
```

Positional Arguments:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>Path to CSV file to parse</td>
</tr>
<tr>
<td>output</td>
<td>Path to output NVS binary file</td>
</tr>
<tr>
<td>size</td>
<td>Size of NVS partition in bytes (must be multiple of 4096)</td>
</tr>
</tbody>
</table>

Optional Arguments:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, --help</td>
<td>Show this help message and exit</td>
</tr>
<tr>
<td>--keygen</td>
<td>Generates key for encrypting NVS partition</td>
</tr>
<tr>
<td>--keyfile</td>
<td>Path to output encryption keys file</td>
</tr>
<tr>
<td>--inputkey</td>
<td>File having key for encrypting NVS partition</td>
</tr>
<tr>
<td>--outdir</td>
<td>Output directory to store files created (Default: current directory)</td>
</tr>
</tbody>
</table>
You can run the utility to encrypt NVS partition using the command below. A sample CSV file is provided with the utility:

- Encrypt by allowing the utility to generate encryption keys:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --keygen
```

**Note:** Encryption key of the following format `<outdir>/keys/keys-<timestamp>.bin` is created.

- Encrypt by allowing the utility to generate encryption keys and store it in provided custom filename:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --keygen --keyfile sample_keys.bin
```

**Note:** Encryption key of the following format `<outdir>/keys/sample_keys.bin` is created.

**Note:** This newly created file having encryption keys in `keys/` directory is compatible with NVS key-partition structure. Refer to NVS Key Partition for more details.

- Encrypt by providing the encryption keys as input binary file:

```
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin --0x3000 --inputkey sample_keys.bin
```

**To Decrypt Encrypted NVS Partition:**

**Usage:**

```
python nvs_partition_gen.py decrypt [-h] [--outdir OUTDIR] input key output
```

**Positional Arguments:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>input</td>
<td>Path to encrypted NVS partition file to parse</td>
</tr>
<tr>
<td>key</td>
<td>Path to file having keys for decryption</td>
</tr>
<tr>
<td>output</td>
<td>Path to output decrypted binary file</td>
</tr>
</tbody>
</table>

**Optional Arguments:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-h, help</td>
<td>Show this help message and exit</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>Output directory to store files created (Default: current directory)</td>
</tr>
</tbody>
</table>

You can run the utility to decrypt encrypted NVS partition using the command below:

```
python nvs_partition_gen.py decrypt sample_encr.bin sample_keys.bin sample_decr.bin
```

You can also provide the format version number:

- Multipage Blob Support Disabled (Version 1)
- Multipage Blob Support Enabled (Version 2)

**Multipage Blob Support Disabled (Version 1):** You can run the utility in this format by setting the version parameter to 1, as shown below. A sample CSV file is provided with the utility:
Chapter 2. API Reference

```
python nvs_partition_gen.py generate sample_singlepage_blob.csv sample.bin 0x3000 --version 1
```

**Multi-page Blob Support Enabled (Version 2):** You can run the utility in this format by setting the version parameter to 2, as shown below. A sample CSV file is provided with the utility:

```
python nvs_partition_gen.py generate sample_multipage_blob.csv sample.bin 0x4000 --version 2
```

**Note:** Minimum NVS Partition Size needed is 0x3000 bytes.

**Note:** When flashing the binary onto the device, make sure it is consistent with the application’s sdkconfig.

**Caveats**

- Utility does not check for duplicate keys and will write data pertaining to both keys. You need to make sure that the keys are distinct.
- Once a new page is created, no data will be written in the space left on the previous page. Fields in the CSV file need to be ordered in such a way as to optimize memory.
- 64-bit datatype is not yet supported.

### 2.9.5 NVS Partition Parser Utility

**Introduction**

The utility `nvs_flash/nvs_partition_tool/nvs_tool.py` loads and parses an NVS storage partition for easier debugging and data extraction. The utility also features integrity check which scans the partition for potential errors. Data blobs are encoded in base64 format.

**Encrypted Partitions**

This utility does not support decryption. To decrypt the NVS partition, please use the NVS Partition Generator Utility which does support NVS partition encryption and decryption.

**Usage**

**There are two output format styles available with the -f or --format option:**

- `json` - All of the output is printed as a JSON.
- `text` - The output is printed as a human-readable text with different selectable output styles mentioned below.

**For the text output format, the utility provides six different output styles with the -d or --dump option:**

- `all` (default) - Prints all entries with metadata.
- `written` - Prints only written entries with metadata.
- `minimal` - Prints written `namespace:key = value` pairs.
- `namespaces` - Prints all written namespaces
- `blobs` - Prints all blobs and strings (reconstructs them if they are chunked).
- `storage_info` - Prints entry states count for every page.
2.9.6 SD/SDIO/MMC Driver

Overview

The SD/SDIO/MMC driver currently supports SD memory, SDIO cards, and eMMC chips. This is a protocol level driver built on top of SDMMC and SD SPI host drivers. SDMMC and SD SPI host drivers (driver/sdmmc/include/driver/sdmmc_host.h and driver/spi/include/driver/sds_p_host.h) provide API functions for:

- Sending commands to slave devices
- Sending and receiving data
- Handling error conditions within the bus

For functions used to initialize and configure:

- SDMMC host, see SDMMC Host API
- SD SPI host, see SD SPI Host API

The SDMMC protocol layer described in this document handles the specifics of the SD protocol, such as the card initialization and data transfer commands. The protocol layer works with the host via the sdmmc_host_t structure. This structure contains pointers to various functions of the host.

Application Example

An example which combines the SDMMC driver with the FATFS library is provided in the storage/sd_card directory of ESP-IDF examples. This example initializes the card, then writes and reads data from it using POSIX and C library APIs. See README.md file in the example directory for more information.

Combo (memory + IO) cards The driver does not support SD combo cards. Combo cards are treated as IO cards.

Thread safety Most applications need to use the protocol layer only in one task. For this reason, the protocol layer does not implement any kind of locking on the sdmmc_card_t structure, or when accessing SDMMC or SD SPI host drivers. Such locking is usually implemented on a higher layer, e.g., in the filesystem driver.

Protocol layer API

The protocol layer is given the sdmmc_host_t structure. This structure describes the SD/MMC host driver, lists its capabilities, and provides pointers to functions of the driver. The protocol layer stores card-specific information in the sdmmc_card_t structure. When sending commands to the SD/MMC host driver, the protocol layer uses the sdmmc_command_t structure to describe the command, arguments, expected return values, and data to transfer if there is any.
Using API with SD memory cards

1. To initialize the host, call the host driver functions, e.g., `sdmmc_host_init()`, `sdmmc_host_init_slot()`.
2. To initialize the card, call `sdmmc_card_init()` and pass to it the parameters `host` - the host driver information, and `card` - a pointer to the structure `sdmmc_card_t` which will be filled with information about the card when the function completes.
3. To read and write sectors of the card, use `sdmmc_read_sectors()` and `sdmmc_write_sectors()` respectively and pass to it the parameter `card` - a pointer to the card information structure.
4. If the card is not used anymore, call the host driver function - e.g., `sdmmc_host_deinit()` - to disable the host peripheral and free the resources allocated by the driver.

Using API with eMMC chips From the protocol layer’s perspective, eMMC memory chips behave exactly like SD memory cards. Even though eMMCs are chips and do not have a card form factor, the terminology for SD cards can still be applied to eMMC due to the similarity of the protocol (`sdmmc_card_t`, `sdmmc_card_init`). Note that eMMC chips cannot be used over SPI, which makes them incompatible with the SD SPI host driver.

To initialize eMMC memory and perform read/write operations, follow the steps listed for SD cards in the previous section.

Using API with SDIO cards Initialization and the probing process are the same as with SD memory cards. The only difference is in data transfer commands in SDIO mode.

During the card initialization and probing, performed with `sdmmc_card_init()`, the driver only configures the following registers of the IO card:

1. The IO portion of the card is reset by setting RES bit in the I/O Abort (0x06) register.
2. If 4-line mode is enabled in host and slot configuration, the driver attempts to set the Bus width field in the Bus Interface Control (0x07) register. If setting the filed is successful, which means that the slave supports 4-line mode, the host is also switched to 4-line mode.
3. If high-speed mode is enabled in the host configuration, the SHS bit is set in the High Speed (0x13) register.

In particular, the driver does not set any bits in (1) I/O Enable and Int Enable registers, (2) I/O block sizes, etc. Applications can set them by calling `sdmmc_io_write_byte()`.

For card configuration and data transfer, choose the pair of functions relevant to your case from the table below.

<table>
<thead>
<tr>
<th>Action</th>
<th>Read Function</th>
<th>Write Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read and write a single byte using IO_RW_DIRECT (CMD52)</td>
<td><code>sdmmc_io_read_byte()</code></td>
<td><code>sdmmc_io_write_byte()</code></td>
</tr>
<tr>
<td>Read and write multiple bytes using IO_RW_EXTENDED (CMD53) in byte mode</td>
<td><code>sdmmc_io_read_bytes()</code></td>
<td><code>sdmmc_io_write_bytes()</code></td>
</tr>
<tr>
<td>Read and write blocks of data using IO_RW_EXTENDED (CMD53) in block mode</td>
<td><code>sdmmc_io_read_blocks()</code></td>
<td><code>sdmmc_io_write_blocks()</code></td>
</tr>
</tbody>
</table>

SDIO interrupts can be enabled by the application using the function `sdmmc_io_enable_int()`. When using SDIO in 1-line mode, the D1 line also needs to be connected to use SDIO interrupts.

If you want the application to wait until the SDIO interrupt occurs, use `sdmmc_io_wait_int()`.

There is a component ESSL (ESP Serial Slave Link) to use if you are communicating with an ESP32 SDIO slave. See [ESP Serial Slave Link][1] and example peripherals/sdio/host.

API Reference

Header File

- `components/sdmmc/include/sdmmc_cmd.h`
Chapter 2. API Reference

Functions

esp_err_t sdmmc_card_init (const sdmmc_host_t *host, sdmmc_card_t *out_card)

Probe and initialize SD/MMC card using given host

Note: Only SD cards (SDSC and SDHC/SDXC) are supported now. Support for MMC/eMMC cards will be added later.

Parameters
- host - pointer to structure defining host controller
- out_card - pointer to structure which will receive information about the card when the function completes

Returns
- ESP_OK on success
- One of the error codes from SDMMC host controller

void sdmmc_card_print_info (FILE *stream, const sdmmc_card_t *card)

Print information about the card to a stream.

Parameters
- stream - stream obtained using fopen or fdopen
- card - card information structure initialized using sdmmc_card_init

esp_err_t sdmmc_get_status (sdmmc_card_t *card)

Get status of SD/MMC card

Parameters card - pointer to card information structure previously initialized using sdmmc_card_init

Returns
- ESP_OK on success
- One of the error codes from SDMMC host controller

esp_err_t sdmmc_write_sectors (sdmmc_card_t *card, const void *src, size_t start_sector, size_t sector_count)

Write given number of sectors to SD/MMC card

Parameters
- card - pointer to card information structure previously initialized using sdmmc_card_init
- src - pointer to data buffer to read data from; data size must be equal to sector_count * card->csd.sector_size
- start_sector - sector where to start writing
- sector_count - number of sectors to write

Returns
- ESP_OK on success or sector_count equal to 0
- One of the error codes from SDMMC host controller

esp_err_t sdmmc_read_sectors (sdmmc_card_t *card, void *dst, size_t start_sector, size_t sector_count)

Read given number of sectors from the SD/MMC card

Parameters
- card - pointer to card information structure previously initialized using sdmmc_card_init
- dst - pointer to data buffer to write into; buffer size must be at least sector_count * card->csd.sector_size
- start_sector - sector where to start reading
- sector_count - number of sectors to read

Returns
- ESP_OK on success or sector_count equal to 0
- One of the error codes from SDMMC host controller

esp_err_t sdmmc_erase_sectors (sdmmc_card_t *card, size_t start_sector, size_t sector_count, sdmmc_erase_arg_t arg)

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Erase given number of sectors from the SD/MMC card

**Note:** When sdmmc_erase_sectors used with cards in SDSPi mode, it was observed that card requires re-init after erase operation.

**Parameters**
- `card` - pointer to card information structure previously initialized using sdmmc_card_init
- `start_sector` - sector where to start erase
- `sector_count` - number of sectors to erase
- `arg` - erase command (CMD38) argument

**Returns**
- ESP_OK on success or sector_count equal to 0
- One of the error codes from SDMMC host controller

```c
esp_err_t sdmmc_can_discard (sdmmc_card_t *card)
```
Check if SD/MMC card supports discard

**Parameters**
- `card` - pointer to card information structure previously initialized using sdmmc_card_init

**Returns**
- ESP_OK if supported by the card/device
- ESP_FAIL if not supported by the card/device

```c
esp_err_t sdmmc_can_trim (sdmmc_card_t *card)
```
Check if SD/MMC card supports trim

**Parameters**
- `card` - pointer to card information structure previously initialized using sdmmc_card_init

**Returns**
- ESP_OK if supported by the card/device
- ESP_FAIL if not supported by the card/device

```c
esp_err_t sdmmc_mmc_can-sanitize (sdmmc_card_t *card)
```
Check if SD/MMC card supports sanitize

**Parameters**
- `card` - pointer to card information structure previously initialized using sdmmc_card_init

**Returns**
- ESP_OK if supported by the card/device
- ESP_FAIL if not supported by the card/device

```c
esp_err_t sdmmc_mmc-sanitize (sdmmc_card_t *card, uint32_t timeout_ms)
```
Sanitize the data that was unmapped by a Discard command

**Note:** Discard command has to precede sanitize operation. To discard, use MMC_DICARD_ARG with sdmmc_erase_sectors argument

**Parameters**
- `card` - pointer to card information structure previously initialized using sdmmc_card_init
- `timeout_ms` - timeout value in milliseconds required to sanitize the selected range of sectors.

**Returns**
- ESP_OK on success
- One of the error codes from SDMMC host controller
**esp_err_t** sdmmc_full_erase(*sdmmc_card_t* card)

Erase complete SD/MMC card

**Parameters**
- *card* - pointer to card information structure previously initialized using `sdmmc_card_init`

**Returns**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**esp_err_t** sdmmc_io_read_byte(*sdmmc_card_t* card, uint32_t function, uint32_t reg, uint8_t *out_byte)

Read one byte from an SDIO card using IO_RW_DIRECT (CMD52)

**Parameters**
- *card* - pointer to card information structure previously initialized using `sdmmc_card_init`
- *function* - IO function number
- *reg* - byte address within IO function
- *out_byte* - [out] output, receives the value read from the card

**Returns**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**esp_err_t** sdmmc_io_write_byte(*sdmmc_card_t* card, uint32_t function, uint32_t reg, uint8_t in_byte, uint8_t *out_byte)

Write one byte to an SDIO card using IO_RW_DIRECT (CMD52)

**Parameters**
- *card* - pointer to card information structure previously initialized using `sdmmc_card_init`
- *function* - IO function number
- *reg* - byte address within IO function
- *in_byte* - value to be written
- *out_byte* - [out] if not NULL, receives new byte value read from the card (read-after-write).

**Returns**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**esp_err_t** sdmmc_io_read_bytes(*sdmmc_card_t* card, uint32_t function, uint32_t addr, void *dst, size_t size)

Read multiple bytes from an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs read operation using CMD53 in byte mode. For block mode, see `sdmmc_io_read_blocks`.

**Parameters**
- *card* - pointer to card information structure previously initialized using `sdmmc_card_init`
- *function* - IO function number
- *addr* - byte address within IO function where reading starts
- *dst* - buffer which receives the data read from card
- *size* - number of bytes to read

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_SIZE if size exceeds 512 bytes
- One of the error codes from SDMMC host controller

**esp_err_t** sdmmc_io_write_bytes(*sdmmc_card_t* card, uint32_t function, uint32_t addr, const void *src, size_t size)

Write multiple bytes to an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs write operation using CMD53 in byte mode. For block mode, see `sdmmc_io_write_blocks`.

**Parameters**
• card - pointer to card information structure previously initialized using sdmmc_card_init
• function - IO function number
• addr - byte address within IO function where writing starts
• src - data to be written
• size - number of bytes to write

Returns
• ESP_OK on success
• ESP_ERR_INVALID_SIZE if size exceeds 512 bytes
• One of the error codes from SDMMC host controller

`esp_err_t sdmmc_io_read_blocks (sdmmc_card_t *card, uint32_t function, uint32_t addr, void *dst, size_t size)`

Read blocks of data from an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs read operation using CMD53 in block mode. For byte mode, see sdmmc_io_read_bytes.

Parameters
• card - pointer to card information structure previously initialized using sdmmc_card_init
• function - IO function number
• addr - byte address within IO function where writing starts
• dst - buffer which receives the data read from card
• size - number of bytes to read, must be divisible by the card block size.

Returns
• ESP_OK on success
• ESP_ERR_INVALID_SIZE if size is not divisible by 512 bytes
• One of the error codes from SDMMC host controller

`esp_err_t sdmmc_io_write_blocks (sdmmc_card_t *card, uint32_t function, uint32_t addr, const void *src, size_t size)`

Write blocks of data to an SDIO card using IO_RW_EXTENDED (CMD53)

This function performs write operation using CMD53 in block mode. For byte mode, see sdmmc_io_write_bytes.

Parameters
• card - pointer to card information structure previously initialized using sdmmc_card_init
• function - IO function number
• addr - byte address within IO function where writing starts
• src - data to be written
• size - number of bytes to read, must be divisible by the card block size.

Returns
• ESP_OK on success
• ESP_ERR_INVALID_SIZE if size is not divisible by 512 bytes
• One of the error codes from SDMMC host controller

`esp_err_t sdmmc_io_enable_int (sdmmc_card_t *card)`

Enable SDIO interrupt in the SDMMC host

Parameters card - pointer to card information structure previously initialized using sdmmc_card_init

Returns
• ESP_OK on success
• ESP_ERR_NOT_SUPPORTED if the host controller does not support IO interrupts

`esp_err_t sdmmc_io_wait_int (sdmmc_card_t *card, TickType_t timeout_ticks)`

Block until an SDIO interrupt is received

Slave uses D1 line to signal interrupt condition to the host. This function can be used to wait for the interrupt.

Parameters
• card - pointer to card information structure previously initialized using sdmmc_card_init
• timeout_ticks - time to wait for the interrupt, in RTOS ticks
Returns

- ESP_OK if the interrupt is received
- ESP_ERR_NOT_SUPPORTED if the host controller does not support IO interrupts
- ESP_ERR_TIMEOUT if the interrupt does not happen in timeout_ticks

```c
esp_err_t sdmmc_io_get_cis_data (sdmmc_card_t *card, uint8_t *out_buffer, size_t buffer_size, size_t *inout_cis_size)
```

Get the data of CIS region of an SDIO card.

You may provide a buffer not sufficient to store all the CIS data. In this case, this function stores as much data into your buffer as possible. Also, this function will try to get and return the size required for you.

Parameters

- `card` - pointer to card information structure previously initialized using `sdmmc_card_init`
- `out_buffer` - Output buffer of the CIS data
- `buffer_size` - Size of the buffer.
- `inout_cis_size` - Mandatory, pointer to a size, input and output.
  - input: Limitation of maximum searching range, should be 0 or larger than `buffer_size`. The function searches for CIS_CODE_END until this range. Set to 0 to search infinitely.
  - output: The size required to store all the CIS data, if CIS_CODE_END is found.

Returns

- ESP_OK: on success
- ESP_ERR_INVALID_RESPONSE: if the card does not (correctly) support CIS.
- ESP_ERR_INVALID_SIZE: CIS_CODE_END found, but `buffer_size` is less than required size, which is stored in the `inout_cis_size` then.
- ESP_ERR_NOT_FOUND: if the CIS_CODE_END not found. Increase input value of `inout_cis_size` or set it to 0, if you still want to search for the end; output value of `inout_cis_size` is invalid in this case.
- and other error code return from `sdmmc_io_read_bytes`

```c
esp_err_t sdmmc_io_print_cis_info (uint8_t *buffer, size_t buffer_size, FILE *fp)
```

Parse and print the CIS information of an SDIO card.

Note: Not all the CIS codes and all kinds of tuples are supported. If you see some unresolved code, you can add the parsing of these code in `sdmmc_io.c` and contribute to the IDF through the Github repository.

```c
using sdmmc_card_init
```

Parameters

- `buffer` - Buffer to parse
- `buffer_size` - Size of the buffer.
- `fp` - File pointer to print to, set to NULL to print to stdout.

Returns

- ESP_OK: on success
- ESP_ERR_NOT_SUPPORTED: if the value from the card is not supported to be parsed.
- ESP_ERR_INVALID_SIZE: if the CIS size fields are not correct.

Header File

- components/driver/sdmmc/include/driver/sdmmc_types.h

Structures

```c
struct sdmmc_csd_t
```

Decoded values from SD card Card Specific Data register
Public Members

int csd_ver
   CSD structure format

int mmc_ver
   MMC version (for CID format)

int capacity
   total number of sectors

int sector_size
   sector size in bytes

int read_block_len
   block length for reads

int card_command_class
   Card Command Class for SD

int tr_speed
   Max transfer speed

struct sdmmc_cid_t
   Decoded values from SD card Card IDentification register

Public Members

int mfg_id
   manufacturer identification number

int oem_id
   OEM/product identification number

char name[8]
   product name (MMC v1 has the longest)

int revision
   product revision

int serial
   product serial number

int date
   manufacturing date

struct sdmmc_scr_t
   Decoded values from SD Configuration Register Note: When new member is added, update reserved bits accordingly
Public Members

uint32_t sd_spec
    SD Physical layer specification version, reported by card

uint32_t erase_mem_state
    Data state on card after erase whether 0 or 1 (card vendor dependent)

uint32_t bus_width
    Bus widths supported by card: BIT(0) — 1-bit bus, BIT(2) — 4-bit bus

uint32_t reserved
    Reserved for future expansion

uint32_t rsvd_mnf
    Reserved for manufacturer usage

struct sdmmc_ssr_t
    Decoded values from SD Status Register Note: When new member is added, update reserved bits accordingly

Public Members

uint32_t alloc_unit_kb
    Allocation unit of the card, in multiples of kB (1024 bytes)

uint32_t erase_size_au
    Erase size for the purpose of timeout calculation, in multiples of allocation unit

uint32_t cur_bus_width
    SD current bus width

uint32_t discard_support
    SD discard feature support

uint32_t fule_support
    SD FULE (Full User Area Logical Erase) feature support

uint32_t erase_timeout
    Timeout (in seconds) for erase of a single allocation unit

uint32_t erase_offset
    Constant timeout offset (in seconds) for any erase operation

uint32_t reserved
    Reserved for future expansion

struct sdmmc_ext_csd_t
    Decoded values of Extended Card Specific Data
Public Members

uint8_t rev
   Extended CSD Revision

uint8_t power_class
   Power class used by the card

uint8_t erase_mem_state
   data state on card after erase whether 0 or 1 (card vendor dependent)

uint8_t sec_feature
   secure data management features supported by the card

struct sdmmc_switch_func_rsp_t
   SD SWITCH_FUNC response buffer

Public Members

uint32_t data[512 / 8 / sizeof(uint32_t)]
   response data

struct sdmmc_command_t
   SD/MMC command information

Public Members

uint32_t opcode
   SD or MMC command index

uint32_t arg
   SD/MMC command argument

sdmmc_response_t response
   response buffer

void *data
   buffer to send or read into

size_t datalen
   length of data buffer

size_t blklen
   block length

int flags
   see below
**Chapter 2. API Reference**

```c
esp_err_t error
error returned from transfer
```

```c
uint32_t timeout_ms
response timeout, in milliseconds
```

```c
struct sdmmc_host_t
SD/MMC Host description
This structure defines properties of SD/MMC host and functions of SD/MMC host which can be used by upper layers.
```

**Public Members**

```c
uint32_t flags
flags defining host properties
```

```c
int slot
slot number, to be passed to host functions
```

```c
int max_freq_khz
max frequency supported by the host
```

```c
float io_voltage
I/O voltage used by the controller (voltage switching is not supported)
```

```c
esp_err_t (*init)(void)
Host function to initialize the driver
```

```c
esp_err_t (*set_bus_width)(int slot, size_t width)
host function to set bus width
```

```c
size_t (*get_bus_width)(int slot)
host function to get bus width
```

```c
esp_err_t (*set_bus_ddr_mode)(int slot, bool ddr_enable)
host function to set DDR mode
```

```c
esp_err_t (*set_card_clk)(int slot, uint32_t freq_khz)
host function to set card clock frequency
```

```c
esp_err_t (*set_cclk_always_on)(int slot, bool cclk_always_on)
host function to set whether the clock is always enabled
```

```c
esp_err_t (*do_transaction)(int slot, sdmmc_command_t *cmdinfo)
host function to do a transaction
```

```c
esp_err_t (*deinit)(void)
host function to deinitialize the driver
```
**Chapter 2. API Reference**

```c
esp_err_t (*deinit_p)(int slot)
    host function to deinitialize the driver, called with the slot

esp_err_t (*io_int_enable)(int slot)
    Host function to enable SDIO interrupt line

esp_err_t (*io_int_wait)(int slot, TickType_t timeout_ticks)
    Host function to wait for SDIO interrupt line to be active

int command_timeout_ms
    timeout, in milliseconds, of a single command. Set to 0 to use the default value.

esp_err_t (*get_real_freq)(int slot, int *real_freq)
    Host function to provide real working freq, based on SDMMC controller setup
```

```c
struct sdmmc_card_t
    SD/MMC card information structure

Public Members

sdmmc_host_t host
    Host with which the card is associated

uint32_t ocr
    OCR (Operation Conditions Register) value

dmmc_cid_t cid
    decoded CID (Card IDentification) register value

dmmc_response_t raw_cid
    raw CID of MMC card to be decoded after the CSD is fetched in the data transfer mode

dmmc_csd_t csd
    decoded CSD (Card-Specific Data) register value

dmmc_scr_t scr
    decoded SCR (SD card Configuration Register) value

dmmc_ssr_t ssr
    decoded SSR (SD Status Register) value

dmmc_ext_csd_t ext_csd
    decoded EXT_CSD (Extended Card Specific Data) register value

uint16_t rca
    RCA (Relative Card Address)
```
uint16_t max_freq_khz
    Maximum frequency, in kHz, supported by the card

int real_freq_khz
    Real working frequency, in kHz, configured on the host controller

uint32_t is_mem
    Bit indicates if the card is a memory card

uint32_t is_sdio
    Bit indicates if the card is an IO card

uint32_t is_mmc
    Bit indicates if the card is MMC

uint32_t num_io_functions
    If is_sdio is 1, contains the number of IO functions on the card

uint32_t log_bus_width
    \log_2(\text{bus width supported by card})

uint32_t is_ddr
    Card supports DDR mode

uint32_t reserved
    Reserved for future expansion

**Macros**

`SDMMC_HOST_FLAG_1BIT`
    host supports 1-line SD and MMC protocol

`SDMMC_HOST_FLAG_4BIT`
    host supports 4-line SD and MMC protocol

`SDMMC_HOST_FLAG_8BIT`
    host supports 8-line MMC protocol

`SDMMC_HOST_FLAG_SPI`
    host supports SPI protocol

`SDMMC_HOST_FLAG_DDR`
    host supports DDR mode for SD/MMC

`SDMMC_HOST_FLAG_DEINIT_ARG`
    host `deinit` function called with the slot argument

`SDMMC_FREQ_DEFAULT`
    SD/MMC Default speed (limited by clock divider)
Chapter 2  API Reference

**SDMMC_FREQ_HIGHSPEED**
- SD High speed (limited by clock divider)

**SDMMC_FREQ_PROBING**
- SD/MMC probing speed

**SDMMC_FREQ_52M**
- MMC 52MHz speed

**SDMMC_FREQ_26M**
- MMC 26MHz speed

**Type Definitions**

typedef uint32_t sdmmc_response_t [4]
- SD/MMC command response buffer

**Enumerations**

enum sdmmc_erase_arg_t
- SD/MMC erase command(38) arguments
  - SD: ERASE: Erase the write blocks, physical/hard erase.
  - DISCARD: Card may deallocate the discarded blocks partially or completely. After discard operation the previously written data may be partially or fully read by the host depending on card implementation.
  - MMC: ERASE: Does TRIM, applies erase operation to write blocks instead of Erase Group.
  - DISCARD: The Discard function allows the host to identify data that is no longer required so that the device can erase the data if necessary during background erase events. Applies to write blocks instead of Erase Group. After discard operation, the original data may be remained partially or fully accessible to the host dependent on device.
  
  **Values:**

  - enumerator SDMMC_ERASE_ARG
    - Erase operation on SD, Trim operation on MMC

  - enumerator SDMMC_DISCARD_ARG
    - Discard operation for SD/MMC

### 2.9.7 Partitions API

**Overview**

The esp_partition component has higher-level API functions which work with partitions defined in the partition table. These APIs are based on lower level API provided by SPI Flash driver.
Partition Table API

ESP-IDF projects use a partition table to maintain information about various regions of SPI flash memory (bootloader, various application binaries, data, filesystems). More information can be found in *Partition Tables*.

This component provides API functions to enumerate partitions found in the partition table and perform operations on them. These functions are declared in `esp_partition.h`:

- `esp_partition_find()` checks a partition table for entries with specific type, returns an opaque iterator.
- `esp_partition_get()` returns a structure describing the partition for a given iterator.
- `esp_partition_next()` shifts the iterator to the next found partition.
- `esp_partition_iterator_release()` releases iterator returned by `esp_partition_find()`.
- `esp_partition_find_first()` is a convenience function which returns the structure describing the first partition found by `esp_partition_find()`.
- `esp_partition_read()`, `esp_partition_write()`, `esp_partition_erase_range()` are equivalent to `esp_flash_read()`, `esp_flash_write()`, `esp_flash_erase_region()`, but operate within partition boundaries.

See Also

- *Partition Table documentation*
- *Over The Air Update (OTA) API* provides high-level API for updating applications stored in flash.
- *Non-Volatile Storage (NVS) API* provides a structured API for storing small pieces of data in SPI flash.

API Reference - Partition Table

Header File

- components/esp_partition/include/esp_partition.h

Functions

```c
const esp_partition_t * esp_partition_find_first(esp_partition_type_t type, esp_partition_subtype_t subtype, const char *label)
```

Find first partition based on one or more parameters.

Parameters

- `type` - Partition type, one of `esp_partition_type_t` values or an 8-bit unsigned integer. To find all partitions, no matter the type, use `ESP_PARTITION_TYPE_ANY`, and set subtype argument to `ESP_PARTITION_SUBTYPE_ANY`.
- `subtype` - Partition subtype, one of `esp_partition_subtype_t` values or an 8-bit unsigned integer. To find all partitions of given type, use `ESP_PARTITION_SUBTYPE_ANY`.
- `label` - (optional) Partition label. Set this value if looking for partition with a specific name. Pass NULL otherwise.

Returns

Iterator which can be used to enumerate all the partitions found, or NULL if no partitions were found. Iterator obtained through this function has to be released using `esp_partition_iterator_release` when not used any more.

```c
const esp_partition_t * esp_partition_find(esp_partition_type_t type, esp_partition_subtype_t subtype, const char *label)
```

Find partition based on one or more parameters.

Parameters

- `type` - Partition type, one of `esp_partition_type_t` values or an 8-bit unsigned integer. To find all partitions, no matter the type, use `ESP_PARTITION_TYPE_ANY`, and set subtype argument to `ESP_PARTITION_SUBTYPE_ANY`.
- `subtype` - Partition subtype, one of `esp_partition_subtype_t` values or an 8-bit unsigned integer. To find all partitions of given type, use `ESP_PARTITION_SUBTYPE_ANY`.
- `label` - (optional) Partition label. Set this value if looking for partition with a specific name. Pass NULL otherwise.
Returns pointer to \texttt{esp\_partition\_t} structure, or NULL if no partition is found. This pointer is valid for the lifetime of the application.

\begin{verbatim}
const \texttt{esp\_partition\_t *esp\_partition\_get (esp\_partition\_iterator\_t iterator)}
\end{verbatim}
Get \texttt{esp\_partition\_t} structure for given partition.

- **Parameters** \texttt{iterator} – Iterator obtained using \texttt{esp\_partition\_find}. Must be non-NULL.
- **Returns** pointer to \texttt{esp\_partition\_t} structure. This pointer is valid for the lifetime of the application.

\begin{verbatim}
\texttt{esp\_partition\_iterator\_t esp\_partition\_next (esp\_partition\_iterator\_t iterator)}
\end{verbatim}
Move partition iterator to the next partition found.

- **Parameters** \texttt{iterator} – Iterator obtained using \texttt{esp\_partition\_find}. Must be non-NULL.
- **Returns** NULL if no partition was found, valid \texttt{esp\_partition\_iterator\_t} otherwise.

\begin{verbatim}
void \texttt{esp\_partition\_iterator\_release (esp\_partition\_iterator\_t iterator)}
\end{verbatim}
Release partition iterator.

- **Parameters** \texttt{iterator} – Iterator obtained using \texttt{esp\_partition\_find}. The iterator is allowed to be NULL, so it is not necessary to check its value before calling this function.

\begin{verbatim}
const \texttt{esp\_partition\_t *esp\_partition\_verify (const \texttt{esp\_partition\_t *partition)}}
\end{verbatim}
Verify partition data.

- **Parameters** \texttt{partition} – Pointer to partition data to verify. Must be non-NULL. All fields of this structure must match the partition table entry in flash for this function to return a successful match.
- **Returns**
  - If partition not found, returns NULL.
  - If found, returns a pointer to the \texttt{esp\_partition\_t} structure in flash. This pointer is always valid for the lifetime of the application.

\begin{verbatim}
\texttt{esp\_err\_t esp\_partition\_read (const \texttt{esp\_partition\_t *partition, size\_t src\_offset, void *dst, size\_t size)}}
\end{verbatim}
Read data from the partition.

- **Parameters**
  - \texttt{partition} – Pointer to partition structure obtained using \texttt{esp\_partition\_find\_first} or \texttt{esp\_partition\_get}. Must be non-NULL.
  - \texttt{dst} – Pointer to the buffer where data should be stored. Pointer must be non-NULL and buffer must be at least ‘size’ bytes long.
  - \texttt{src\_offset} – Address of the data to be read, relative to the beginning of the partition.
  - \texttt{size} – Size of data to be read, in bytes.
- **Returns** ESP\_OK, if data was read successfully; ESP\_ERR\_INVALID\_ARG, if \texttt{src\_offset} exceeds partition size; ESP\_ERR\_INVALID\_SIZE, if \texttt{read} would go out of bounds of the partition; or one of error codes from lower-level flash driver.

\begin{verbatim}
\texttt{esp\_err\_t esp\_partition\_write (const \texttt{esp\_partition\_t *partition, size\_t dst\_offset, const void *src, size\_t size)}}
\end{verbatim}
Write data to the partition.

- **Parameters**
  - \texttt{partition} – Pointer to partition structure obtained using \texttt{esp\_partition\_find\_first} or \texttt{esp\_partition\_get}. Must be non-NULL.

Before writing data to flash, corresponding region of flash needs to be erased. This can be done using \texttt{esp\_partition\_erase\_range} function.
Partitions marked with an encryption flag will automatically be written via the esp_flash_write_encrypted() function. If writing to an encrypted partition, all write offsets and lengths must be multiples of 16 bytes. See the esp_flash_write_encrypted() function for more details. Unencrypted partitions do not have this restriction.

**Note:** Prior to writing to flash memory, make sure it has been erased with esp_partition_erase_range call.

**Parameters**

- **partition** – Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- **dst_offset** – Address where the data should be written, relative to the beginning of the partition.
- **src** – Pointer to the source buffer. Pointer must be non-NULL and buffer must be at least ‘size’ bytes long.
- **size** – Size of data to be written, in bytes.

**Returns** ESP_OK, if data was written successfully; ESP_ERR_INVALID_ARG, if dst_offset exceeds partition size; ESP_ERR_INVALID_SIZE, if write would go out of bounds of the partition; or one of error codes from lower-level flash driver.

```c
esp_err_t esp_partition_write_raw(const esp_partition_t *partition, size_t dst_offset, const void *src, size_t size)
```

Write data to the partition without any transformation/encryption.

Before writing data to flash, corresponding region of flash needs to be erased. This can be done using esp_partition_erase_range function.

**Note:** This function is essentially the same as esp_partition_write() above. It just never encrypts data but writes it as is.

```c
esp_err_t esp_partition_write_raw(const esp_partition_t *partition, size_t dst_offset, const void *src, size_t size)
```

Write data to the partition without any transformation/encryption.

**Parameters**

- **partition** – Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- **dst_offset** – Address where the data should be written, relative to the beginning of the partition.
- **src_offset** – Address of the data to be read, relative to the beginning of the partition.
- **size** – Size of data to be read, in bytes.

**Returns** ESP_OK, if data was read successfully; ESP_ERR_INVALID_ARG, if src_offset exceeds partition size; ESP_ERR_INVALID_SIZE, if read would go out of bounds of the partition; or one of error codes from lower-level flash driver.

```c
esp_err_t esp_partition_read_raw(const esp_partition_t *partition, size_t src_offset, void *dst, size_t size)
```

Read data from the partition without any transformation/decryption.

**Note:** This function is essentially the same as esp_partition_read() above. It just never decrypts data but returns it as is.
• **partition** – Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
• **dst_offset** – Address where the data should be written, relative to the beginning of the partition.
• **src** – Pointer to the source buffer. Pointer must be non-NULL and buffer must be at least `size` bytes long.
• **size** – Size of data to be written, in bytes.

**Returns** ESP_OK, if data was written successfully; ESP_ERR_INVALID_ARG, if dst_offset exceeds partition size; ESP_ERR_INVALID_SIZE, if write would go out of bounds of the partition; or one of the error codes from lower-level flash driver.

```c
esp_err_t esp_partition_erase_range(const esp_partition_t *partition, size_t offset, size_t size)
```

Erase part of the partition.

**Parameters**
• **partition** – Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
• **offset** – Offset from the beginning of partition where erase operation should start. Must be aligned to partition->erase_size.
• **size** – Size of the range which should be erased, in bytes. Must be divisible by partition->erase_size.

**Returns** ESP_OK, if the range was erased successfully; ESP_ERR_INVALID_ARG, if iterator or dst are NULL; ESP_ERR_INVALID_SIZE, if erase would go out of bounds of the partition; or one of error codes from lower-level flash driver.

```c
esp_err_t esp_partition_mmap(const esp_partition_t *partition, size_t offset, size_t size, esp_partition_mmap_memory_t memory, const void **out_ptr, esp_partition_mmap_handle_t *out_handle)
```

Configure MMU to map partition into data memory.

Unlike spi_flash_mmap function, which requires a 64kB aligned base address, this function doesn’t impose such a requirement. If offset results in a flash address which is not aligned to 64kB boundary, address will be rounded to the lower 64kB boundary, so that mapped region includes requested range. Pointer returned via out_ptr argument will be adjusted to point to the requested offset (not necessarily to the beginning of mmap-ed region).

To release mapped memory, pass handle returned via out_handle argument to esp_partition_munmap function.

**Parameters**
• **partition** – Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
• **offset** – Offset from the beginning of partition where mapping should start.
• **size** – Size of the area to be mapped.
• **memory** – Memory space where the region should be mapped
• **out_ptr** – Output, pointer to the mapped memory region
• **out_handle** – Output, handle which should be used for esp_partition_munmap call

**Returns** ESP_OK, if successful

```c
void esp_partition_munmap(esp_partition_mmap_handle_t handle)
```

Release region previously obtained using esp_partition_mmap.

**Note:** Calling this function will not necessarily unmap memory region. Region will only be unmapped when there are no other handles which reference this region. In case of partially overlapping regions it is possible that memory will be unmapped partially.

**Parameters** handle – Handle obtained from spi_flash_mmap
**esp_err_t esp_partition_get_sha256 (const esp_partition_t *partition, uint8_t *sha_256)**

Get SHA-256 digest for required partition.

For apps with SHA-256 appended to the app image, the result is the appended SHA-256 value for the app image content. The hash is verified before returning, if app content is invalid then the function returns ESP_ERR_IMAGE_INVALID. For apps without SHA-256 appended to the image, the result is the SHA-256 of all bytes in the app image. For other partition types, the result is the SHA-256 of the entire partition.

**Parameters**
- **partition** – [in] Pointer to info for partition containing app or data. (fields: address, size and type, are required to be filled).
- **sha_256** – [out] Returned SHA-256 digest for a given partition.

**Returns**
- ESP_OK: In case of successful operation.
- ESP_ERR_INVALID_ARG: The size was 0 or the sha_256 was NULL.
- ESP_ERR_NO_MEM: Cannot allocate memory for sha256 operation.
- ESP_ERR_IMAGE_INVALID: App partition doesn’t contain a valid app image.
- ESP_FAIL: An allocation error occurred.

**bool esp_partition_check_identity (const esp_partition_t *partition_1, const esp_partition_t *partition_2)**

Check for the identity of two partitions by SHA-256 digest.

**Parameters**
- **partition_1** – [in] Pointer to info for partition 1 containing app or data. (fields: address, size and type, are required to be filled).
- **partition_2** – [in] Pointer to info for partition 2 containing app or data. (fields: address, size and type, are required to be filled).

**Returns**
- True: In case of the two firmware is equal.
- False: Otherwise

**esp_err_t esp_partition_register_external (esp_flash_t *flash_chip, size_t offset, size_t size, const char *label, esp_partition_type_t type, esp_partition_subtype_t subtype, const esp_partition_t **out_partition)**

Register a partition on an external flash chip.

This API allows designating certain areas of external flash chips (identified by the esp_flash_t structure) as partitions. This allows using them with components which access SPI flash through the esp_partition API.

**Parameters**
- **flash_chip** – Pointer to the structure identifying the flash chip
- **offset** – Address in bytes, where the partition starts
- **size** – Size of the partition in bytes
- **label** – Partition name
- **type** – One of the partition types (ESP_PARTITION_TYPE_*), or an integer. Note that applications cannot be booted from external flash chips, so using ESP_PARTITION_TYPE_APP is not supported.
- **subtype** – One of the partition subtypes (ESP_PARTITION_SUBTYPE_*), or an integer.
- **out_partition** – [out] Output, if non-NULL, receives the pointer to the resulting esp_partition_t structure

**Returns**
- ESP_OK on success
- ESP_ERR_NO_MEM if memory allocation has failed
- ESP_ERR_INVALID_ARG if the new partition overlaps another partition on the same flash chip
- ESP_ERR_INVALID_SIZE if the partition doesn’t fit into the flash chip size
```c
esp_err_t esp_partition_deregister_external (const esp_partition_t *partition)
```

Deregister the partition previously registered using esp_partition_register_external.

**Parameters**

- `partition` pointer to the partition structure obtained from esp_partition_register_external.

**Returns**

- ESP_OK on success
- ESP_ERR_NOT_FOUND if the partition pointer is not found
- ESP_ERR_INVALID_ARG if the partition comes from the partition table
- ESP_ERR_INVALID_ARG if the partition was not registered using esp_partition_register_external function.

**Structures**

```c
struct esp_partition_t
```

Partition information structure

This is not the format in flash, that format is esp_partition_info_t.

However, this is the format used by this API.

**Public Members**

```c
esp_flash_t *flash_chip
```

SPI flash chip on which the partition resides

```c
esp_partition_type_t type
```

Partition type (app/data)

```c
esp_partition_subtype_t subtype
```

Partition subtype

```c
uint32_t address
```

Starting address of the partition in flash

```c
uint32_t size
```

Size of the partition, in bytes

```c
uint32_t erase_size
```

Size the erase operation should be aligned to

```c
char label[17]
```

Partition label, zero-terminated ASCII string

```c
bool encrypted
```

Flag is set to true if partition is encrypted

**Macros**

```c
ESP_PARTITION_SUBTYPE_OTA (i)
```

Convenience macro to get esp_partition_subtype_t value for the i-th OTA partition.
Chapter 2. API Reference

Type Definitions

typedef uint32_t esp_partition_mmap_handle_t
    Opaque handle for memory region obtained from esp_partition_mmap.

typedef struct esp_partition_iterator_opaque_ *esp_partition_iterator_t
    Opaque partition iterator type.

Enumerations

enum esp_partition_mmap_memory_t
    Enumeration which specifies memory space requested in an mmap call.

    Values:

    enumerator ESP_PARTITION_MMAP_DATA
        map to data memory (Vaddr0), allows byte-aligned access, 4 MB total

    enumerator ESP_PARTITION_MMAP_INST
        map to instruction memory (Vaddr1-3), allows only 4-byte-aligned access, 11 MB total

enum esp_partition_type_t
    Partition type.

    Values:

    enumerator ESP_PARTITION_TYPE_APP
        Application partition type.

    enumerator ESP_PARTITION_TYPE_DATA
        Data partition type.

    enumerator ESP_PARTITION_TYPE_ANY
        Used to search for partitions with any type.

enum esp_partition_subtype_t
    Partition subtype.

    Application-defined partition types (0x40-0xFE) can set any numeric subtype value.

    Note: These ESP-IDF-defined partition subtypes apply to partitions of type ESP_PARTITION_TYPE_APP
          and ESP_PARTITION_TYPE_DATA.

    Values:

    enumerator ESP_PARTITION_SUBTYPE_APP_FACTORY
        Factory application partition.
enumerator ESP_PARTITION_SUBTYPE_APP_OTA_MIN
Base for OTA partition subtypes.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_0
OTA partition 0.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_1
OTA partition 1.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_2
OTA partition 2.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_3
OTA partition 3.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_4
OTA partition 4.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_5
OTA partition 5.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_6
OTA partition 6.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_7
OTA partition 7.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_8
OTA partition 8.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_9
OTA partition 9.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_10
OTA partition 10.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_11
OTA partition 11.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_12
OTA partition 12.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_13
OTA partition 13.

enumerator ESP_PARTITION_SUBTYPE_APP_OTA_14
OTA partition 14.
enumerator `ESP_PARTITION_SUBTYPE_APP_OTA_15`
OTA partition 15.

eventuator `ESP_PARTITION_SUBTYPE_APP_OTA_MAX`
Max subtype of OTA partition.

eventuator `ESP_PARTITION_SUBTYPE_APP_TEST`
Test application partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_OTA`
OTA selection partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_PHY`
PHY init data partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_NVS`
NVS partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_COREDUMP`
COREDUMP partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_NVS_KEYS`
Partition for NVS keys.

eventuator `ESP_PARTITION_SUBTYPE_DATA_EFUSE_EM`
Partition for emulate eFuse bits.

eventuator `ESP_PARTITION_SUBTYPE_DATA_UNDEFINED`
Undefined (or unspecified) data partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_ESPHTTPD`
ESPHTTPD partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_FAT`
FAT partition.

eventuator `ESP_PARTITION_SUBTYPE_DATA_SPIFFS`
SPIFFS partition.

eventuator `ESP_PARTITION_SUBTYPE_ANY`
Used to search for partitions with any subtype.

**2.9.8 SPIFFS Filesystem**

**Overview**

SPIFFS is a file system intended for SPI NOR flash devices on embedded targets. It supports wear levelling, file system consistency checks, and more.
Notes

- Currently, SPIFFS does not support directories, it produces a flat structure. If SPIFFS is mounted under /spiffs, then creating a file with the path /spiffs/tmp/myfile.txt will create a file called /tmp/myfile.txt in SPIFFS, instead of myfile.txt in the directory /spiffs/tmp.
- It is not a real-time stack. One write operation might take much longer than another.
- For now, it does not detect or handle bad blocks.
- SPIFFS is able to reliably utilize only around 75% of assigned partition space.
- When the filesystem is running out of space, the garbage collector is trying to find free space by scanning the filesystem multiple times, which can take up to several seconds per write function call, depending on required space. This is caused by the SPIFFS design and the issue has been reported multiple times (e.g. here) and in the official SPIFFS github repository. The issue can be partially mitigated by the SPIFFS configuration.
- Deleting a file does not always remove the whole file, which leaves unusable sections throughout the filesystem.
- When the chip experiences a power loss during a file system operation it could result in SPIFFS corruption. However the file system still might be recovered via esp_spiffs_check function. More details in the official SPIFFS FAQ.

Tools

**spiffsgen.py**  
spiffsgen.py is a write-only Python SPIFFS implementation used to create filesystem images from the contents of a host folder. To use spiffsgen.py, open Terminal and run:

```
python spiffsgen.py <image_size> <base_dir> <output_file>
```

The required arguments are as follows:
- **image_size**: size of the partition onto which the created SPIFFS image will be flashed.
- **base_dir**: directory for which the SPIFFS image needs to be created.
- **output_file**: SPIFFS image output file.

There are also other arguments that control image generation. Documentation on these arguments can be found in the tool’s help:

```
python spiffsgen.py --help
```

These optional arguments correspond to a possible SPIFFS build configuration. To generate the right image, please make sure that you use the same arguments/configuration as were used to build SPIFFS. As a guide, the help output indicates the SPIFFS build configuration to which the argument corresponds. In cases when these arguments are not specified, the default values shown in the help output will be used.

When the image is created, it can be flashed using `esptool.py` or `parttool.py`.

Aside from invoking the `spiffsgen.py` standalone by manually running it from the command line or a script, it is also possible to invoke spiffsgen.py directly from the build system by calling `spiffs_create_partition_image`:

```
spiffs_create_partition_image(<partition> <base_dir> [FLASH_IN_PROJECT] [DEPENDS... --dep dep dep...])
```

This is more convenient as the build configuration is automatically passed to the tool, ensuring that the generated image is valid for that build. An example of this is while the **image_size** is required for the standalone invocation, only the **partition** name is required when using `spiffs_create_partition_image` - the image size is automatically obtained from the project’s partition table.

`spiffs_create_partition_image` must be called from one of the component CMakeLists.txt files.

Optionally, users can opt to have the image automatically flashed together with the app binaries, partition tables, etc. on `idf.py flash` by specifying `FLASH_IN_PROJECT`. For example:

```
spiffs_create_partition_image(my_spiffs_partition my_folder FLASH_IN_PROJECT)
```
If `FLASH_IN_PROJECT/ SPIFFS_IMAGE_FLASH_IN_PROJECT` is not specified, the image will still be generated, but you will have to flash it manually using `esptool.py`, `parttool.py`, or a custom build system target.

There are cases where the contents of the base directory itself is generated at build time. Users can use `DEPENDS/ SPIFFS_IMAGE_DEPENDS` to specify targets that should be executed before generating the image:

```plaintext
add_custom_target(dep COMMAND ...)
spiffs_create_partition_image(my_spiffs_partition my_folder DEPENDS dep)
```

For an example, see `storage/spiffsgen`.

**mkspiffs**  Another tool for creating SPIFFS partition images is `mkspiffs`. Similar to `spiffsgen.py`, it can be used to create an image from a given folder and then flash that image using `esptool.py`.

For that, you need to obtain the following parameters:

- **Block Size**: 4096 (standard for SPI Flash)
- **Page Size**: 256 (standard for SPI Flash)
- **Image Size**: Size of the partition in bytes (can be obtained from a partition table)
- **Partition Offset**: Starting address of the partition (can be obtained from a partition table)

To pack a folder into a 1-Megabyte image, run:

```plaintext
mkspiffs -c [src_folder] -b 4096 -p 256 -s 0x100000 spiffs.bin
```

To flash the image onto ESP32 at offset 0x110000, run:

```plaintext
python esptool.py --chip esp32 --port [port] --baud [baud] write_flash -z 0x110000... --spiffs.bin
```

**Notes on which SPIFFS tool to use**  The two tools presented above offer very similar functionality. However, there are reasons to prefer one over the other, depending on the use case.

Use `spiffsgen.py` in the following cases:

1. If you want to simply generate a SPIFFS image during the build. `spiffsgen.py` makes it very convenient by providing functions/commands from the build system itself.
2. If the host has no C/C++ compiler available, because `spiffsgen.py` does not require compilation.

Use `mkspiffs` in the following cases:

1. If you need to unpack SPIFFS images in addition to image generation. For now, it is not possible with `spiffsgen.py`.
2. If you have an environment where a Python interpreter is not available, but a host compiler is available. Otherwise, a pre-compiled `mkspiffs` binary can do the job. However, there is no build system integration for `mkspiffs` and the user has to do the corresponding work: compiling `mkspiffs` during build (if a pre-compiled binary is not used), creating build rules/targets for the output files, passing proper parameters to the tool, etc.

**See also**

- *Partition Table documentation*

**Application Example**

An example of using SPIFFS is provided in the `storage/spiffs` directory. This example initializes and mounts a SPIFFS partition, then writes and reads data from it using POSIX and C library APIs. See the README.md file in the example directory for more information.
Chapter 2. API Reference

High-level API Reference

Header File

- components/spiffs/include/esp_spiffs.h

Functions

`esp_err_t esp_vfs_spiffs_register` (const `esp_vfs_spiffs_conf_t *conf`)

Register and mount SPIFFS to VFS with given path prefix.

**Parameters**

`conf` – Pointer to `esp_vfs_spiffs_conf_t` configuration structure

**Returns**

- ESP_OK if success
- ESP_ERR_NO_MEM if objects could not be allocated
- ESP_ERR_INVALID_STATE if already mounted or partition is encrypted
- ESP_ERR_NOT_FOUND if partition for SPIFFS was not found
- ESP_FAIL if mount or format fails

`esp_err_t esp_vfs_spiffs_unregister` (const char* `partition_label`)

Unregister and unmount SPIFFS from VFS

**Parameters**

`partition_label` – Same label as passed to `esp_vfs_spiffs_register`.

**Returns**

- ESP_OK if successful
- ESP_ERR_INVALID_STATE already unregistered

`bool esp_spiffs_mounted` (const char* `partition_label`)

Check if SPIFFS is mounted

**Parameters**

`partition_label` – Optional, label of the partition to check. If not specified, first partition with subtype=spiffs is used.

**Returns**

- true if mounted
- false if not mounted

`esp_err_t esp_spiffs_format` (const char* `partition_label`)

Format the SPIFFS partition

**Parameters**

`partition_label` – Same label as passed to `esp_vfs_spiffs_register`.

**Returns**

- ESP_OK if successful
- ESP_FAIL on error

`esp_err_t esp_spiffs_info` (const char* `partition_label`, size_t* `total_bytes`, size_t* `used_bytes`)

Get information for SPIFFS

**Parameters**

`partition_label` – Same label as passed to `esp_vfs_spiffs_register`

**Returns**

- ESP_OK if success
- ESP_ERR_INVALID_STATE if not mounted

`esp_err_t esp_spiffs_check` (const char* `partition_label`)

Check integrity of SPIFFS

**Parameters**

`partition_label` – Same label as passed to `esp_vfs_spiffs_register`

**Returns**

- ESP_OK if successful
- ESP_ERR_INVALID_STATE if not mounted
- ESP_FAIL on error
esp_err_t esp_spiffs_gc(const char* partition_label, size_t size_to_gc)

Perform garbage collection in SPIFFS partition.

Call this function to run GC and ensure that at least the given amount of space is available in the partition. This function will fail with ESP_ERR_NOT_FINISHED if it is not possible to reclaim the requested space (that is, not enough free or deleted pages in the filesystem). This function will also fail if it fails to reclaim the requested space after CONFIG_SPIFFS_GC_MAX_RUNS number of GC iterations. On one GC iteration, SPIFFS will erase one logical block (4kB). Therefore the value of CONFIG_SPIFFS_GC_MAX_RUNS should be set at least to the maximum expected size_to_gc, divided by 4096. For example, if the application expects to make room for a 1MB file and calls esp_spiffs_gc(label, 1024 * 1024), CONFIG_SPIFFS_GC_MAX_RUNS should be set to at least 256. On the other hand, increasing CONFIG_SPIFFS_GC_MAX_RUNS value increases the maximum amount of time for which any SPIFFS GC or write operation may potentially block.

**Parameters**
- **partition_label**: Label of the partition to be garbage-collected. The partition must be already mounted.
- **size_to_gc**: The number of bytes that the GC process should attempt to make available.

**Returns**
- ESP_OK on success
- ESP_ERR_NOT_FINISHED if GC fails to reclaim the size given by size_to_gc
- ESP_ERR_INVALID_STATE if the partition is not mounted
- ESP_FAIL on all other errors

**Structures**

struct esp_vfs_spiffs_conf_t

Configuration structure for esp_vfs_spiffs_register.

**Public Members**

const char *base_path

File path prefix associated with the filesystem.

const char *partition_label

Optional, label of SPIFFS partition to use. If set to NULL, first partition with subtype=spiffs will be used.

size_t max_files

Maximum files that could be open at the same time.

bool format_if_mount_failed

If true, it will format the file system if it fails to mount.

### 2.9.9 Virtual filesystem component

**Overview**

Virtual filesystem (VFS) component provides a unified interface for drivers which can perform operations on file-like objects. These can be real filesystems (FAT, SPIFFS, etc.) or device drivers which provide a file-like interface.
This component allows C library functions, such as fopen and fprintf, to work with FS drivers. At a high level, each FS driver is associated with some path prefix. When one of C library functions needs to open a file, the VFS component searches for the FS driver associated with the file path and forwards the call to that driver. VFS also forwards read, write, and other calls for the given file to the same FS driver.

For example, one can register a FAT filesystem driver with the /fat prefix and call fopen("/fat/file.txt", "w"). The VFS component will then call the function open of the FAT driver and pass the argument /file.txt to it together with appropriate mode flags. All subsequent calls to C library functions for the returned FILE* stream will also be forwarded to the FAT driver.

FS registration

To register an FS driver, an application needs to define an instance of the esp_vfs_t structure and populate it with function pointers to FS APIs:

```c
esp_vfs_t myfs = {
    .flags = ESP_VFS_FLAG_DEFAULT,
    .write = &myfs_write,
    .open = &myfs_open,
    .fstat = &myfs_fstat,
    .close = &myfs_close,
    .read = &myfs_read,
};
ESP_ERROR_CHECK(esp_vfs_register("/data", &myfs, NULL));
```

Depending on the way how the FS driver declares its API functions, either read, write, etc., or read_p, write_p, etc., should be used.

Case 1: API functions are declared without an extra context pointer (the FS driver is a singleton):

```c
ssize_t myfs_write(int fd, const void * data, size_t size);
```

```c
// In definition of esp_vfs_t:
    .flags = ESP_VFS_FLAG_DEFAULT,
    .write = &myfs_write,
// ... other members initialized

// When registering FS, context pointer (third argument) is NULL:
ESP_ERROR_CHECK(esp_vfs_register("/data", &myfs, NULL));
```

Case 2: API functions are declared with an extra context pointer (the FS driver supports multiple instances):

```c
ssize_t myfs_write(myfs_t * fs, int fd, const void * data, size_t size);
```

```c
// In definition of esp_vfs_t:
    .flags = ESP_VFS_FLAG_CONTEXT_PTR,
    .write_p = &myfs_write,
// ... other members initialized

// When registering FS, pass the FS context pointer into the third argument
// (hypothetical myfs_mount function is used for illustrative purposes)
myfs_t * myfs_inst1 = myfs_mount(partition1->offset, partition1->size);
ESP_ERROR_CHECK(esp_vfs_register("/data1", &myfs, myfs_inst1));

// Can register another instance:
myfs_t * myfs_inst2 = myfs_mount(partition2->offset, partition2->size);
ESP_ERROR_CHECK(esp_vfs_register("/data2", &myfs, myfs_inst2));
```

Synchronous input/output multiplexing  Synchronous input/output multiplexing by select() is supported in the VFS component. The implementation works in the following way.
1. `select()` is called with file descriptors which could belong to various VFS drivers.
2. The file descriptors are divided into groups each belonging to one VFS driver.
3. The file descriptors belonging to non-socket VFS drivers are handed over to the given VFS drivers by `start_select()`, described later on this page. This function represents the driver-specific implementation of `select()` for the given driver. This should be a non-blocking call which means the function should immediately return after setting up the environment for checking events related to the given file descriptors.
4. The file descriptors belonging to the socket VFS driver are handed over to the socket driver by `socket_select()` described later on this page. This is a blocking call which means that it will return only if there is an event related to socket file descriptors or a non-socket driver signals `socket_select()` to exit.
5. Results are collected from each VFS driver and all drivers are stopped by de-initialization of the environment for checking events.
6. The `select()` call ends and returns the appropriate results.

**Non-socket VFS drivers**  If you want to use `select()` with a file descriptor belonging to a non-socket VFS driver, then you need to register the driver with functions `start_select()` and `end_select()` similarly to the following example:

```c
// In definition of esp_vfs_t:
    .start_select = &uart_start_select,
    .end_select = &uart_end_select,
// ... other members initialized
```

`start_select()` is called for setting up the environment for detection of read/write/error conditions on file descriptors belonging to the given VFS driver.

`end_select()` is called to stop/deinitialize/free the environment which was setup by `start_select()`.

**Note:** `end_select()` might be called without a previous `start_select()` call in some rare circumstances. `end_select()` should fail gracefully if this is the case (i.e., should not crash but return an error instead).

Please refer to the reference implementation for the UART peripheral in `vfs/vfs_uart.c` and most particularly to the functions `esp_vfs_dev_uart_register()`, `uart_start_select()`, and `uart_end_select()` for more information.

Please check the following examples that demonstrate the use of `select()` with VFS file descriptors:

- `peripherals/uart/uart_select`
- `system/select`

**Socket VFS drivers**  A socket VFS driver is using its own internal implementation of `select()` and non-socket VFS drivers notify it upon read/write/error conditions.

A socket VFS driver needs to be registered with the following functions defined:

```c
// In definition of esp_vfs_t:
    .socket_select = &lwip_select,
    .get_socket_select_semaphore = &lwip_get_socket_select_semaphore,
    .stop_socket_select = &lwip_stop_socket_select,
    .stop_socket_select_isr = &lwip_stop_socket_select_isr,
// ... other members initialized
```

`socket_select()` is the internal implementation of `select()` for the socket driver. It works only with file descriptors belonging to the socket VFS.

`get_socket_select_semaphore()` returns the signalization object (semaphore) which will be used in non-socket drivers to stop the waiting in `socket_select()`.

`stop_socket_select()` call is used to stop the waiting in `socket_select()` by passing the object returned by `get_socket_select_semaphore()`.
stop_socket_select_isr() has the same functionality as stop_socket_select() but it can be used from ISR.

Please see lwip/port/esp32xx/vfs_lwip.c for a reference socket driver implementation using LWIP.

**Note:** If you use select() for socket file descriptors only then you can disable the CONFIG_VFS_SUPPORT_SELECT option to reduce the code size and improve performance. You should not change the socket driver during an active select() call or you might experience some undefined behavior.

**Paths**

Each registered FS has a path prefix associated with it. This prefix can be considered as a “mount point” of this partition.

In case when mount points are nested, the mount point with the longest matching path prefix is used when opening the file. For instance, suppose that the following filesystems are registered in VFS:

- FS 1 on /data
- FS 2 on /data/static

Then:

- FS 1 will be used when opening a file called /data/log.txt
- FS 2 will be used when opening a file called /data/static/index.html
- Even if /index.html does not exist in FS 2, FS 1 will *not* be searched for /static/index.html.

As a general rule, mount point names must start with the path separator (/) and must contain at least one character after path separator. However, an empty mount point name is also supported and might be used in cases when an application needs to provide a “fallback” filesystem or to override VFS functionality altogether. Such filesystem will be used if no prefix matches the path given.

VFS does not handle dots (.) in path names in any special way. VFS does not treat .. as a reference to the parent directory. In the above example, using a path /data/static/../../log.txt will not result in a call to FS 1 to open /log.txt. Specific FS drivers (such as FATFS) might handle dots in file names differently.

When opening files, the FS driver receives only relative paths to files. For example:

1. The myfs driver is registered with /data as a path prefix.
2. The application calls fopen("/data/config.json", ...).
3. The VFS component calls myfs_open("/config.json", ...).
4. The myfs driver opens the /config.json file.

VFS does not impose any limit on total file path length, but it does limit the FS path prefix to ESP_VFS_PATH_MAX characters. Individual FS drivers may have their own filename length limitations.

**File descriptors**

File descriptors are small positive integers from 0 to FD_SETSIZE - 1, where FD_SETSIZE is defined in newlib’s sys/types.h. The largest file descriptors (configured by CONFIG_LWIP_MAX_SOCKETS) are reserved for sockets. The VFS component contains a lookup-table called s_fd_table for mapping global file descriptors to VFS driver indexes registered in the s_vfs array.

**Standard IO streams (stdin, stdout, stderr)**

If the menuconfig option UART for console output is not set to None, then stdin, stdout, and stderr are configured to read from, and write to, a UART. It is possible to use UART0 or UART1 for standard IO. By default, UART0 is used with 115200 baud rate; TX pin is GPIO1; RX pin is GPIO3. These parameters can be changed in menuconfig.
Writing to stdout or stderr will send characters to the UART transmit FIFO. Reading from stdin will retrieve characters from the UART receive FIFO.

By default, VFS uses simple functions for reading from and writing to UART. Writes busy-wait until all data is put into UART FIFO, and reads are non-blocking, returning only the data present in the FIFO. Due to this non-blocking read behavior, higher level C library calls, such as scanf("%d\n", &var);, might not have desired results.

Applications which use the UART driver can instruct VFS to use the driver’s interrupt driven, blocking read and write functions instead. This can be done using a call to the esp_vfs_dev_uart_use_driver function. It is also possible to revert to the basic non-blocking functions using a call to esp_vfs_dev_uart_use_nonblocking.

VFS also provides an optional newline conversion feature for input and output. Internally, most applications send and receive lines terminated by the LF (‘\n’) character. Different terminal programs may require different line termination, such as CR or CRLF. Applications can configure this separately for input and output either via menuconfig, or by calls to the functions esp_vfs_dev_uart_port_set_rx_line_endings and esp_vfs_dev_uart_port_set_tx_line_endings.

Standard streams and FreeRTOS tasks FILE objects for stdin, stdout, and stderr are shared between all FreeRTOS tasks, but the pointers to these objects are stored in per-task struct _reent.

The following code is transferred to fprintf(__getreent()-> stderr, "42\n"); by the preprocessor:

```c
fprintf(stderr, "42\n");
```

The __getreent() function returns a per-task pointer to struct _reent in newlib libc. This structure is allocated on the TCB of each task. When a task is initialized, _stdin, _stdout, and _stderr members of struct _reent are set to the values of _stdin, _stdout, and _stderr of _GLOBAL_REENT (i.e., the structure which is used before FreeRTOS is started).

Such a design has the following consequences:

- It is possible to set stdin, stdout, and stderr for any given task without affecting other tasks, e.g., by doing stdin = fopen("/dev/uart/1", "r").
- Closing default stdin, stdout, or stderr using fclose will close the FILE stream object, which will affect all other tasks.
- To change the default stdin, stdout, stderr streams for new tasks, modify _GLOBAL_REENT->stdin(_stdin,_stdout,_stderr) before creating the task.

Event fds

eventfd() call is a powerful tool to notify a select() based loop of custom events. The eventfd() implementation in ESP-IDF is generally the same as described in man(2) eventfd except for:

- esp_vfs_eventfd_register() has to be called before calling eventfd()
- Options EFD_CLOEXEC, EFD_NONBLOCK and EFD_SEMAPHORE are not supported in flags.
- Option EFD_SUPPORT_ISR has been added in flags. This flag is required to read and write the eventfd in an interrupt handler.

Note that creating an eventfd with EFD_SUPPORT_ISR will cause interrupts to be temporarily disabled when reading, writing the file and during the beginning and the ending of the select() when this file is set.

API Reference

Header File

- components/vfs/include/esp_vfs.h
**Functions**

`ssize_t esp_vfs_write` (struct _reent *r, int fd, const void *data, size_t size)

These functions are to be used in newlib syscall table. They will be called by newlib when it needs to use any of the syscalls.

`off_t esp_vfs_lseek` (struct _reent *r, int fd, off_t size, int mode)

`ssize_t esp_vfs_read` (struct _reent *r, int fd, void *dst, size_t size)

`int esp_vfs_open` (struct _reent *r, const char *path, int flags, int mode)

`int esp_vfs_close` (struct _reent *r, int fd)

`int esp_vfs_fstat` (struct _reent *r, int fd, struct stat *st)

`int esp_vfs_stat` (struct _reent *r, const char *path, struct stat *st)

`int esp_vfs_link` (struct _reent *r, const char *n1, const char *n2)

`int esp_vfs_unlink` (struct _reent *r, const char *path)

`int esp_vfs_rename` (struct _reent *r, const char *src, const char *dst)

`int esp_vfs_utime` (const char *path, const struct utimbuf *times)

`esp_err_t esp_vfs_register` (const char *base_path, const esp_vfs_t *vfs, void *ctx)

Register a virtual filesystem for given path prefix.

**Parameters**

- **base_path** – file path prefix associated with the filesystem. Must be a zero-terminated C string, may be empty. If not empty, must be up to ESP_VFS_PATH_MAX characters long, and at least 2 characters long. Name must start with a “/” and must not end with “/”. For example, “/data” or “/dev/spi” are valid. These VFSes would then be called to handle file paths such as “/data/myfile.txt” or “/dev/spi/0”. In the special case of an empty base_path, a “fallback” VFS is registered. Such VFS will handle paths which are not matched by any other registered VFS.

- **vfs** – Pointer to esp_vfs_t, a structure which maps syscalls to the filesystem driver functions. VFS component doesn’t assume ownership of this pointer.

- **ctx** – If vfs->flags has ESP_VFS_FLAG_CONTEXT_PTR set, a pointer which should be passed to VFS functions. Otherwise, NULL.

**Returns** ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered.

`esp_err_t esp_vfs_register_fd_range` (const esp_vfs_t *vfs, void *ctx, int min_fd, int max_fd)

Special case function for registering a VFS that uses a method other than open() to open new file descriptors from the interval <min_fd; max_fd).

This is a special-purpose function intended for registering LWIP sockets to VFS.

**Parameters**

- **vfs** – Pointer to esp_vfs_t. Meaning is the same as for esp_vfs_register().

- **ctx** – Pointer to context structure. Meaning is the same as for esp_vfs_register().

- **min_fd** – The smallest file descriptor this VFS will use.

- **max_fd** – Upper boundary for file descriptors this VFS will use (the biggest file descriptor plus one).

**Returns** ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered, ESP_ERR_INVALID_ARG if the file descriptor boundaries are incorrect.

`esp_err_t esp_vfs_register_with_id` (const esp_vfs_t *vfs, void *ctx, esp_vfs_id_t *vfs_id)

Special case function for registering a VFS that uses a method other than open() to open new file descriptors. In comparison with esp_vfs_register_fd_range, this function doesn’t pre-registers an interval of file descriptors. File descriptors can be registered later, by using esp_vfs_register_fd.

**Parameters**

- **vfs** – Pointer to esp_vfs_t. Meaning is the same as for esp_vfs_register().
• **ctx** – Pointer to context structure. Meaning is the same as for esp_vfs_register().
• **vfs_id** – Here will be written the VFS ID which can be passed to esp_vfs_register_fd for registering file descriptors.

**Returns**
- ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered,
- ESP_ERR_INVALID_ARG if the file descriptor boundaries are incorrect.

```c
esp_err_t esp_vfs_unregister(const char* base_path)
```

Unregister a virtual filesystem for given path prefix

**Parameters**
- **base_path** – File prefix previously used in esp_vfs_register call

**Returns**
- ESP_OK if successful, ESP_ERR_INVALID_STATE if VFS for given prefix hasn’t been registered

```c
esp_err_t esp_vfs_unregister_with_id(esp_vfs_id_t vfs_id)
```

Unregister a virtual filesystem with the given index

**Parameters**
- **vfs_id** – The VFS ID returned by esp_vfs_register_with_id

**Returns**
- ESP_OK if successful, ESP_ERR_INVALID_STATE if VFS for the given index hasn’t been registered

```c
esp_err_t esp_vfs_register_fd(esp_vfs_id_t vfs_id, int* fd)
```

Special function for registering another file descriptor for a VFS registered by esp_vfs_register_with_id.

**Parameters**
- **vfs_id** – VFS identificator returned by esp_vfs_register_with_id.
- **fd** – The registered file descriptor will be written to this address.

**Returns**
- ESP_OK if the registration is successful, ESP_ERR_NO_MEM if too many file descriptors are registered, ESP_ERR_INVALID_ARG if the arguments are incorrect.

```c
esp_err_t esp_vfs_register_fd_with_local_fd(esp_vfs_id_t vfs_id, int local_fd, bool permanent, int* fd)
```

Special function for registering another file descriptor with given local_fd for a VFS registered by esp_vfs_register_with_id.

**Parameters**
- **vfs_id** – VFS identificator returned by esp_vfs_register_with_id.
- **local_fd** – The fd in the local vfs. Passing -1 will set the local fd as the (*fd) value.
- **permanent** – Whether the fd should be treated as permanent (not removed after close())
- **fd** – The registered file descriptor will be written to this address.

**Returns**
- ESP_OK if the registration is successful, ESP_ERR_NO_MEM if too many file descriptors are registered, ESP_ERR_INVALID_ARG if the arguments are incorrect.

```c
esp_err_t esp_vfs_unregister_fd(esp_vfs_id_t vfs_id, int fd)
```

Special function for unregistering a file descriptor belonging to a VFS registered by esp_vfs_register_with_id.

**Parameters**
- **vfs_id** – VFS identificator returned by esp_vfs_register_with_id.
- **fd** – File descriptor which should be unregistered.

**Returns**
- ESP_OK if the registration is successful, ESP_ERR_INVALID_ARG if the arguments are incorrect.

```c
int esp_vfs_select(int nfds, fd_set* readfds, fd_set* writedfs, fd_set* errorfds, struct timeval* timeout)
```

Synchronous I/O multiplexing which implements the functionality of POSIX select() for VFS.

**Parameters**
- **nfds** – Specifies the range of descriptors which should be checked. The first nfds descriptors will be checked in each set.
- **readfds** – If not NULL, then points to a descriptor set that on input specifies which descriptors should be checked for being ready to read, and on output indicates which descriptors are ready to read.
- **writedfs** – If not NULL, then points to a descriptor set that on input specifies which descriptors should be checked for being ready to write, and on output indicates which descriptors are ready to write.
errorfds - If not NULL, then points to a descriptor set that on input specifies which descriptors should be checked for error conditions, and on output indicates which descriptors have error conditions.

timeout - If not NULL, then points to timeval structure which specifies the time period after which the functions should time-out and return. If it is NULL, then the function will not time-out. Note that the timeout period is rounded up to the system tick and incremented by one.

Returns The number of descriptors set in the descriptor sets, or -1 when an error (specified by errno) have occurred.

```c
void esp_vfs_select_triggered(esp_vfs_select_sem_t sem)
```
Notification from a VFS driver about a read/write/error condition.

This function is called when the VFS driver detects a read/write/error condition as it was requested by the previous call to start_select.

**Parameters**
- `sem` - semaphore structure which was passed to the driver by the start_select call

```c
void esp_vfs_select_triggered_isr(esp_vfs_select_sem_t sem, BaseType_t *woken)
```
Notification from a VFS driver about a read/write/error condition (ISR version)

This function is called when the VFS driver detects a read/write/error condition as it was requested by the previous call to start_select.

**Parameters**
- `sem` - semaphore structure which was passed to the driver by the start_select call
- `woken` - is set to pdTRUE if the function wakes up a task with higher priority

```c
ssize_t esp_vfs_pread(int fd, void *dst, size_t size, off_t offset)
```
Implements the VFS layer of POSIX pread()

**Parameters**
- `fd` - File descriptor used for read
- `dst` - Pointer to the buffer where the output will be written
- `size` - Number of bytes to be read
- `offset` - Starting offset of the read

**Returns** A positive return value indicates the number of bytes read. -1 is return on failure and errno is set accordingly.

```c
ssize_t esp_vfs_pwrite(int fd, const void *src, size_t size, off_t offset)
```
Implements the VFS layer of POSIX pwrite()

**Parameters**
- `fd` - File descriptor used for write
- `src` - Pointer to the buffer from where the output will be read
- `size` - Number of bytes to write
- `offset` - Starting offset of the write

**Returns** A positive return value indicates the number of bytes written. -1 is return on failure and errno is set accordingly.

**Structures**

```c
struct esp_vfs_select_sem_t
```
VFS semaphore type for select()

**Public Members**

```c
bool is_sem_local
```
type of “sem” is SemaphoreHandle_t when true, defined by socket driver otherwise
Chapter 2. API Reference

```c
void *sem
    semaphore instance

struct esp_vfs_t
    VFS definition structure.

    This structure should be filled with pointers to corresponding FS driver functions.

    VFS component will translate all FDs so that the filesystem implementation sees them starting at zero. The
    caller sees a global FD which is prefixed with an pre-filesystem-implementation.

    Some FS implementations expect some state (e.g. pointer to some structure) to be passed in as a first argument.
    For these implementations, populate the members of this structure which have _p suffix, set flags member
    to ESP_VFS_FLAG_CONTEXT_PTR and provide the context pointer to esp_vfs_register function. If the
    implementation doesn’t use this extra argument, populate the members without _p suffix and set flags member
    to ESP_VFS_FLAG_DEFAULT.

    If the FS driver doesn’t provide some of the functions, set corresponding members to NULL.

Public Members

int flags
    ESP_VFS_FLAG_CONTEXT_PTR or ESP_VFS_FLAG_DEFAULT

ssize_t (*write_p)(void *p, int fd, const void *data, size_t size)
    Write with context pointer

ssize_t (*write)(int fd, const void *data, size_t size)
    Write without context pointer

off_t (*lseek_p)(void *p, int fd, off_t size, int mode)
    Seek with context pointer

off_t (*lseek)(int fd, off_t size, int mode)
    Seek without context pointer

ssize_t (*read_p)(void *ctx, int fd, void *dst, size_t size)
    Read with context pointer

ssize_t (*read)(int fd, void *dst, size_t size)
    Read without context pointer

ssize_t (*pread_p)(void *ctx, int fd, void *dst, size_t size, off_t offset)
    pread with context pointer

ssize_t (*pread)(int fd, void *dst, size_t size, off_t offset)
    pread without context pointer

ssize_t (*pwrite_p)(void *ctx, int fd, const void *src, size_t size, off_t offset)
    pwrite with context pointer
```
ssize_t (*pwrite)(int fd, const void *src, size_t size, off_t offset)
    pwrite without context pointer

int (*open_p)(void *ctx, const char *path, int flags, int mode)
    open with context pointer

int (*open)(const char *path, int flags, int mode)
    open without context pointer

int (*close_p)(void *ctx, int fd)
    close with context pointer

int (*close)(int fd)
    close without context pointer

int (*fstat_p)(void *ctx, int fd, struct stat *st)
    fstat with context pointer

int (*fstat)(int fd, struct stat *st)
    fstat without context pointer

int (*stat_p)(void *ctx, const char *path, struct stat *st)
    stat with context pointer

int (*stat)(const char *path, struct stat *st)
    stat without context pointer

int (*link_p)(void *ctx, const char *n1, const char *n2)
    link with context pointer

int (*link)(const char *n1, const char *n2)
    link without context pointer

int (*unlink_p)(void *ctx, const char *path)
    unlink with context pointer

int (*unlink)(const char *path)
    unlink without context pointer

int (*rename_p)(void *ctx, const char *src, const char *dst)
    rename with context pointer

int (*rename)(const char *src, const char *dst)
    rename without context pointer

DIR *(*opendir_p)(void *ctx, const char *name)
    opendir with context pointer
Chapter 2. API Reference

DIR *(*opendir)(const char *name)
   opendir without context pointer

struct dirent *(*readdir_p)(void *ctx, DIR *pdir)
   readdir with context pointer

struct dirent *(*readdir)(DIR *pdir)
   readdir without context pointer

int (*readdir_r_p)(void *ctx, DIR *pdir, struct dirent *entry, struct dirent **out_dirent)
   readdir_r with context pointer

int (*readdir_r)(DIR *pdir, struct dirent *entry, struct dirent **out_dirent)
   readdir_r without context pointer

long (*telldir_p)(void *ctx, DIR *pdir)
   telldir with context pointer

long (*telldir)(DIR *pdir)
   telldir without context pointer

void (*seekdir_p)(void *ctx, DIR *pdir, long offset)
   seekdir with context pointer

void (*seekdir)(DIR *pdir, long offset)
   seekdir without context pointer

int (*closedir_p)(void *ctx, DIR *pdir)
   closedir with context pointer

int (*closedir)(DIR *pdir)
   closedir without context pointer

int (*mkdir_p)(void *ctx, const char *name, mode_t mode)
   mkdir with context pointer

int (*mkdir)(const char *name, mode_t mode)
   mkdir without context pointer

int (*rmdir_p)(void *ctx, const char *name)
   rmdir with context pointer

int (*rmdir)(const char *name)
   rmdir without context pointer

int (*fcntl_p)(void *ctx, int fd, int cmd, int arg)
   fcntl with context pointer

int (*fcntl)(int fd, int cmd, int arg)
int (*fcntl)(int fd, int cmd, int arg)
   fcntl without context pointer

int (*ioctl_p)(void *ctx, int fd, int cmd, va_list args)
   ioctl with context pointer

int (*ioctl)(int fd, int cmd, va_list args)
   ioctl without context pointer

int (*fsync_p)(void *ctx, int fd)
   fsync with context pointer

int (*fsync)(int fd)
   fsync without context pointer

int (*access_p)(void *ctx, const char *path, int amode)
   access with context pointer

int (*access)(const char *path, int amode)
   access without context pointer

int (*truncate_p)(void *ctx, const char *path, off_t length)
   truncate with context pointer

int (*truncate)(const char *path, off_t length)
   truncate without context pointer

int (*ftruncate_p)(void *ctx, int fd, off_t length)
   ftruncate with context pointer

int (*ftruncate)(int fd, off_t length)
   ftruncate without context pointer

int (*utime_p)(void *ctx, const char *path, const struct utimbuf *times)
   utime with context pointer

int (*utime)(const char *path, const struct utimbuf *times)
   utime without context pointer

int (*tcsetattr_p)(void *ctx, int fd, int optional_actions, const struct termios *p)
   tcsetattr with context pointer

int (*tcsetattr)(int fd, int optional_actions, const struct termios *p)
   tcsetattr without context pointer

int (*tcgetattr_p)(void *ctx, int fd, struct termios *p)
   tcgetattr with context pointer

int (*tcgetattr)(int fd, struct termios *p)
   tcgetattr without context pointer
int (*tcgetattr)(int fd, struct termios *p)
tcgetattr without context pointer

int (*tcdrain_p)(void *ctx, int fd)
tcdrain with context pointer

int (*tcdrain)(int fd)
tcdrain without context pointer

int (*tcflush_p)(void *ctx, int fd, int select)
tcflush with context pointer

int (*tcflush)(int fd, int select)
tcflush without context pointer

int (*tcflow_p)(void *ctx, int fd, int action)
tcflow with context pointer

int (*tcflow)(int fd, int action)
tcflow without context pointer

pid_t (*tcgetsid_p)(void *ctx, int fd)
tcgetsid with context pointer

pid_t (*tcgetsid)(int fd)
tcgetsid without context pointer

int (*tcsendbreak_p)(void *ctx, int fd, int duration)
tcsendbreak with context pointer

int (*tcsendbreak)(int fd, int duration)
tcsendbreak without context pointer

esp_err_t (*start_select)(int nfds, fd_set *readfds, fd_set *writefds, fd_set *exceptfds, esp_vfs_select_sem_t sem, void **end_select_args)
start_select is called for setting up synchronous I/O multiplexing of the desired file descriptors in the given VFS

int (*socket_select)(int nfds, fd_set *readfds, fd_set *writefds, fd_set *errorfds, struct timeval *timeout)
socket select function for socket FDs with the functionality of POSIX select(); this should be set only for the socket VFS

void (*stop_socket_select)(void *sem)
called by VFS to interrupt the socket_select call when select is activated from a non-socket VFS driver; set only for the socket driver

void (*stop_socket_select_isr)(void *sem, BaseType_t *woken)
stop_socket_select which can be called from ISR; set only for the socket driver
void *(*get_socket_select_semaphore)(void)

end select is called to stop the I/O multiplexing and deinitialize the environment created by start_select for the given VFS

esp_err_t (*end_select)(void *end_select_args)

get_socket_select_semaphore returns semaphore allocated in the socket driver; set only for the socket driver

Macros

MAX_FDS

Maximum number of (global) file descriptors.

ESP_VFS_PATH_MAX

Maximum length of path prefix (not including zero terminator)

ESP_VFS_FLAG_DEFAULT

Default value of flags member in esp_vfs_t structure.

ESP_VFS_FLAG_CONTEXT_PTR

Flag which indicates that FS needs extra context pointer in syscalls.

Type Definitions

typedef int esp_vfs_id_t

Header File

• components/vfs/include/esp_vfs_dev.h

Functions

void esp_vfs_dev_uart_register (void)

add /dev/uart virtual filesystem driver

This function is called from startup code to enable serial output

void esp_vfs_dev_uart_set_rx_line_endings (esp_line_endings_t mode)

Set the line endings expected to be received on UART. This specifies the conversion between line endings received on UART and newlines (\n, LF) passed into stdin:

• ESP_LINE_ENDINGS_CRLF: convert CRLF to LF
• ESP_LINE_ENDINGS_CR: convert CR to LF
• ESP_LINE_ENDINGS_LF: no modification

Note: this function is not thread safe w.r.t. reading from UART

Parameters mode – line endings expected on UART
void \texttt{esp_vfs_dev_uart_set_tx_line_endings} (esp_line_endings_t mode)

Set the line endings to sent to UART.

This specifies the conversion between newlines (\texttt{\textbackslash n}, LF) on stdout and line endings sent over UART:

- ESP\_LINE\_ENDINGS\_CRLF: convert LF to CRLF
- ESP\_LINE\_ENDINGS\_CR: convert LF to CR
- ESP\_LINE\_ENDINGS\_LF: no modification

\textbf{Note:} this function is not thread safe w.r.t. writing to UART

\textbf{Parameters} \texttt{mode} – line endings to send to UART

\textbf{Parameters} \texttt{uart\_num} – the UART number, \texttt{mode} – line endings to send to UART

\textbf{Returns} \texttt{0} if successed, or \texttt{-1} when an error (specified by \texttt{errno}) have occurred.

int \texttt{esp_vfs_dev_uart_port_set_rx_line_endings} (int uart\_num, esp\_line\_endings\_t mode)

Set the line endings expected to be received on specified UART.

This specifies the conversion between line endings received on UART and newlines (\texttt{\textbackslash n}, LF) passed into stdin:

- ESP\_LINE\_ENDINGS\_CRLF: convert CRLF to LF
- ESP\_LINE\_ENDINGS\_CR: convert CR to LF
- ESP\_LINE\_ENDINGS\_LF: no modification

\textbf{Note:} this function is not thread safe w.r.t. reading from UART

\textbf{Parameters} \texttt{uart\_num} – the UART number, \texttt{mode} – line endings to send to UART

\textbf{Returns} \texttt{0} if successed, or \texttt{-1} when an error (specified by \texttt{errno}) have occurred.

int \texttt{esp_vfs_dev_uart_port_set_tx_line_endings} (int uart\_num, esp\_line\_endings\_t mode)

Set the line endings to sent to specified UART.

This specifies the conversion between newlines (\texttt{\textbackslash n}, LF) on stdout and line endings sent over UART:

- ESP\_LINE\_ENDINGS\_CRLF: convert LF to CRLF
- ESP\_LINE\_ENDINGS\_CR: convert LF to CR
- ESP\_LINE\_ENDINGS\_LF: no modification

\textbf{Note:} this function is not thread safe w.r.t. writing to UART

\textbf{Parameters} \texttt{uart\_num} – the UART number
**mode** – line endings to send to UART

**Returns** 0 if succeeded, or -1 when an error (specified by errno) have occurred.

```c
void esp_vfs_dev_uart_use_nonblocking(int uart_num)
```

set VFS to use simple functions for reading and writing UART Read is non-blocking, write is busy waiting until TX FIFO has enough space. These functions are used by default.

**Parameters** `uart_num` – UART peripheral number

```c
void esp_vfs_dev_uart_use_driver(int uart_num)
```

set VFS to use UART driver for reading and writing

**Note:** application must configure UART driver before calling these functions With these functions, read and write are blocking and interrupt-driven.

```c
void esp_vfs_dev_uart_use_driver(int uart_num)
```

**Parameters** `uart_num` – UART peripheral number

```c
void esp_vfs_usb_serial_jtag_use_driver(void)
```

set VFS to use USB-SERIAL-JTAG driver for reading and writing

**Note:** application must configure USB-SERIAL-JTAG driver before calling these functions With these functions, read and write are blocking and interrupt-driven.

```c
void esp_vfs_usb_serial_jtag_use_nonblocking(void)
```

set VFS to use simple functions for reading and writing UART Read is non-blocking, write is busy waiting until TX FIFO has enough space. These functions are used by default.

**Header File**

- `components/vfs/include/esp_vfs_eventfd.h`

**Functions**

```c
esp_err_t esp_vfs_eventfd_register(const esp_vfs_eventfd_config_t *config)
```

Registers the event vfs.

**Returns** ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered.

```c
esp_err_t esp_vfs_eventfd_unregister(void)
```

Unregisters the event vfs.

**Returns** ESP_OK if successful, ESP_ERR_INVALID_STATE if VFS for given prefix hasn’t been registered

```c
int eventfd(unsigned int initval, int flags)
```

**Structures**

```c
struct esp_vfs_eventfd_config_t
```

Eventfd vfs initialization settings.

**Public Members**

```c
size_t max_fds
```

The maximum number of eventfds supported
Chapter 2. API Reference

Macros

EFD_SUPPORT_ISR
ESP_VFS_EVENTD_CONFIG_DEFAULT()

2.9.10 Wear Levelling API

Overview

Most of flash memory and especially SPI flash that is used in ESP32 has a sector-based organization and also has a limited number of erase/modification cycles per memory sector. The wear levelling component helps to distribute wear and tear among sectors more evenly without requiring any attention from the user.

The wear levelling component provides API functions related to reading, writing, erasing, and memory mapping of data in external SPI flash through the partition component. The component also has higher-level API functions which work with the FAT filesystem defined in FAT filesystem.

The wear levelling component, together with the FAT FS component, uses FAT FS sectors of 4096 bytes, which is a standard size for flash memory. With this size, the component shows the best performance but needs additional memory in RAM.

To save internal memory, the component has two additional modes which both use sectors of 512 bytes:

• **Performance mode.** Erase sector operation data is stored in RAM, the sector is erased, and then data is copied back to flash memory. However, if a device is powered off for any reason, all 4096 bytes of data is lost.

• **Safety mode.** The data is first saved to flash memory, and after the sector is erased, the data is saved back. If a device is powered off, the data can be recovered as soon as the device boots up.

The default settings are as follows:

• Sector size is 512 bytes
• Performance mode

You can change the settings through the configuration menu.

The wear levelling component does not cache data in RAM. The write and erase functions modify flash directly, and flash contents are consistent when the function returns.

Wear Levelling access API functions

This is the set of API functions for working with data in flash:

• `wl_mount` - initializes the wear levelling module and mounts the specified partition
• `wlUnmount` - unmounts the partition and deinitializes the wear levelling module
• `wl_erase_range` - erases a range of addresses in flash
• `wl_write` - writes data to a partition
• `wl_read` - reads data from a partition
• `wl_size` - returns the size of available memory in bytes
• `wl_sector_size` - returns the size of one sector

As a rule, try to avoid using raw wear levelling functions and use filesystem-specific functions instead.

Memory Size

The memory size is calculated in the wear levelling module based on partition parameters. The module uses some sectors of flash for internal data.
See also

• **FAT Filesystem Support**
• **Partition Tables**

Application Example

An example that combines the wear levelling driver with the FATFS library is provided in the `storage/wear_levelling` directory. This example initializes the wear levelling driver, mounts FatFs partition, as well as writes and reads data from it using POSIX and C library APIs. See `storage/wear_levelling/README.md` for more information.

High-level API Reference

**Header Files**

• `fatfs/vfs/esp_vfs_fat.h`

High-level wear levelling functions `esp_vfsFat_spiflash_mount_rw_wl()`, `esp_vfsFat_spiflashUnmount_rw_wl()` and struct `esp_vfsFatMountConfig_t` are described in **FAT Filesystem Support**.

Mid-level API Reference

**Header File**

• `components/wear_levelling/include/wear_levelling.h`

**Functions**

`esp_err_t wlMount(const esp_partition_t *partition, wl_handle_t *out_handle)`

Mount WL for defined partition.

**Parameters**

• `partition` – that will be used for access
• `out_handle` – handle of the WL instance

**Returns**

• ESP_OK, if the allocation was successfully;
• ESP_ERR_INVALID_ARG, if WL allocation was unsuccessful;
• ESP_ERR_NO_MEM, if there was no memory to allocate WL components;

`esp_err_t wlUnmount(wl_handle_t handle)`

Unmount WL for defined partition.

**Parameters**

• `handle` – WL partition handle

**Returns**

• ESP_OK, if the operation completed successfully;
• or one of error codes from lower-level flash driver.

`esp_err_t wlEraseRange(wl_handle_t handle, size_t start_addr, size_t size)`

Erase part of the WL storage.

**Parameters**

• `handle` – WL handle that are related to the partition
• `start_addr` – Address where erase operation should start. Must be aligned to the result of function `wl_sector_size(…)`.
• `size` – Size of the range which should be erased, in bytes. Must be divisible by result of function `wl_sector_size(…)`.

**Returns**

• ESP_OK, if the range was erased successfully;
• ESP_ERR_INVALID_ARG, if iterator or dst are NULL;
• ESP_ERR_INVALID_SIZE, if erase would go out of bounds of the partition;
• or one of error codes from lower-level flash driver.

`esp_err_t wl_write (wl_handle_t handle, size_t dest_addr, const void *src, size_t size)`

Write data to the WL storage.

Before writing data to flash, corresponding region of flash needs to be erased. This can be done using `wl_erase_range` function.

**Note:** Prior to writing to WL storage, make sure it has been erased with `wl_erase_range` call.

**Parameters**

- `handle` - WL handle that are related to the partition
- `dest_addr` - Address where the data should be written, relative to the beginning of the partition.
- `src` - Pointer to the source buffer. Pointer must be non-NULL and buffer must be at least `size` bytes long.
- `size` - Size of data to be written, in bytes.

**Returns**

- ESP_OK, if data was written successfully;
- ESP_ERR_INVALID_ARG, if `dst_offset` exceeds partition size;
- ESP_ERR_INVALID_SIZE, if write would go out of bounds of the partition;
- or one of error codes from lower-level flash driver.

`esp_err_t wl_read (wl_handle_t handle, size_t src_addr, void *dest, size_t size)`

Read data from the WL storage.

**Parameters**

- `handle` - WL module instance that was initialized before
- `dest` - Pointer to the buffer where data should be stored. Pointer must be non-NULL and buffer must be at least `size` bytes long.
- `src_addr` - Address of the data to be read, relative to the beginning of the partition.
- `size` - Size of data to be read, in bytes.

**Returns**

- ESP_OK, if data was read successfully;
- ESP_ERR_INVALID_ARG, if `src_offset` exceeds partition size;
- ESP_ERR_INVALID_SIZE, if read would go out of bounds of the partition;
- or one of error codes from lower-level flash driver.

`size_t wl_size (wl_handle_t handle)`

Get size of the WL storage.

**Parameters**

- `handle` - WL module handle that was initialized before

**Returns**

usable size, in bytes

`size_t wl_sector_size (wl_handle_t handle)`

Get sector size of the WL instance.

**Parameters**

- `handle` - WL module handle that was initialized before

**Returns**

sector size, in bytes

**Macros**

WL_INVALID_HANDLE

**Type Definitions**
typedef int32_t wl_handle_t
wear levelling handle
Code examples for this API section are provided in the storage directory of ESP-IDF examples.

2.10 System API

2.10.1 App Image Format

An application image consists of the following structures:

1. The `esp_image_header_t` structure describes the mode of SPI flash and the count of memory segments.
2. The `esp_image_segment_header_t` structure describes each segment, its length, and its location in ESP32's memory, followed by the data with a length of `data_len`. The data offset for each segment in the image is calculated in the following way:

   - offset for 0 Segment = sizeof(`esp_image_header_t`) + sizeof(`esp_image_segment_header_t`).
   - offset for 1 Segment = offset for 0 Segment + length of 0 Segment + sizeof(`esp_image_segment_header_t`).
   - offset for 2 Segment = offset for 1 Segment + length of 1 Segment + sizeof(`esp_image_segment_header_t`).
   - ...

The count of each segment is defined in the `segment_count` field that is stored in `esp_image_header_t`. The count cannot be more than `ESP_IMAGE_MAX_SEGMENTS`.

To get the list of your image segments, please run the following command:

```
esptool.py --chip esp32 image_info build/app.bin
```

<table>
<thead>
<tr>
<th>Image version: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry point: 40080ea4</td>
</tr>
<tr>
<td>13 segments</td>
</tr>
<tr>
<td>Segment 1: len 0x13ce0 load 0x3f400020 file_offs 0x00000018 SOC_DROM</td>
</tr>
<tr>
<td>Segment 2: len 0x000000 load 0x3ff80000 file_offs 0x00000000 SOC_RTC_DRAM</td>
</tr>
<tr>
<td>Segment 3: len 0x000000 load 0x3ff80000 file_offs 0x00000000 SOC_RTC_DRAM</td>
</tr>
<tr>
<td>Segment 4: len 0x028e0 load 0x3ff80000 file_offs 0x00000018 DRAM</td>
</tr>
<tr>
<td>Segment 5: len 0x000000 load 0x3ff80000 file_offs 0x00000018 DRAM</td>
</tr>
<tr>
<td>Segment 6: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 7: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 8: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 9: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_IRAM</td>
</tr>
<tr>
<td>Segment 10: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_RTC_IRAM</td>
</tr>
<tr>
<td>Segment 11: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_RTC_IRAM</td>
</tr>
<tr>
<td>Segment 12: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_RTC_IRAM</td>
</tr>
<tr>
<td>Segment 13: len 0x000000 load 0x40080000 file_offs 0x00000000 SOC_RTC_IRAM</td>
</tr>
<tr>
<td>Checksum: e8 (valid)</td>
</tr>
<tr>
<td>Validation Hash: 407089ca0eae2bbf83b4120979d3354b1c938a49c7a0c997f240474ef2e76b_...</td>
</tr>
</tbody>
</table>

You can also see the information on segments in the ESP-IDF logs while your application is booting:

```
I (443) esp_image: segment 0: paddr=0x00000000 vaddr=0x3f400020 size=0x13ce0 ...
I (489) esp_image: segment 1: paddr=0x00000000 vaddr=0x3f400020 size=0x13ce0 ...
```

(continues on next page)
I (530) esp_image: segment 2: paddr=0x00033d10 vaddr=0x3ff80000 size=0x000000 { 0}-----
  load
I (571) esp_image: segment 3: paddr=0x00033d18 vaddr=0x3ff80000 size=0x0028e0 { 0}-----
  load
I (612) esp_image: segment 4: paddr=0x00033d60 vaddr=0x40080000 size=0x000000 { 0}-----
  load
I (654) esp_image: segment 5: paddr=0x00033d68 vaddr=0x40080400 size=0x009600 { 0}-----
  load
I (737) esp_image: segment 7: paddr=0x00040018 vaddr=0x400d0018 size=0x62e4c { 405068}map
I (847) esp_image: segment 8: paddr=0x000a2e6c vaddr=0x40089a00 size=0x06cec { 27884}load
I (888) esp_image: segment 9: paddr=0x000a9b60 vaddr=0x400c0000 size=0x000000 { 0}-----
  load
I (929) esp_image: segment 10: paddr=0x000a9b68 vaddr=0x50000000 size=0x000004 ( 4)-----
  load
I (971) esp_image: segment 11: paddr=0x000a9b74 vaddr=0x50000004 size=0x000000 ( 0)-----
  load
I (1012) esp_image: segment 12: paddr=0x000a9b7c vaddr=0x50000004 size=0x000000 { 0}-----
  load

For more details on the type of memory segments and their address ranges, see ESP32 Technical Reference Manual > System and Memory > Embedded Memory [PDF].

3. The image has a single checksum byte after the last segment. This byte is written on a sixteen byte padded boundary, so the application image might need padding.
4. If the hash_appended field from esp_image_header_t is set then a SHA256 checksum will be appended. The value of the SHA256 hash is calculated on the range from the first byte and up to this field. The length of this field is 32 bytes.
5. If the option CONFIG_SECURE_SIGNED_APPS_SCHEME is set to ECDSA then the application image will have an additional 68 bytes for an ECDSA signature, which includes:
   • version word (4 bytes),
   • signature data (64 bytes).
6. If the option CONFIG_SECURE_SIGNED_APPS_SCHEME is set to RSA or ECDSA (V2) then the application image will have an additional signature sector of 4K size. For more details on the format of this signature sector, please refer to Signature Block Format.

**Application Description**

The DROM segment of the application binary starts with the esp_app_desc_t structure which carries specific fields describing the application:

- **magic_word** - the magic word for the esp_app_desc structure.
- **secure_version** - see Anti-rollback.
- **version** - see App version. *
- **project_name** is filled from PROJECT_NAME. *
- **time and date** - compile time and date.
- **idf_ver** - version of ESP-IDF. *
- **app_elf_sha256** - contains sha256 hash for the application ELF file.

* - The maximum length is 32 characters, including null-termination character. For example, if the length of PROJECT_NAME exceeds 31 characters, the excess characters will be disregarded.

This structure is useful for identification of images uploaded via Over-the-Air (OTA) updates because it has a fixed offset = sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t). As soon as a device receives the first fragment containing this structure, it has all the information to determine whether the update should be continued with or not.
To obtain the `esp_app_desc_t` structure for the currently running application, use `esp_app_get_description()`.
To obtain the `esp_app_desc_t` structure for another OTA partition, use `esp_ota_get_partition_description()`.

Adding a Custom Structure to an Application

Users also have the opportunity to have similar structure with a fixed offset relative to the beginning of the image. The following pattern can be used to add a custom structure to your image:

```c
const __attribute__((section(".rodata_custom_desc"))) esp_custom_app_desc_t custom_app_desc = { ... }
```

Offset for custom structure is `sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t) + sizeof(esp_app_desc_t)`.
To guarantee that the custom structure is located in the image even if it is not used, you need to add `target_link_libraries(${COMPONENT_TARGET} "-u custom_app_desc")` into CMakeLists.txt.

API Reference

Header File

- components/bootloader_support/include/esp_app_format.h

Structures

`struct esp_image_header_t`

Main header of binary image.

Public Members

`uint8_t magic`
Magic word ESP_IMAGE_HEADER_MAGIC

`uint8_t segment_count`
Count of memory segments

`uint8_t spi_mode`
flash read mode (esp_image_spi_mode_t as uint8_t)

`uint8_t spi_speed`
flash frequency (esp_image_spi_freq_t as uint8_t)

`uint8_t spi_size`
flash chip size (esp_image_flash_size_t as uint8_t)

`uint32_t entry_addr`
Entry address
uint8_t wp_pin
    WP pin when SPI pins set via efuse (read by ROM bootloader, the IDF bootloader uses software to configure the WP pin and sets this field to 0xEE=disabled)

uint8_t spi_pin_drv[3]
    Drive settings for the SPI flash pins (read by ROM bootloader)

*esp_chip_id_t* chip_id
    Chip identification number

uint8_t min_chip_rev
    Minimal chip revision supported by image. After the Major and Minor revision eFuses were introduced into the chips, this field is no longer used. But for compatibility reasons, we keep this field and the data in it. Use min_chip_rev_full instead. The software interprets this as a Major version for most of the chips and as a Minor version for the ESP32-C3.

uint16_t min_chip_rev_full
    Minimal chip revision supported by image, in format: major * 100 + minor

uint16_t max_chip_rev_full
    Maximal chip revision supported by image, in format: major * 100 + minor

uint8_t reserved[4]
    Reserved bytes in additional header space, currently unused

uint8_t hash_appended
    If 1, a SHA256 digest “simple hash” (of the entire image) is appended after the checksum. Included in image length. This digest is separate to secure boot and only used for detecting corruption. For secure boot signed images, the signature is appended after this (and the simple hash is included in the signed data).

struct esp_image_segment_header_t
    Header of binary image segment.

**Public Members**

uint32_t load_addr
    Address of segment

uint32_t data_len
    Length of data

**Macros**

ESP_IMAGE_HEADER_MAGIC
    The magic word for the esp_image_header_t structure.

ESP_IMAGE_MAX_SEGMENTS
    Max count of segments in the image.
Enumerations

enum esp_chip_id_t
    ESP chip ID.

Values:

enumerator ESP_CHIP_ID_ESP32
    chip ID: ESP32

enumerator ESP_CHIP_ID_ESP32S2
    chip ID: ESP32-S2

enumerator ESP_CHIP_ID_ESP32C3
    chip ID: ESP32-C3

enumerator ESP_CHIP_ID_ESP32S3
    chip ID: ESP32-S3

enumerator ESP_CHIP_ID_ESP32C2
    chip ID: ESP32-C2

enumerator ESP_CHIP_ID_ESP32C6
    chip ID: ESP32-C6

enumerator ESP_CHIP_ID_ESP32H2
    chip ID: ESP32-H2

enumerator ESP_CHIP_ID_INVALID
    Invalid chip ID (we defined it to make sure the esp_chip_id_t is 2 bytes size)

denum esp_image_spi_mode_t
    SPI flash mode, used in esp_image_header_t.

Values:

enumerator ESP_IMAGE_SPI_MODE_QIO
    SPI mode QIO

enumerator ESP_IMAGE_SPI_MODE_QOUT
    SPI mode QOUT

enumerator ESP_IMAGE_SPI_MODE_DIO
    SPI mode DIO

enumerator ESP_IMAGE_SPI_MODE_DOUT
    SPI mode DOUT

enumerator ESP_IMAGE_SPI_MODE_FAST_READ
    SPI mode FAST_READ
enumerator **ESP_IMAGE_SPI_MODE_SLOW_READ**
    SPI mode SLOW_READ

define **SPImodeSLOW_READ**

enum **esp_image_spi_freq_t**
    SPI flash clock division factor.

*Values:*

enumerator **ESP_IMAGE_SPI_SPEED_DIV_2**
    The SPI flash clock frequency is divided by 2 of the clock source

enumerator **ESP_IMAGE_SPI_SPEED_DIV_3**
    The SPI flash clock frequency is divided by 3 of the clock source

enumerator **ESP_IMAGE_SPI_SPEED_DIV_4**
    The SPI flash clock frequency is divided by 4 of the clock source

enumerator **ESP_IMAGE_SPI_SPEED_DIV_1**
    The SPI flash clock frequency equals to the clock source

enum **esp_image_flash_size_t**
    Supported SPI flash sizes.

*Values:*

enumerator **ESP_IMAGE_FLASH_SIZE_1MB**
    SPI flash size 1 MB

enumerator **ESP_IMAGE_FLASH_SIZE_2MB**
    SPI flash size 2 MB

enumerator **ESP_IMAGE_FLASH_SIZE_4MB**
    SPI flash size 4 MB

enumerator **ESP_IMAGE_FLASH_SIZE_8MB**
    SPI flash size 8 MB

enumerator **ESP_IMAGE_FLASH_SIZE_16MB**
    SPI flash size 16 MB

enumerator **ESP_IMAGE_FLASH_SIZE_32MB**
    SPI flash size 32 MB

enumerator **ESP_IMAGE_FLASH_SIZE_64MB**
    SPI flash size 64 MB

enumerator **ESP_IMAGE_FLASH_SIZE_128MB**
    SPI flash size 128 MB

enumerator **ESP_IMAGE_FLASH_SIZE_MAX**
    SPI flash size MAX
Chapter 2. API Reference

2.10.2 Application Level Tracing

Overview

IDF provides a useful feature for program behavior analysis called Application Level Tracing. The feature can be enabled in menuconfig and allows transfer of arbitrary data between the host and ESP32 via JTAG interface with minimal overhead on program execution. Developers can use this library to send application specific state of execution to the host and receive commands or other type of information in the opposite direction at runtime. The main use cases of this library are:

1. Collecting application specific data, see Application Specific Tracing
2. Lightweight logging to the host, see Logging to Host
3. System behaviour analysis, see System Behavior Analysis with SEGGER SystemView

API Reference

Header File

- components/app_trace/include/esp_app_trace.h

Functions

**esp_err_t esp_apptrace_init** (void)

Initializes application tracing module.

**Note:** Should be called before any esp_apptrace_xxx call.

**Returns** ESP_OK on success, otherwise see esp_err_t

**void esp_apptrace_down_buffer_config** (uint8_t *buf, uint32_t size)

Configures down buffer.

**Note:** Needs to be called before attempting to receive any data using esp_apptrace_down_buffer_get and esp_apptrace_read. This function does not protect internal data by lock.

**Parameters**

- **buf** – Address of buffer to use for down channel (host to target) data.
- **size** – Size of the buffer.

uint8_t * **esp_apptrace_buffer_get** (esp_apptrace_dest_t dest, uint32_t size, uint32_t tmo)

Allocates buffer for trace data. Once the data in the buffer is ready to be sent, esp_apptrace_buffer_put must be called to indicate it.

**Parameters**

- **dest** – Indicates HW interface to send data.
- **size** – Size of data to write to trace buffer.
- **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** non-NULL on success, otherwise NULL.

**esp_err_t esp_apptrace_buffer_put** (esp_apptrace_dest_t dest, uint8_t *ptr, uint32_t tmo)

Indicates that the data in the buffer is ready to be sent. This function is a counterpart of and must be preceded by esp_apptrace_buffer_get.

**Parameters**

- **dest** – Indicates HW interface to send data. Should be identical to the same parameter in call to esp_apptrace_buffer_get.
• **ptr** – Address of trace buffer to release. Should be the value returned by call to esp_apptrace_buffer_get.
  • **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** ESP_OK on success, otherwise see esp_err_t

*esp_err_t esp_apptrace_write*( **esp_apptrace_dest_t** dest, const void *data, uint32_t size, uint32_t tmo)

Writes data to trace buffer.

**Parameters**
  • **dest** – Indicates HW interface to send data.
  • **data** – Address of data to write to trace buffer.
  • **size** – Size of data to write to trace buffer.
  • **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** ESP_OK on success, otherwise see esp_err_t

*int esp_apptrace_vprintf_to*( **esp_apptrace_dest_t** dest, uint32_t tmo, const char *fmt, va_list ap)

vprintf-like function to send log messages to host via specified HW interface.

**Parameters**
  • **dest** – Indicates HW interface to send data.
  • **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.
  • **fmt** – Address of format string.
  • **ap** – List of arguments.

**Returns** Number of bytes written.

*int esp_apptrace_vprintf*( const char *fmt, va_list ap)

vprintf-like function to send log messages to host.

**Parameters**
  • **fmt** – Address of format string.
  • **ap** – List of arguments.

**Returns** Number of bytes written.

*esp_err_t esp_apptrace_flush*( **esp_apptrace_dest_t** dest, uint32_t tmo)

Flushes remaining data in trace buffer to host.

**Parameters**
  • **dest** – Indicates HW interface to flush data on.
  • **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** ESP_OK on success, otherwise see esp_err_t

*esp_err_t esp_apptrace_flush_nolock*( **esp_apptrace_dest_t** dest, uint32_t min_sz, uint32_t tmo)

Flushes remaining data in trace buffer to host without locking internal data. This is a special version of esp_apptrace_flush which should be called from panic handler.

**Parameters**
  • **dest** – Indicates HW interface to flush data on.
  • **min_sz** – Threshold for flushing data. If current filling level is above this value, data will be flushed. TRAX destinations only.
  • **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** ESP_OK on success, otherwise see esp_err_t

*esp_err_t esp_apptrace_read*( **esp_apptrace_dest_t** dest, void *data, uint32_t *size, uint32_t tmo)

Reads host data from trace buffer.

**Parameters**
  • **dest** – Indicates HW interface to read the data on.
  • **data** – Address of buffer to put data from trace buffer.
• **size** – Pointer to store size of read data. Before call to this function pointed memory must hold requested size of data.
• **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** ESP_OK on success, otherwise see esp_err_t

```c
uint8_t* esp_apptrace_down_buffer_get (esp_apptrace_dest_t dest, uint32_t* size, uint32_t tmo)
```

Retrieves incoming data buffer if any. Once data in the buffer is processed, esp_apptrace_down_buffer_put must be called to indicate it.

**Parameters**

• **dest** – Indicates HW interface to receive data.
• **size** – Address to store size of available data in down buffer. Must be initialized with requested value.
• **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** non-NULL on success, otherwise NULL.

```c
esp_err_t esp_apptrace_down_buffer_put (esp_apptrace_dest_t dest, uint8_t* ptr, uint32_t tmo)
```

Indicates that the data in the down buffer is processed. This function is a counterpart of and must be preceded by esp_apptrace_down_buffer_get.

**Parameters**

• **dest** – Indicates HW interface to receive data. Should be identical to the same parameter in call to esp_apptrace_down_buffer_get.
• **ptr** – Address of trace buffer to release. Should be the value returned by call to esp_apptrace_down_buffer_get.
• **tmo** – Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

**Returns** ESP_OK on success, otherwise see esp_err_t

```c
bool esp_apptrace_host_is_connected (esp_apptrace_dest_t dest)
```

Checks whether host is connected.

**Parameters** **dest** – Indicates HW interface to use.

**Returns** true if host is connected, otherwise false

```c
void *esp_apptrace_fopen (esp_apptrace_dest_t dest, const char* path, const char *mode)
```

Opens file on host. This function has the same semantic as ‘fopen’ except for the first argument.

**Parameters**

• **dest** – Indicates HW interface to use.
• **path** – Path to file.
• **mode** – Mode string. See fopen for details.

**Returns** non zero file handle on success, otherwise 0

```c
int esp_apptrace_fclose (esp_apptrace_dest_t dest, void *stream)
```

Closes file on host. This function has the same semantic as ‘fclose’ except for the first argument.

**Parameters**

• **dest** – Indicates HW interface to use.
• **stream** – File handle returned by esp_apptrace_fopen.

**Returns** Zero on success, otherwise non-zero. See fclose for details.

```c
size_t esp_apptrace_fwrite (esp_apptrace_dest_t dest, const void *ptr, size_t size, size_t nmemb, void *stream)
```

Writes to file on host. This function has the same semantic as ‘fwrite’ except for the first argument.

**Parameters**

• **dest** – Indicates HW interface to use.
• **ptr** – Address of data to write.
• **size** – Size of an item.
• **nmemb** – Number of items to write.
• stream – File handle returned by esp_apptrace_fopen.

Returns  Number of written items. See fwrite for details.

size_t esp_apptrace_fread (esp_apptrace_dest_t dest, void *ptr, size_t size, size_t nmemb, void *stream)

Read file on host. This function has the same semantic as ‘fread’ except for the first argument.

Parameters
  • dest – Indicates HW interface to use.
  • ptr – Address to store read data.
  • size – Size of an item.
  • nmemb – Number of items to read.
  • stream – File handle returned by esp_apptrace_fopen.

Returns  Number of read items. See fread for details.

int esp_apptrace_fseek (esp_apptrace_dest_t dest, void *stream, long offset, int whence)

Set position indicator in file on host. This function has the same semantic as ‘fseek’ except for the first argument.

Parameters
  • dest – Indicates HW interface to use.
  • stream – File handle returned by esp_apptrace_fopen.
  • offset – Offset. See fseek for details.
  • whence – Position in file. See fseek for details.

Returns  Zero on success, otherwise non-zero. See fseek for details.

int esp_apptrace_ftell (esp_apptrace_dest_t dest, void *stream)

Get current position indicator for file on host. This function has the same semantic as ‘ftell’ except for the first argument.

Parameters
  • dest – Indicates HW interface to use.
  • stream – File handle returned by esp_apptrace_fopen.

Returns  Current position in file. See ftell for details.

int esp_apptrace_fstop (esp_apptrace_dest_t dest)

Indicates to the host that all file operations are complete. This function should be called after all file operations are finished and indicate to the host that it can perform cleanup operations (close open files etc.).

Parameters dest – Indicates HW interface to use.

Returns  ESP_OK on success, otherwise see esp_err_t

void esp_gcov_dump (void)

Triggers gcov info dump. This function waits for the host to connect to target before dumping data.

Enumerations

enum esp_apptrace_dest_t

Application trace data destinations bits.

Values:

enumerator ESP_APTRACE_DEST_JTAG
  JTAG destination.

enumerator ESP_APTRACE_DEST_TRAX
  xxx_TRAX name is obsolete, use more common xxx_JTAG

enumerator ESP_APTRACE_DEST_UART
  UART destination.
Chapter 2. API Reference

enumerator **ESP_APPTRACE_DEST_MAX**

enumerator **ESP_APPTRACE_DEST_NUM**

Header File
- components/app_trace/include/esp_sysview_trace.h

Functions

static inline **esp_err_t esp_sysview_flush(uint32_t tmo)**
Flushes remaining data in SystemView trace buffer to host.

Parameters
- **tmo** - Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

Returns **ESP_OK**.

int **esp_sysview_vprintf(const char* format, va_list args)**
vprintf-like function to sent log messages to the host.

Parameters
- **format** - Address of format string.
- **args** - List of arguments.

Returns **Number of bytes written.**

**esp_err_t esp_sysview_heap_trace_start(uint32_t tmo)**
Starts SystemView heap tracing.

Parameters
- **tmo** - Timeout (in us) to wait for the host to be connected. Use -1 to wait forever.

Returns **ESP_OK on success, ESP_ERR_TIMEOUT if operation has been timed out.**

**esp_err_t esp_sysview_heap_trace_stop(void)**
Stops SystemView heap tracing.

Returns **ESP_OK.**

void **esp_sysview_heap_trace_alloc(void *addr, uint32_t size, const void *callers)**
Sends heap allocation event to the host.

Parameters
- **addr** - Address of allocated block.
- **size** - Size of allocated block.
- **callers** - Pointer to array with callstack addresses. Array size must be CONFIG_HEAP_TRACING_STACK_DEPTH.

void **esp_sysview_heap_trace_free(void *addr, const void *callers)**
Sends heap de-allocation event to the host.

Parameters
- **addr** - Address of de-allocated block.
- **callers** - Pointer to array with callstack addresses. Array size must be CONFIG_HEAP_TRACING_STACK_DEPTH.

2.10.3 Call function with external stack

Overview

A given function can be executed with a user allocated stack space which is independent of current task stack, this mechanism can be used to save stack space wasted by tasks which call a common function with intensive stack usage such as printf. The given function can be called inside the shared stack space which is a callback function deferred by calling **esp_execute_shared_stack_function()**, passing that function as parameter.
Usage

`esp_execute_shared_stack_function()` takes four arguments:

- a mutex object allocated by the caller, which is used to protect if the same function shares its allocated stack
- a pointer to the top of stack used for that function
- the size of stack in bytes
- a pointer to the shared stack function

The user defined function will be deferred as a callback and can be called using the user allocated space without taking space from current task stack.

The usage may look like the code below:

```c
void external_stack_function(void)
{
    printf("Executing this printf from external stack! \n");
}

// Let's suppose we want to call printf using a separated stack space
// allowing the app to reduce its stack size.
void app_main()
{
    // Allocate a stack buffer, from heap or as a static form:
    portSTACK_TYPE *shared_stack = malloc(8192 * sizeof(portSTACK_TYPE));
    assert(shared_stack != NULL);

    // Allocate a mutex to protect its usage:
    SemaphoreHandle_t printf_lock = xSemaphoreCreateMutex();
    assert(printf_lock != NULL);

    // Call the desired function using the macro helper:
    esp_execute_shared_stack_function(printf_lock, shared_stack, 8192, external_stack_function);

    vSemaphoreDelete(printf_lock);
    free(shared_stack);
}
```

API Reference

Header File

- components/esp_system/include/esp_expression_with_stack.h

Functions

void `esp_execute_shared_stack_function`(<SemaphoreHandle_t lock, void *stack, size_t stack_size, shared_stack_function function>)

Calls user defined shared stack space function.

Note: if either lock, stack or stack size is invalid, the expression will be called using the current stack.

Parameters

- lock - Mutex object to protect in case of shared stack
- stack - Pointer to user allocated stack
- stack_size - Size of current stack in bytes
- function - Pointer to the shared stack function to be executed
Chapter 2. API Reference

Macros

ESP_EXECUTE_EXPRESSION_WITH_STACK (lock, stack, stack_size, expression)

Type Definitions

typedef void (*shared_stack_function)(void)

2.10.4 Chip Revision

Overview

A new chip versioning logic was introduced in new chips. Chips have several eFuse version fields:

- Major wafer version (WAFER_VERSION_MAJOR eFuse)
- Minor wafer version (WAFER_VERSION_MINOR eFuse)
- Ignore maximal revision (DISABLE_WAFER_VERSION_MAJOR eFuse)

The new versioning logic is being introduced to distinguish changes in chips as breaking changes and non-breaking changes. Chips with non-breaking changes can run the same software as the previous chip. The previous chip means that the major version is the same.

If the newly released chip does not have breaking changes, that means it can run the same software as the previous chip, then in that chip we keep the same major version and increment the minor version by 1. Otherwise, if there is a breaking change in the newly released chip, meaning it can not run the same software as the previous chip, then in that chip we increase the major version and set the minor version to 0.

The software supports a number of revisions, from the minimum to the maximum (the min/max configs are defined in Kconfig). If the software is unaware of a new chip (when the chip version is out of range), it will refuse to run on it unless the Ignore maximum revision restrictions bit is set. This bit removes the upper revision limit.

Minimum versions limits the software to only run on a chip revision that is high enough to support some features. Maximum version is the maximum version that is well-supported by current software. When chip version is above the maximum version, software will reject to boot, because it may not work on, or work with risk on the chip.

Adding the major and minor wafer revision make the versioning logic is branchable.

Note: The previous versioning logic was based on a single eFuse version field (WAFER_VERSION). This approach makes it impossible to mark chips as breaking or non-breaking changes, and the versioning logic becomes linear.

Using the branched versioning scheme allows us to support more chips in the software without updating the software when a new released compatible chip is used. Thus, the software will be compatible with as many new chip revisions as possible. If the software is no longer compatible with a new chip with breaking changes, the software will abort.

Revisions

<table>
<thead>
<tr>
<th>ECO</th>
<th>Revision (Major.Minor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECO0</td>
<td>v0.0</td>
</tr>
<tr>
<td>ECO1</td>
<td>v1.0</td>
</tr>
<tr>
<td>ECO1.1</td>
<td>v1.1</td>
</tr>
<tr>
<td>ECO2</td>
<td>v2.0</td>
</tr>
<tr>
<td>ECO3</td>
<td>v3.0</td>
</tr>
<tr>
<td>ECO4</td>
<td>v3.1</td>
</tr>
</tbody>
</table>

Chip Revision vX.Y, where:

- X means Major wafer version. If it is changed, it means that the current software version is not compatible with this released chip and the software must be updated to use this chip.
Y means Minor wafer version. If it is changed that means the current software version is compatible with the released chip, and there is no need to update the software.

The vX.Y chip version format will be used further instead of the ECO number.

**Representing Revision Requirement Of A Binary Image**

The 2nd stage bootloader and the application binary images have the `esp_image_header_t` header, which stores the revision numbers of the chip on which the software can be run. This header has 3 fields related to revisions:

- **min_chip_rev** - Minimal chip MAJOR revision required by image (but for ESP32-C3 it is MINOR revision). Its value is determined by `CONFIG_ESP32_REV_MIN`.
- **min_chip_rev_full** - Minimal chip MINOR revision required by image in format: `major * 100 + minor`. Its value is determined by `CONFIG_ESP32_REV_MIN`.
- **max_chip_rev_full** - Maximal chip revision required by image in format: `major * 100 + minor`. Its value is determined by `CONFIG_ESP32_REV_MAX_FULL`. It can not be changed by user. Only Espressif can change it when a new version will be supported in IDF.

**Chip Revision APIs**

These APIs helps to get chip revision from eFuses:

- `efuse_hal_chip_revision()`. It returns revision in the `major * 100 + minor` format.
- `efuse_hal_get_major_chip_version()`. It returns Major revision.
- `efuse_hal_get_minor_chip_version()`. It returns Minor revision.

The following Kconfig definitions (in `major * 100 + minor` format) that can help add the chip revision dependency to the code:

- `CONFIG_ESP32_REV_MIN_FULL`
- `CONFIG_ESP_REV_MIN_FULL`
- `CONFIG_ESP32_REV_MAX_FULL`
- `CONFIG_ESP_REV_MAX_FULL`

**Maximal And Minimal Revision Restrictions**

The order for checking the minimum and maximum revisions:

1. The 1st stage bootloader (ROM bootloader) does not check minimal and maximal revision fields from `esp_image_header_t` before running the 2nd stage bootloader.
2. The 2nd stage bootloader checks at the initialization phase that bootloader itself can be launched on the chip of this revision. It extracts the minimum revision from the header of the bootloader image and checks against the chip revision from eFuses. If the chip revision is less than the minimum revision, the bootloader refuses to boot up and aborts. The maximum revision is not checked at this phase.
3. Then the 2nd stage bootloader checks the revision requirements of the application. It extracts the minimum and maximum revisions from the header of the application image and checks against the chip revision from eFuses. If the chip revision is less than the minimum revision or higher than the maximum revision, the bootloader refuses to boot up and aborts. However, if the Ignore maximal revision bit is set, the maximum revision constraint can be ignored. The ignore bit is set by the customer themself when there is confirmation that the software is able to work with this chip revision.
4. Further, at the OTA update stage, the running application checks if the new software matches the chip revision. It extracts the minimum and maximum revisions from the header of the new application image and checks against the chip revision from eFuses. It checks for revision matching in the same way that the bootloader does, so that the chip revision is between the min and max revisions (logic of ignoring max revision also applies).
Chapter 2. API Reference

Issues

1. If the 2nd stage bootloader is run on the chip revision < minimum revision shown in the image, a reboot occurs. The following message will be printed:

   **Image requires chip rev >= v3.0, but chip is v1.0**

To resolve this issue:

   - make sure the chip you are using is suitable for the software, or use a chip with the required minimum revision or higher.
   - update the software with `CONFIG_ESP32_REV_MIN` to get it <= the revision of chip being used

2. If application does not match minimal and maximal chip revisions, a reboot occurs. The following message will be printed:

   **Image requires chip rev <= v2.99, but chip is v3.0**

To resolve this issue, update the IDF to a newer version that supports the used chip (`CONFIG_ESP32_REV_MAX_FULL`). Another way to fix this is to set the `Ignore maximal revision` bit in eFuse or use a chip that is suitable for the software.

Backward Compatible With Bootloaders Built By Older ESP-IDF Versions

The old bootloaders (IDF < 5.0) do not know about Major and Minor wafer version eFuses. They use one single eFuse for this wafer version.

The old bootloaders did not read the minor wafer version eFuse, the major version can be only <= 3. So it means that the old bootloader can detect correctly only chip version in range v0.0 - v3.0, where the minor version is always 0.

Please check the chip version using `esptool chip_id` command.

API Reference

**Header File**

- components/hal/include/hal/efuse_hal.h

**Functions**

```c
void efuse_hal_get_mac (uint8_t*mac)
get factory mac address

uint32_t efuse_hal_chip_revision (void)
Returns chip version.

   **Returns** Chip version in format: Major * 100 + Minor

uint32_t efuse_hal_blk_version (void)
Return block version.

   **Returns** Block version in format: Major * 100 + Minor

bool efuse_hal_flash_encryption_enabled (void)
Is flash encryption currently enabled in hardware?

   Flash encryption is enabled if the FLASH_CRYPT_CNT eFuse has an odd number of bits set.

   **Returns** true if flash encryption is enabled.

uint32_t efuse_hal_get_major_chip_version (void)
Returns major chip version.
```
### 2.10.5 Console

ESP-IDF provides console component, which includes building blocks needed to develop an interactive console over serial port. This component includes the following features:

- Line editing, provided by `linenoise` library. This includes handling of backspace and arrow keys, scrolling through command history, command auto-completion, and argument hints.
- Splitting of command line into arguments.
- Argument parsing, provided by `argtable3` library. This library includes APIs used for parsing GNU style command line arguments.
- Functions for registration and dispatching of commands.
- Functions to establish a basic REPL (Read-Evaluate-Print-Loop) environment.

**Note:** These features can be used together or independently. For example, it is possible to use line editing and command registration features, but use `getopt` or custom code for argument parsing, instead of `argtable3`. Likewise, it is possible to use simpler means of command input (such as `fgets`) together with the rest of the means for command splitting and argument parsing.

#### Line editing

Line editing feature lets users compose commands by typing them, erasing symbols using the ‘backspace’ key, navigating within the command using the left/right keys, navigating to previously typed commands using the up/down keys, and performing auto-completion using the ‘tab’ key.

**Note:** This feature relies on ANSI escape sequence support in the terminal application. As such, serial monitors which display raw UART data cannot be used together with the line editing library. If you see `[6n` or similar escape sequence when running `system/console` example instead of a command prompt (e.g. `esp>`), it means that the serial monitor does not support escape sequences. Programs which are known to work are GNU screen, minicom, and esp-idf-monitor (which can be invoked using `idf.py monitor` from project directory).

Here is an overview of functions provided by `linenoise` library.

**Configuration**  Linenoise library does not need explicit initialization. However, some configuration defaults may need to be changed before invoking the main line editing function.

```c
void linenoiseClearScreen()
```

Clear terminal screen using an escape sequence and position the cursor at the top left corner.

```c
void linenoiseSetMultiLine()
```

Switch between single line and multi line editing modes. In single line mode, if the length of the command exceeds the width of the terminal, the command text is scrolled within the line to show the end of the text. In this case the beginning of the text is hidden. Single line mode needs less data to be sent to refresh screen on each key press, so exhibits less glitching compared to the multi line mode. On the flip side, editing commands and copying command text from terminal in single line mode is harder. Default is single line mode.

```c
bool linenoiseAllowEmpty()
```

Set whether linenoise library will return a zero-length string (if `true`) or NULL (if `false`) for empty lines. By default, zero-length strings are returned.
linenoiseSetMaxLineLen()

Set maximum length of the line for linenoise library. Default length is 4096 bytes. The default value can be updated to optimize RAM memory usage.

Main loop   linenoise()

In most cases, console applications have some form of read/eval loop. linenoise() is the single function which handles user’s key presses and returns the completed line once the ‘enter’ key is pressed. As such, it handles the ‘read’ part of the loop.

linenoiseFree()

This function must be called to release the command line buffer obtained from linenoise() function.

Hints and completions   linenoiseSetCompletionCallback()

When the user presses the ‘tab’ key, linenoise library invokes the completion callback. The callback should inspect the contents of the command typed so far and provide a list of possible completions using calls to linenoiseAddCompletion() function. linenoiseSetCompletionCallback() function should be called to register this completion callback, if completion feature is desired.

core console provides a ready made function to provide completions for registered commands, esp_console_get_completion() (see below).

linenoiseAddCompletion()

Function to be called by completion callback to inform the library about possible completions of the currently typed command.

linenoiseSetHintsCallback()

Whenever user input changes, linenoise invokes the hints callback. This callback can inspect the command line typed so far, and provide a string with hints (which can include list of command arguments, for example). The library then displays the hint text on the same line where editing happens, possibly with a different color.

linenoiseSetFreeHintsCallback()

If the hint string returned by hints callback is dynamically allocated or needs to be otherwise recycled, the function which performs such cleanup should be registered via linenoiseSetFreeHintsCallback().

History   linenoiseHistorySetMaxLen()

This function sets the number of most recently typed commands to be kept in memory. Users can navigate the history using the up/down arrows keys.

linenoiseHistoryAdd()

Linenoise does not automatically add commands to history. Instead, applications need to call this function to add command strings to the history.

linenoiseHistorySave()

Function saves command history from RAM to a text file, for example on an SD card or on a filesystem in flash memory.

linenoiseHistoryLoad()

Counterpart to linenoiseHistorySave(), loads history from a file.

linenoiseHistoryFree()

Releases memory used to store command history. Call this function when done working with linenoise library.
Splitting of command line into arguments

console component provides esp_console_split_argv() function to split command line string into arguments. The function returns the number of arguments found (argc) and fills an array of pointers which can be passed as argv argument to any function which accepts arguments in argc, argv format.

The command line is split into arguments according to the following rules:

- Arguments are separated by spaces
- If spaces within arguments are required, they can be escaped using \ (backslash) character.
- Other escape sequences which are recognized are \\\n  (which produces literal backslash) and ", which produces a double quote.
- Arguments can be quoted using double quotes. Quotes may appear only in the beginning and at the end of the argument. Quotes within the argument must be escaped as mentioned above. Quotes surrounding the argument are stripped by esp_console_split_argv function.

Examples:

- abc def 1 20 .3 ⟷ [ abc, def, 1, 20, .3 ]
- abc "123 456" def ⟷ [ abc, 123 456, def ]
- `a\ b\\c" ⟷ [ a b\c ]`

Argument parsing

For argument parsing, console component includes argtable3 library. Please see tutorial for an introduction to argtable3. Github repository also includes examples.

Command registration and dispatching

console component includes utility functions which handle registration of commands, matching commands typed by the user to registered ones, and calling these commands with the arguments given on the command line.

Application first initializes command registration module using a call to esp_console_init(), and calls esp_console_cmd_register() function to register command handlers.

For each command, application provides the following information (in the form of esp_console_cmd_t structure):

- Command name (string without spaces)
- Help text explaining what the command does
- Optional hint text listing the arguments of the command. If application uses Argtable3 for argument parsing, hint text can be generated automatically by providing a pointer to argtable argument definitions structure instead.
- The command handler function.

A few other functions are provided by the command registration module:

esp_console_run()

This function takes the command line string, splits it into argc/argv argument list using esp_console_split_argv(), looks up the command in the list of registered components, and if it is found, executes its handler.

esp_console_register_help_command()

Adds help command to the list of registered commands. This command prints the list of all the registered commands, along with their arguments and help texts.

esp_console_get_completion()

Callback function to be used with linenoiseSetCompletionCallback() from linenoise library. Provides completions to linenoise based on the list of registered commands.

esp_console_get_hint()
Chapter 2. API Reference

Callback function to be used with `linenoiseSetHintsCallback()` from linenoise library. Provides argument hints for registered commands to linenoise.

Initialize console REPL environment

To establish a basic REPL environment, `console` component provides several useful APIs, combining those functions described above.

In a typical application, you only need to call `esp_console_new_repl_uart()` to initialize the REPL environment based on UART device, including driver install, basic console configuration, spawning a thread to do REPL task and register several useful commands (e.g. `help`).

After that, you can register your own commands with `esp_console_cmd_register()`. The REPL environment keeps in init state until you call `esp_console_start_repl()`.

Application Example

Example application illustrating usage of the `console` component is available in `system/console` directory. This example shows how to initialize UART and VFS functions, set up linenoise library, read and handle commands from UART, and store command history in Flash. See README.md in the example directory for more details.

Besides that, ESP-IDF contains several useful examples which are based on the `console` component and can be treated as “tools” when developing applications. For example, `peripherals/i2c/i2c_tools`, `wifi/iperf`.

API Reference

Header File

- components/console/esp_console.h

Functions

```
esp_err_t esp_console_init (const esp_console_config_t *config)
initialize console module

esp_err_t esp_console_deinit (void)
de-initialize console module
```

Note: Call this once before using other console module features

Parameters

- `config` - console configuration

Returns

- ESP_OK on success
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_INVALID_STATE if already initialized
- ESP_ERR_INVALID_ARG if the configuration is invalid

```
esp_err_t esp_console_deinit (void)
de-initialize console module
```

Note: Call this once when done using console module functions

Parameters

- `config` - console configuration

Returns

- ESP_OK on success
- ESP_ERR_INVALID_STATE if not initialized yet
esp_err_t esp_console_cmd_register (const esp_console_cmd_t *cmd)

Register console command.

Parameters  
cmd – pointer to the command description; can point to a temporary value

Returns  
• ESP_OK on success  
• ESP_ERR_NO_MEM if out of memory  
• ESP_ERR_INVALID_ARG if command description includes invalid arguments

esp_err_t esp_console_run (const char *cmdline, int *cmd_ret)

Run command line.

Parameters  
• cmdline – command line (command name followed by a number of arguments)  
• cmd_ret – [out] return code from the command (set if command was run)

Returns  
• ESP_OK, if command was run  
• ESP_ERR_INVALID_ARG, if the command line is empty, or only contained whitespace  
• ESP_ERR_NOT_FOUND, if command with given name wasn’t registered  
• ESP_ERR_INVALID_STATE, if esp_console_init wasn’t called

size_t esp_console_split_argv (char *line, char **argv, size_t argv_size)

Split command line into arguments in place.

```c
- This function finds whitespace-separated arguments in the given input line.  
  - 'abc def 1 20 .3' -> [ 'abc', 'def', '1', '20', '.3' ]  
  - Argument which include spaces may be surrounded with quotes. In this case  
    spaces are preserved and quotes are stripped.  
  - 'abc "123 456" def' -> [ 'abc', '123 456', 'def' ]  
  - Escape sequences may be used to produce backslash, double quote, and space:  
    - 'a \ b\c"' -> [ 'a b\c"' ]
```

Note:  
Pointers to at most argv_size - 1 arguments are returned in argv array. The pointer after the last one (i.e. argv[argc]) is set to NULL.

Parameters  
• line – pointer to buffer to parse; it is modified in place  
• argv – array where the pointers to arguments are written  
• argv_size – number of elements in argv_array (max. number of arguments)

Returns  
number of arguments found (argc)

void esp_console_get_completion (const char *buf, linenoiseCompletions *lc)

Callback which provides command completion for linenoise library.

When using linenoise for line editing, command completion support can be enabled like this:

```c
linenoiseSetCompletionCallback(&esp_console_get_completion);
```

Parameters  
• buf – the string typed by the user  
• lc – linenoiseCompletions to be filled in
const char *esp_console_get_hint (const char *buf, int *color, int *bold)
Callback which provides command hints for linenoise library.

When using linenoise for line editing, hints support can be enabled as follows:
linenoiseSetHintsCallback((linenoiseHintsCallback*)&esp_console_get_hint);
The extra cast is needed because linenoiseHintsCallback is defined as returning a char* instead of const char*.

Parameters
• buf – line typed by the user
• color – [out] ANSI color code to be used when displaying the hint
• bold – [out] set to 1 if hint has to be displayed in bold

Returns string containing the hint text. This string is persistent and should not be freed (i.e. linenoiseSetFreeHintsCallback should not be used).

esp_err_t esp_console_register_help_command (void)
Register a ‘help’ command.

Default ‘help’ command prints the list of registered commands along with hints and help strings.

Returns
• ESP_OK on success
• ESP_ERR_INVALID_STATE, if esp_console_init wasn’t called

esp_err_t esp_console_new_repl_uart (const esp_console_dev_uart_config_t *dev_config, const esp_console_repl_config_t *repl_config, esp_console_repl_t **ret_repl)
Establish a console REPL environment over UART driver.

Attention This function is meant to be used in the examples to make the code more compact. Applications which use console functionality should be based on the underlying linenoise and esp_console functions.

Note: This is an all-in-one function to establish the environment needed for REPL, includes:
• Install the UART driver on the console UART (8n1, 115200, REF_TICK clock source)
• Configures the stdin/stdout to go through the UART driver
• Initializes linenoise
• Spawn new thread to run REPL in the background

Parameters
• dev_config – [in] UART device configuration
• repl_config – [in] REPL configuration
• ret_repl – [out] return REPL handle after initialization succeed, return NULL otherwise

Returns
• ESP_OK on success
• ESP_FAIL: Parameter error

esp_err_t esp_console_start_repl (esp_console_repl_t *repl)
Start REPL environment.

Note: Once the REPL gets started, it won’t be stopped until the user calls repl->del(repl) to destroy the REPL environment.

Parameters repl – [in] REPL handle returned from esp_console_new_repl_xxx
Returns
• ESP_OK on success
• ESP_ERR_INVALID_STATE, if repl has started already

Structures

struct esp_console_config_t
Parameters for console initialization.

Public Members

size_t max_cmdline_length
length of command line buffer, in bytes

size_t max_cmdline_args
maximum number of command line arguments to parse

int hint_color
ASCII color code of hint text.

int hint_bold
Set to 1 to print hint text in bold.

struct esp_console_repl_config_t
Parameters for console REPL (Read Eval Print Loop)

Public Members

uint32_t max_history_len
maximum length for the history

const char *history_save_path
file path used to save history commands, set to NULL won’t save to file system

uint32_t task_stack_size
repl task stack size

uint32_t task_priority
repl task priority

const char *prompt
prompt (NULL represents default: “esp> “)

size_t max_cmdline_length
maximum length of a command line. If 0, default value will be used

struct esp_console_dev_uart_config_t
Parameters for console device: UART.
Public Members

int channel
  UART channel number (count from zero)

int baud_rate
  Communication baud rate.

int tx_gpio_num
  GPIO number for TX path, -1 means using default one.

int rx_gpio_num
  GPIO number for RX path, -1 means using default one.

struct esp_console_cmd_t
  Console command description.

Public Members

const char *command
  Command name. Must not be NULL, must not contain spaces. The pointer must be valid until the call to esp_console_deinit.

const char *help
  Help text for the command, shown by help command. If set, the pointer must be valid until the call to esp_console_deinit. If not set, the command will not be listed in ‘help’ output.

const char *hint
  Hint text, usually lists possible arguments. If set to NULL, and ‘argtable’ field is non-NULL, hint will be generated automatically

esp_console_cmd_func_t func
  Pointer to a function which implements the command.

void *argtable
  Array or structure of pointers to arg_xxx structures, may be NULL. Used to generate hint text if ‘hint’ is set to NULL. Array/structure which this field points to must end with an arg_end. Only used for the duration of esp_console_cmd_register call.

struct esp_console_repl_s
  Console REPL base structure.

Public Members

esp_err_t (*del)(esp_console_repl_t *repl)
  Delete console REPL environment.
  
  Param repl [in] REPL handle returned from esp_console_new_repl_xxx
  Return
• ESP_OK on success
• ESP_FAIL on errors

Macros

ESP_CONSOLE_CONFIG_DEFAULT()
Default console configuration value.

ESP_CONSOLE_REPL_CONFIG_DEFAULT()
Default console repl configuration value.

ESP_CONSOLE_DEV_UART_CONFIG_DEFAULT()

Type Definitions

typedef struct linenoiseCompletions linenoiseCompletions

typedef int (*esp_console_cmd_func_t)(int argc, char **argv)
Console command main function.

Param argc  number of arguments
Param argv  array with argc entries, each pointing to a zero-terminated string argument
Return  console command return code, 0 indicates “success”

typedef struct esp_console_repl_s esp_console_repl_t
Type defined for console REPL.

2.10.6 eFuse Manager

Introduction
The eFuse Manager library is designed to structure access to eFuse bits and make using these easy. This library operates eFuse bits by a structure name which is assigned in eFuse table. This sections introduces some concepts used by eFuse Manager.

Hardware description
The ESP32 has a number of eFuses which can store system and user parameters. Each eFuse is a one-bit field which can be programmed to 1 after which it cannot be reverted back to 0. Some of system parameters are using these eFuse bits directly by hardware modules and have special place (for example EFUSE_BLK0).

For more details, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) [PDF]. Some eFuse bits are available for user applications.

ESP32 has 4 eFuse blocks each of the size of 256 bits (not all bits are available):

• EFUSE_BLK0 is used entirely for system purposes;
• EFUSE_BLK1 is used for flash encrypt key. If not using that Flash Encryption feature, they can be used for another purpose;
• EFUSE_BLK2 is used for security boot key. If not using that Secure Boot feature, they can be used for another purpose;
• EFUSE_BLK3 can be partially reserved for the custom MAC address, or used entirely for user application.

Note that some bits are already used in IDF.

Each block is divided into 8 32-bits registers.
Chapter 2. API Reference

**eFuse Manager component**

The component has API functions for reading and writing fields. Access to the fields is carried out through the structures that describe the location of the eFuse bits in the blocks. The component provides the ability to form fields of any length and from any number of individual bits. The description of the fields is made in a CSV file in a table form. To generate from a tabular form (CSV file) in the C-source uses the tool `efuse_table_gen.py`. The tool checks the CSV file for uniqueness of field names and bit intersection, in case of using a custom file from the user’s project directory, the utility will check with the common CSV file.

CSV files:

- **common** *(esp_efuse_table.csv)* - contains eFuse fields which are used inside the IDF. C-source generation should be done manually when changing this file (run command `idf.py efuse-common-table`). Note that changes in this file can lead to incorrect operation.
- **custom** *(optional and can be enabled by CONFIG_EFUSE_CUSTOM_TABLE)* contains eFuse fields that are used by the user in their application. C-source generation should be done manually when changing this file and running `idf.py efuse-custom-table`.

### Description CSV file

The CSV file contains a description of the eFuse fields. In the simple case, one field has one line of description. Table header:

```plaintext
# field_name, efuse_block(EFUSE_BLK0..EFUSE_BLK3), bit_start(0..255), bit_count(1..256), comment
```

Individual params in CSV file the following meanings:

- **field_name** Name of field. The prefix `ESP_EFUSE_` will be added to the name, and this field name will be available in the code. This name will be used to access the fields. The name must be unique for all fields. If the line has an empty name, then this line is combined with the previous field. This allows you to set an arbitrary order of bits in the field, and expand the field as well (see `MAC_FACTORY` field in the common table). The `field_name` supports structured format using `.`, to show that the field belongs to another field (see `WR_DIS` and `RD_DIS` in the common table).

- **efuse_block** Block number. It determines where the eFuse bits will be placed for this field. Available `EFUSE_BLK0..EFUSE_BLK3`.

- **bit_start** Start bit number (0..255). The `bit_start` field can be omitted. In this case, it will be set to `bit_start + bit_count` from the previous record, if it has the same `efuse_block`. Otherwise (if `efuse_block` is different, or this is the first entry), an error will be generated.

- **bit_count** The number of bits to use in this field (1..-). This parameter can not be omitted. This field also may be `MAX_BLK_LEN` in this case, the field length will have the maximum block length, taking into account the coding scheme (applicable for `ESP_EFUSE_SECURE_BOOT_KEY` and `ESP_EFUSE_ENCRYPT_FLASH_KEY` fields). The value `MAX_BLK_LEN` depends on `CONFIG_EFUSE_CODE_SCHEME_SELECTOR`, will be replaced with “None” - 256, “3/4” - 192, “REPEAT” - 128.

- **comment** This param is using for comment field, it also move to C-header file. The comment field can be omitted.

If a non-sequential bit order is required to describe a field, then the field description in the following lines should be continued without specifying a name, this will indicate that it belongs to one field. For example two fields `MAC_FACTORY` and `MAC_FACTORY_CRC`:

```plaintext
# Factory MAC address #

+-----------------------+-------+-------+-----------------------------+
| MAC_FACTORY,          | EFUSE_BLK0, | 72, | Factory MAC addr [0]        |
| EFUSE_BLK0,           | 64, | 8,   | Factory MAC addr [1]        |
| EFUSE_BLK0,           | 56, | 8,   | Factory MAC addr [2]        |
| EFUSE_BLK0,           | 48, | 8,   | Factory MAC addr [3]        |
| EFUSE_BLK0,           | 40, | 8,   | Factory MAC addr [4]        |
```

(continues on next page)
This field will available in code as ESP_EFUSE_MAC_FACTORY and ESP_EFUSE_MAC_FACTORY_CRC.

### Structured efuse fields

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Block</th>
<th>Offset</th>
<th>Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WR_DIS,</td>
<td>EFUSE_BLK0</td>
<td>0</td>
<td>32</td>
<td>Write protection</td>
</tr>
<tr>
<td>WR_DIS.RD_DIS,</td>
<td>EFUSE_BLK0</td>
<td>0</td>
<td>1</td>
<td>Write protection for RD_DIS</td>
</tr>
<tr>
<td>WR_DIS.FIELD_1,</td>
<td>EFUSE_BLK0</td>
<td>1</td>
<td>1</td>
<td>Write protection for FIELD_1</td>
</tr>
<tr>
<td>WR_DIS.FIELD_2,</td>
<td>EFUSE_BLK0</td>
<td>2</td>
<td>4</td>
<td>Write protection for FIELD_2</td>
</tr>
<tr>
<td>WR_DIS.FIELD_2.B1,</td>
<td>EFUSE_BLK0</td>
<td>2</td>
<td>2</td>
<td>Write protection for FIELD_2.B1</td>
</tr>
<tr>
<td>WR_DIS.FIELD_2.B2,</td>
<td>EFUSE_BLK0</td>
<td>4</td>
<td>2</td>
<td>Write protection for FIELD_2.B2</td>
</tr>
<tr>
<td>WR_DIS.FIELD_3,</td>
<td>EFUSE_BLK0</td>
<td>5</td>
<td>1</td>
<td>Write protection for FIELD_3</td>
</tr>
<tr>
<td>WR_DIS.FIELD_3.ALIAS,</td>
<td>EFUSE_BLK0</td>
<td>5</td>
<td>1</td>
<td>Write protection for FIELD_3.ALIAS</td>
</tr>
<tr>
<td>WR_DIS.FIELD_4,</td>
<td>EFUSE_BLK0</td>
<td>7</td>
<td>1</td>
<td>Write protection for FIELD_4</td>
</tr>
</tbody>
</table>

The structured eFuse field looks like WR_DIS.RD_DIS where the dot points that this field belongs to the parent field - WR_DIS and can not be out of the parent’s range.

It is possible to use some levels of structured fields as WR_DIS.FIELD_2.B1 and B2. These fields should not be crossed each other and should be in the range of two fields: WR_DIS and WR_DIS.FIELD_2.

It is possible to create aliases for fields with the same range, see WR_DIS.FIELD_3 and WR_DIS.FIELD_3.ALIAS.

The IDF names for structured efuse fields should be unique. The efuse_table_gen tool will generate the final names where the dot will be replaced by _. The names for using in IDF are ESP_EFUSE_WR_DIS, ESP_EFUSE_WR_DIS_RDIS, ESP_EFUSE_WR_DIS_FIELD_2_B1, etc.

The efuse_table_gen tool checks that the fields do not overlap each other and must be within the range of a field if there is a violation, then throws the following error:

**Field at USER_DATA, EFUSE_BLK3, 0, 256 intersected with SERIAL_NUMBER, EFUSE_BLK3, 0, 32**

**Solution:** Describe SERIAL_NUMBER to be included in USER_DATA.(USER_DATA.SERIAL_NUMBER).

**Field at FEILD, EFUSE_BLK3, 0, 50 out of range FEILD.MAJOR_NUMBER, EFUSE_BLK3, 0, 60, 32**

**Solution:** Change bit_start for FIELD.MAJOR_NUMBER from 60 to 0, so MAJOR_NUMBER is in the FEILD range.

**efuse_table_gen.py tool**

The tool is designed to generate C-source files from CSV file and validate fields. First of all, the check is carried out on the uniqueness of the names and overlaps of the field bits. If an additional custom file is used, it will be checked with the existing common file (esp_efuse_table.csv). In case of errors, a message will be displayed and the string that caused the error. C-source files contain structures of type esp_efuse_desc_t.

To generate a common files, use the following command `idf.py efuse-common-table` or:
cd $IDF_PATH/components/efuse/
./efuse_table_gen.py --idf_target esp32 esp32/esp_efuse_table.csv

After generation in the folder $IDF_PATH/components/efuse/esp32 create:

• esp_efuse_table.c file.
• In include folder esp_efuse_table.c file.

To generate a custom files, use the following command idf.py efuse-custom-table or:

cd $IDF_PATH/components/efuse/
./efuse_table_gen.py --idf_target esp32 esp32/esp_efuse_table.csv PROJECT_PATH/
→ main/esp_efuse_custom_table.csv

After generation in the folder PROJECT_PATH/main create:

• esp_efuse_custom_table.c file.
• In include folder esp_efuse_custom_table.c file.

To use the generated fields, you need to include two files:

#include "esp_efuse.h"
#include "esp_efuse_table.h" // or "esp_efuse_custom_table.h"

Supported coding scheme

eFuse have three coding schemes:

• None (value 0).
• 3/4 (value 1).
• Repeat (value 2).

The coding scheme affects only EFUSE_BLK1, EFUSE_BLK2 and EFUSE_BLK3 blocks. EUSE_BLK0 block always has a coding scheme None. Coding changes the number of bits that can be written into a block, the block length is constant 256, some of these bits are used for encoding and not available for the user.

When using a coding scheme, the length of the payload that can be written is limited (for more details 20.3.1.3 System Parameter coding_scheme):

• None 256 bits.
• 3/4 192 bits.
• Repeat 128 bits.

You can find out the coding scheme of your chip:

• run a espfuse.py -p PORT summary command.
• from esptool utility logs (during flashing).
• calling the function in the code esp_efuse_get_coding_scheme() for the EFUSE_BLK3 block.

eFuse tables must always comply with the coding scheme in the chip. There is an CONFIG_EFUSE_CODE_SCHEME_SELECTOR option to select the coding type for tables in a Kconfig. When generating source files, if your tables do not follow the coding scheme, an error message will be displayed. Adjust the length or offset fields. If your program was compiled with None encoding and 3/4 is used in the chip, then the ESP_ERR_CODING error may occur when calling the eFuse API (the field is outside the block boundaries). If the field matches the new block boundaries, then the API will work without errors.

Also, 3/4 coding scheme imposes restrictions on writing bits belonging to one coding unit. The whole block with a length of 256 bits is divided into 4 coding units, and in each coding unit there are 6 bytes of useful data and 2 service bytes. These 2 service bytes contain the checksum of the previous 6 data bytes.

It turns out that only one field can be written into one coding unit. Repeated rewriting in one coding unit is prohibited. But if the record was made in advance or through a esp_efuse_write_block() function, then reading the fields belonging to one coding unit is possible.
In case 3/4 coding scheme, the writing process is divided into the coding units and we cannot use the usual mode of writing some fields. We can prepare all the data for writing and burn it in one time. You can also use this mode for None coding scheme but it is not necessary. It is important for 3/4 coding scheme. The batch writing mode blocks esp_efuse_read... operations.

After changing the coding scheme, run efuse_common_table and efuse_custom_table commands to check the tables of the new coding scheme.

To write some fields into one block, or different blocks in one time, you need to use the batch writing mode. Firstly set this mode through esp_efuse_batch_write_begin() function then write some fields as usual using the esp_efuse_write... functions. At the end to burn them, call the esp_efuse_batch_write_commit() function. It burns prepared data to the eFuse blocks and disables the batch recording mode.

Note: If there is already pre-written data in the eFuse block using the 3/4 or Repeat encoding scheme, then it is not possible to write anything extra (even if the required bits are empty) without breaking the previous encoding data. This encoding data will be overwritten with new encoding data and completely destroyed (however, the payload eFuses are not damaged). It can be related to: CUSTOM_MAC, SPI_PAD_CONFIG_HD, SPI_PAD_CONFIG_CS, etc. Please contact Espressif to order the required pre-burnt eFuses.

FOR TESTING ONLY (NOT RECOMMENDED): You can ignore or suppress errors that violate encoding scheme data in order to burn the necessary bits in the eFuse block.

eFuse API

Access to the fields is via a pointer to the description structure. API functions have some basic operation:

- esp_efuse_read_field_blob() - returns an array of read eFuse bits.
- esp_efuse_read_field_cnt() - returns the number of bits programmed as “1”.
- esp_efuse_write_field_blob() - writes an array.
- esp_efuse_write_field_cnt() - writes a required count of bits as “1”.
- esp_efuse_get_field_size() - returns the number of bits by the field name.
- esp_efuse_read_reg() - returns value of eFuse register.
- esp_efuse_write_reg() - writes value to eFuse register.
- esp_efuse_get_coding_scheme() - returns eFuse coding scheme for blocks.
- esp_efuse_read_block() - reads key to eFuse block starting at the offset and the required size.
- esp_efuse_write_block() - writes key to eFuse block starting at the offset and the required size.
- esp_efuse_batch_write.begin() - set the batch mode of writing fields.
- esp_efuse_batch_write.commit() - writes all prepared data for batch writing mode and resets the batch writing mode.
- esp_efuse_batch_write.cancel() - reset the batch writing mode and prepared data.
- esp_efuse_get_key_dis_read() - Returns a read protection for the key block.
- esp_efuse_set_key_dis_read() - Sets a read protection for the key block.
- esp_efuse_get_key_dis_write() - Returns a write protection for the key block.
- esp_efuse_set_key_dis_write() - Sets a write protection for the key block.
- esp_efuse_get_key_purpose() - Returns the current purpose set for an eFuse key block.
- esp_efuse_write_key() - Programs a block of key data to an eFuse block
- esp_efuse_write_keys() - Programs keys to unused eFuse blocks
- esp_efuse_find_purpose() - Finds a key block with the particular purpose set.
- esp_efuse_get_keypurpose_dis_write() - Returns a write protection of the key purpose field for an eFuse key block (for esp32 always true).
- esp_efuse_key_block_unused() - Returns true if the key block is unused, false otherwise.

For frequently used fields, special functions are made, like this esp_efuse_get_pkg_ver().
## How to add a new field

1. Find a free bits for field. Show `esp_efuse_table.csv` file or run `idf.py show-efuse-table` or the next command:

   ```bash
   $ ./efuse_table_gen.py esp32/esp_efuse_table.csv --info
   ```

   Parsing efuse CSV input file $IDF_PATH/components/efuse/esp32/esp_efuse_table.csv.

   Verifying efuse table...

   Max number of bits in BLK 192

<table>
<thead>
<tr>
<th>#</th>
<th>field_name</th>
<th>efuse_block</th>
<th>bit_start</th>
<th>bit_count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WR_DIS</td>
<td>EFUSE_BLK0</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>WR_DIS.RD_DIS</td>
<td>EFUSE_BLK0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>WR_DIS.WR_DIS</td>
<td>EFUSE_BLK0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>WR_DIS.FLASH_CRYPT_CNT</td>
<td>EFUSE_BLK0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>WR_DIS.UART_DOWNLOAD_DIS</td>
<td>EFUSE_BLK0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>WR_DIS.MAC</td>
<td>EFUSE_BLK0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>WR_DIS.MAC_CRC</td>
<td>EFUSE_BLK0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>WR_DIS.DISABLE_APP_CPU</td>
<td>EFUSE_BLK0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>WR_DIS.DISABLE_BT</td>
<td>EFUSE_BLK0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>WR_DIS.DISABLE_CACHE</td>
<td>EFUSE_BLK0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>WR_DIS.VOL_LEVEL_HP_INV</td>
<td>EFUSE_BLK0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>WR_DIS.CLR8M_FREQ</td>
<td>EFUSE_BLK0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>13</td>
<td>WR_DIS.ADC_VREF</td>
<td>EFUSE_BLK0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>WR_DIS.XPD_SDIO_REG</td>
<td>EFUSE_BLK0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>WR_DIS.XPD_SDIO_TIEH</td>
<td>EFUSE_BLK0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>WR_DIS.XPD_SDIO_FORCE</td>
<td>EFUSE_BLK0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>WR_DIS.SPI_PAD_CONFIG_CLK</td>
<td>EFUSE_BLK0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>WR_DIS.SPI_PAD_CONFIG_Q</td>
<td>EFUSE_BLK0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>WR_DIS.SPI_PAD_CONFIG_D</td>
<td>EFUSE_BLK0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
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<td>EFUSE_BLK0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>WR_DIS.BLOCK1</td>
<td>EFUSE_BLK0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>WR_DIS.BLOCK2</td>
<td>EFUSE_BLK0</td>
<td>8</td>
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</tr>
<tr>
<td>23</td>
<td>WR_DIS.BLOCK3</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>24</td>
<td>WR_DIS.CUSTOM_MAC_CRC</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>WR_DIS.CUSTOM_MAC</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>26</td>
<td>WR_DIS.ADC1_TP_LOW</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>27</td>
<td>WR_DIS.ADC1_TP_HIGH</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>28</td>
<td>WR_DIS.ADC2_TP_LOW</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>WR_DIS.ADC2_TP_HIGH</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>WR_DIS.SECURE_VERSION</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>WR_DIS.MAC_VERSION</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>WR_DIS.BLK3_PART_RESERVE</td>
<td>EFUSE_BLK0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>WR_DIS.FLASH_CRYPT_CONFIG</td>
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</tr>
<tr>
<td>34</td>
<td>WR_DIS.CODING_SCHEME</td>
<td>EFUSE_BLK0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>35</td>
<td>WR_DIS.KEY_STATUS</td>
<td>EFUSE_BLK0</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>WR_DIS.ABS_DONE_0</td>
<td>EFUSE_BLK0</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>37</td>
<td>WR_DIS.ABS_DONE_1</td>
<td>EFUSE_BLK0</td>
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<td>1</td>
</tr>
<tr>
<td>38</td>
<td>WR_DIS.JTAG_DISABLE</td>
<td>EFUSE_BLK0</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>39</td>
<td>WR_DIS.CONSOLE_DEBUG_DISABLE</td>
<td>EFUSE_BLK0</td>
<td>15</td>
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</tr>
<tr>
<td>40</td>
<td>WR_DIS.DISABLE_DL_ENCRYPT</td>
<td>EFUSE_BLK0</td>
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<tr>
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<tr>
<td>42</td>
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<td>EFUSE_BLK0</td>
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<tr>
<td>43</td>
<td>RD_DIS</td>
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<td>16</td>
<td>4</td>
</tr>
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<tr>
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<td>RD_DIS.BLOCK3</td>
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<td>RD_DIS.CUSTOM_MAC_CRC</td>
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</tr>
<tr>
<td>48</td>
<td>RD_DIS.CUSTOM_MAC</td>
<td>EFUSE_BLK0</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>49</td>
<td>RD_DIS.ADC1_TP_LOW</td>
<td>EFUSE_BLK0</td>
<td>18</td>
<td>1</td>
</tr>
</tbody>
</table>

(continues on next page)
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Block</th>
<th>Offset</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>RD_DIS.ADC1_TP_HIGH</td>
<td>EFUSE_BLK0</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>51</td>
<td>RD_DIS.ADC2_TP_LOW</td>
<td>EFUSE_BLK0</td>
<td>18</td>
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</tr>
<tr>
<td>52</td>
<td>RD_DIS.ADC2_TP_HIGH</td>
<td>EFUSE_BLK0</td>
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<td>RD_DIS.SECURE_VERSION</td>
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<td>RD_DIS.BLK3_PART_RESERVE</td>
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<td>56</td>
<td>RD_DIS.FLASH_CRYPT_CONFIG</td>
<td>EFUSE_BLK0</td>
<td>19</td>
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<tr>
<td>57</td>
<td>RD_DIS.CODING_SCHEME</td>
<td>EFUSE_BLK0</td>
<td>19</td>
<td>1</td>
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<td>RD_DIS.KEY_STATUS</td>
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<td>FLASH_CRYPT_CNT</td>
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<td>UART_DOWNLOAD_DIS</td>
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<td>61</td>
<td>MAC</td>
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<td>32</td>
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<td>62</td>
<td>MAC</td>
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<td>40</td>
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<td>MAC</td>
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<td>48</td>
<td>8</td>
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<td>MAC</td>
<td>EFUSE_BLK0</td>
<td>72</td>
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<td>67</td>
<td>MAC_CRC</td>
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</tr>
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<td>DISABLE_APP_CPU</td>
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<td>1</td>
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<td>DISABLE_BT</td>
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<td>CHIP_PACKAGE_4BIT</td>
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<td>71</td>
<td>DIS_CACHE</td>
<td>EFUSE_BLK0</td>
<td>99</td>
<td>1</td>
</tr>
<tr>
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<td>SPI_PAD_CONFIG_HD</td>
<td>EFUSE_BLK0</td>
<td>100</td>
<td>5</td>
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<td>CHIP_PACKAGE</td>
<td>EFUSE_BLK0</td>
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<td>3</td>
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<td>CHIP_CPU_FREQ_LOW</td>
<td>EFUSE_BLK0</td>
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<td>CHIP_CPU_FREQ_RATED</td>
<td>EFUSE_BLK0</td>
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<td>BLK3_PART_RESERVE</td>
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<td>CHIP_VER_REVI</td>
<td>EFUSE_BLK0</td>
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<td>CLK8M_FREQ</td>
<td>EFUSE_BLK0</td>
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<td>8</td>
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<td>ADC_VREF</td>
<td>EFUSE_BLK0</td>
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<td>XPD_Sdio_REG</td>
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<td>142</td>
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<td>XPD_Sdio_TIEH</td>
<td>EFUSE_BLK0</td>
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<td>EFUSE_BLK0</td>
<td>144</td>
<td>1</td>
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<tr>
<td>83</td>
<td>SPI_PAD_CONFIG_CLK</td>
<td>EFUSE_BLK0</td>
<td>160</td>
<td>5</td>
</tr>
<tr>
<td>84</td>
<td>SPI_PAD_CONFIG_Q</td>
<td>EFUSE_BLK0</td>
<td>165</td>
<td>5</td>
</tr>
<tr>
<td>85</td>
<td>SPI_PAD_CONFIG_D</td>
<td>EFUSE_BLK0</td>
<td>170</td>
<td>5</td>
</tr>
<tr>
<td>86</td>
<td>SPI_PAD_CONFIG_CS0</td>
<td>EFUSE_BLK0</td>
<td>175</td>
<td>5</td>
</tr>
<tr>
<td>87</td>
<td>CHIP_VER_REV2</td>
<td>EFUSE_BLK0</td>
<td>180</td>
<td>1</td>
</tr>
<tr>
<td>88</td>
<td>VOL_LEVEL_HP_INV</td>
<td>EFUSE_BLK0</td>
<td>182</td>
<td>2</td>
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<td>89</td>
<td>WAFER_VERSION_MINOR</td>
<td>EFUSE_BLK0</td>
<td>184</td>
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<td>90</td>
<td>FLASH_CRYPT_CONFIG</td>
<td>EFUSE_BLK0</td>
<td>188</td>
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<td>91</td>
<td>CODING_SCHEME</td>
<td>EFUSE_BLK0</td>
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<td>92</td>
<td>CONSOLE_DEBUG_DISABLE</td>
<td>EFUSE_BLK0</td>
<td>194</td>
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<td>DISABLE_Sdio_HOST</td>
<td>EFUSE_BLK0</td>
<td>195</td>
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<td>94</td>
<td>ABS_DONE_0</td>
<td>EFUSE_BLK0</td>
<td>196</td>
<td>1</td>
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<td>ABS_DONE_1</td>
<td>EFUSE_BLK0</td>
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<td>DISABLE_DL_CACHE</td>
<td>EFUSE_BLK0</td>
<td>201</td>
<td>1</td>
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<tr>
<td>100</td>
<td>KEY_STATUS</td>
<td>EFUSE_BLK0</td>
<td>202</td>
<td>1</td>
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<tr>
<td>101</td>
<td>BLOCK1</td>
<td>EFUSE_BLK1</td>
<td>0</td>
<td>192</td>
</tr>
<tr>
<td>102</td>
<td>BLOCK2</td>
<td>EFUSE_BLK2</td>
<td>0</td>
<td>192</td>
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<td>103</td>
<td>CUSTOM_Mac_CRC</td>
<td>EFUSE_BLK3</td>
<td>0</td>
<td>8</td>
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<td>104</td>
<td>MAC_CUSTOM</td>
<td>EFUSE_BLK3</td>
<td>8</td>
<td>48</td>
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<td>ADC1_TP_LOW</td>
<td>EFUSE_BLK3</td>
<td>96</td>
<td>7</td>
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<td>106</td>
<td>ADC1_TP_HIGH</td>
<td>EFUSE_BLK3</td>
<td>103</td>
<td>9</td>
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<tr>
<td>107</td>
<td>ADC2_TP_LOW</td>
<td>EFUSE_BLK3</td>
<td>112</td>
<td>7</td>
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<tr>
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<td>ADC2_TP_HIGH</td>
<td>EFUSE_BLK3</td>
<td>119</td>
<td>9</td>
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<td>109</td>
<td>SECURE_VERSION</td>
<td>EFUSE_BLK3</td>
<td>128</td>
<td>32</td>
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<tr>
<td>110</td>
<td>MAC_VERSION</td>
<td>EFUSE_BLK3</td>
<td>184</td>
<td>8</td>
</tr>
</tbody>
</table>
Used bits in efuse table:

EFUSE_BLK0
[0 15] [0 2] [2 3] ... [19 19] [19 27] [32 87] [96 111] [128 140] [142 144] [160...
→ 180] [182 185] [188 202]
EFUSE_BLK1
[0 191]
EFUSE_BLK2
[0 191]
EFUSE_BLK3
[0 191] [96 159] [184 191]

Note: Not printed ranges are free for using. (bits in EFUSE_BLK0 are reserved for...
→ Espressif)

The number of bits not included in square brackets is free (some bits are reserved for Espressif). All fields are checked for overlapping.

To add fields to an existing field, use the **Structured efuse fields** technique. For example, adding the fields: SERIAL_NUMBER, MODEL_NUMBER and HARDWARE REV to an existing USER_DATA field. Use . (dot) to show an attachment in a field.

| USER_DATA.SERIAL_NUMBER, USER_DATA.MODEL_NUMBER, USER_DATA.HARDWARE_REV, |
| EFUSE_BLK3, 0, 32, EFUSE_BLK3, 32, 10, EFUSE_BLK3, 42, 10, |

2. Fill a line for field: field_name, efuse_block, bit_start, bit_count, comment.
3. Run a show_efuse_table command to check eFuse table. To generate source files run efuse_common_table or efuse_custom_table command.

You may get errors such as intersects with or out of range. Please see how to solve them in the **Structured efuse fields** article.

### Bit Order

The eFuses bit order is little endian (see the example below), it means that eFuse bits are read and written from LSB to MSB:

```
$ espefuse.py dump
```

| USER_DATA | (BLOCK3 ) [3 ] read_regs: 03020100 07060504 0B0A0908...
| BLOCK4 | (BLOCK4 ) [4 ] read_regs: 03020100 07060504 0B0A0908...

where is the register representation:

| EFUSE_RD_USR_DATA0_REG = 0x03020100 |
| EFUSE_RD_USR_DATA1_REG = 0x07060504 |
| EFUSE_RD_USR_DATA2_REG = 0x0B0A0908 |
| EFUSE_RD_USR_DATA3_REG = 0x0F0E0D0C |
| EFUSE_RD_USR_DATA4_REG = 0x13121111 |
| EFUSE_RD_USR_DATA5_REG = 0x17161514 |
| EFUSE_RD_USR_DATA6_REG = 0x1B1A1918 |
| EFUSE_RD_USR_DATA7_REG = 0x1F1E1D1C |

where is the byte representation:

| byte[0] = 0x00, byte[1] = 0x01, ... byte[3] = 0x03, byte[4] = 0x04, ..., byte[31]...
| = 0x1F |

For example, csv file describes the USER_DATA field, which occupies all 256 bits (a whole block).
Thus, reading the eFuse USER_DATA block written as above gives the following results:

```c
uint8_t buf[32] = { 0 };
esp_efuse_read_field_blob(ESP_EFUSE_USER_DATA, &buf, sizeof(buf) * 8);
// buf[0] = 0x00, buf[1] = 0x01, ... buf[31] = 0x1F

uint32_t field1_size = ESP_EFUSE_USER_DATA[0]->bit_count; // can be used for this case because it only consists of one entry
esp_efuse_read_field_blob(ESP_EFUSE_USER_DATA, &field1, field1_size);
// field1 = 0x0302

uint32_t field1_1 = 0;
esp_efuse_read_field_blob(ESP_EFUSE_USER_DATA, &field1_1, 2); // reads only first 2 bits
// field1 = 0x0002

uint8_t id = 0;
size_t id_size = esp_efuse_get_field_size(ESP_EFUSE_ID); // returns 6
// size_t id_size = ESP_EFUSE_USER_DATA[0]->bit_count; // can NOT be used because it consists of 3 entries. It returns 3 not 6.
esp_efuse_read_field_blob(ESP_EFUSE_ID, &id, id_size);
// id = 0x91
// b'100 10 001
// [3] [2] [1]

uint8_t id_1 = 0;
esp_efuse_read_field_blob(ESP_EFUSE_ID, &id_1, 3);
// id = 0x01
// b'001
```

### Get eFuses During Build

There is a way to get the state of eFuses at the build stage of the project. There are two cmake functions for this:

- `espefuse_get_json_summary()` - It calls the `espefuse.py summary --format json` command and returns a json string (it is not stored in a file).
- `espefuse_get_efuse()` - It finds a given eFuse name in the json string and returns its property.

The json string has the following properties:

```json
{
    "MAC": {
        "bit_len": 48,
        "block": 0,
        "category": "identity",
        "description": "Factory MAC Address",
        "efuse_type": "bytes:6",
        "name": "MAC",
        "pos": 0,
        "readable": true,
        "value": "94:b9:7e:5a:6e:58 (CRC 0xe2 OK)",
        "word": 1,
        "writeable": true
    }
}
```

(continues on next page)
These functions can be used from a top-level project CMakeLists.txt (get-started/hello_world/CMakeLists.txt):

```cpp
# ...
project(hello_world)
esefuse_get_json_summary(efuse_json)
esefuse_get_efuse(ret_data '${efuse_json}' "MAC" "value")
message("MAC:" ${ret_data})
```

The format of the value property is the same as shown in esefuse.py summary.

```
MAC:94:b9:7e:5a:6e:58 (CRC 0xe2 OK)
```

There is an example test system/efuse/CMakeLists.txt which adds a custom target efuse-summary. This allows you to run the idf.py efuse-summary command to read the required eFuses (specified in the efuse_names list) at any time, not just at project build time.

### Debug eFuse & Unit tests

**Virtual eFuses**  The Kconfig option `CONFIG_EFUSE_VIRTUAL` will virtualize eFuse values inside the eFuse Manager, so writes are emulated and no eFuse values are permanently changed. This can be useful for debugging app and unit tests. During startup, the eFuses are copied to RAM. All eFuse operations (read and write) are performed with RAM instead of the real eFuse registers.

In addition to the `CONFIG_EFUSE_VIRTUAL` option there is `CONFIG_EFUSE_VIRTUAL_KEEP_IN_FLASH` option that adds a feature to keep eFuses in flash memory. To use this mode the partition_table should have the efuse partition. partition.csv: "efuse_em, data, efuse, , 0x2000,". During startup, the eFuses are copied from flash or, in case if flash is empty, from real eFuse to RAM and then update flash. This option allows keeping eFuses after reboots (possible to test secure_boot and flash_encryption features with this option).

**Flash Encryption Testing**  Flash Encryption (FE) is a hardware feature that requires the physical burning of eFuses: key and FLASH_CRYPT_CNT. If FE is not actually enabled then enabling the `CONFIG_EFUSE_VIRTUAL_KEEP_IN_FLASH` option just gives testing possibilities and does not encrypt anything in the flash, even though the logs say encryption happens. The bootloader\_flash\_write() is adapted for this purpose. But if FE is already enabled on the chip and you run an application or bootloader created with the `CONFIG_EFUSE_VIRTUAL_KEEP_IN_FLASH` option then the flash encryption/decryption operations will work properly (data are encrypted as it is written into an encrypted flash partition and decrypted when they are read from an encrypted partition).

**esefuse.py**  esptool includes a useful tool for reading/writing ESP32 eFuse bits - esefuse.py.

```
esefuse.py -p PORT summary
esefuse.py v4.6-dev
Connecting....
Detecting chip type... Unsupported detection protocol, switching and trying again...
Connecting....
Detecting chip type... ESP32
--- Run "summary" command ---
EFUSE_NAME (Block) Description = [Meaningful Value] [Readable/Writeable] (Hex_Value)
```

(continues on next page)
Calibration fuses:
ADC_VREF (BLOCK0) = 1121 R/W (0b00011)
Config fuses:
WR_DIS (BLOCK0) = 0 R/W (0x0000)
RD_DIS (BLOCK0) = 0 R/W (0x0)
DISABLE_APP_CPU (BLOCK0) = False R/W (0b0)
DISABLE_BT (BLOCK0) = False R/W (0b0)
DIS_CACHE (BLOCK0) = False R/W (0b0)
CHIP_CPU_FREQ_LOW (BLOCK0) = False R/W (0b0)
chip_freq_rated: False R/W (0b0)
chip_cpu_freq_rated (BLOCK0) = True R/W (0b1)
BLK3_PART_RESERVE (BLOCK0) = False R/W (0b0)
CLK8M_FREQ (BLOCK0) = 51 R/W (0x33)
VOL_LEVEL_HP_INV (BLOCK0) = 0 R/W (0b0), (0x0), level 7; (0x1); level 6; (0x2)
CHIP_Crypt_CNT (BLOCK0) = 0 R/W (0b000000)
CHIP_Crypt_CONFIG (BLOCK0) = 0 R/W (0x0)
Identity fuses:
CHIP_PACKAGE_4BIT (BLOCK0) = False R/W (0b0)
CHIP_PACKAGE (BLOCK0) = 1 R/W (0b001)
CHIP_VER_REV1 (BLOCK0) = True R/W (0b1)
CHIP_VER_REV2 (BLOCK0) = True R/W (0b1)
WAFER_VERSION_MINOR (BLOCK0) = 0 R/W (0b00)
Chapter 2. API Reference

WAVER_VERSION_MAJOR (BLOCK0) calc WAVER VERSION MAJOR from_
→ CHIP_VER_REV1 and CH = 3 R/W (0b011)
→ (read only)
PKG_VERSION (BLOCK0)
→ PACKAGE_4BIT << 3 + CHIP_ = 1 R/W (0x1)
→ (read only)

Jtag fuses:
JTAG_DISABLE (BLOCK0) Disable JTAG
→ = False R/W (0b0)

Mac fuses:
MAC (BLOCK0)
→ = 94:b9:7e:5a:6e:58 (CRC 0xe2 OK) R/W
MAC_CRC (BLOCK0)
→ = 226 R/W (0x1)
MAC_VERSION (BLOCK3)
→ = 0 R/W (0x00)

Security fuses:
UART_DOWNLOAD_DIS (BLOCK0) Disable UART download mode...
→ = False R/W (0b0)

ABS_DONE_0 (BLOCK0)
→ bootloader image = False R/W (0b0)
ABS_DONE_1 (BLOCK0)
→ bootloader image = False R/W (0b0)
DISABLE_DL_ENCRYPT (BLOCK0)
→ UART bootloader = False R/W (0b0)
DISABLE_DL_DECRYPT (BLOCK0)
→ UART bootloader = False R/W (0b0)
KEY_STATUS (BLOCK0)
→ (reserved) = False R/W (0b0)
SECURE_VERSION (BLOCK3)
→ = 0 R/W (0x00000000)

BLOCK1 (BLOCK1)
→ = 0 R/W (0x00000000)

BLOCK2 (BLOCK2)
→ = 0 R/W (0x00000000)

BLOCK3 (BLOCK3)
→ = 0 R/W (0x00000000)

Spi Pad fuses:
SPI_PAD_CONFIG_HD (BLOCK0) read for SPI_pad_config_hd
→ = 0 R/W (0b000000)
SPI_PAD_CONFIG_CLK (BLOCK0)
→ = 0 R/W (0b000000)
SPI_PAD_CONFIG_Q (BLOCK0)
→ = 0 R/W (0b000000)
SPI_PAD_CONFIG_CS0 (BLOCK0)
→ = 0 R/W (0b000000)

Vdd fuses:
XPD_SDIO_REG (BLOCK0) read for XPD_SDIO_REG
→ = False R/W (0b0)

(continues on next page)
XPD_SDIO_TIEH (BLOCK0) If XPD_SDIO_FORCE & XPD_SDIO__
→REG = 1.8V R/W (0b0)
XPD_SDIO_FORCE (BLOCK0) Ignore MTDI pin (GPIO12) for_
→VDD_SDIO on reset = False R/W (0b0)

Flash voltage (VDD_SDIO) determined by GPIO12 on reset (High for 1.8V, Low/NC for_
→3.3V)

To get a dump for all eFuse registers.

esefuse.py -p PORT dump
esefuse.py v4.6-dev
Connecting....
Detecting chip type... Unsupported detection protocol, switching and trying again..
→
Connecting....
Detecting chip type... ESP32
BLOCK0 ( ) [0 ] read_regs: 00000000 7e5a6e58 00e294b9_
→0000a200 00000333 00100000 00000004
BLOCK1 (flash_encryption) [1 ] read_regs: 00000000 00000000 00000000_
→00000000 00000000 00000000 00000000
BLOCK2 (secure_boot_v1 s) [2 ] read_regs: 00000000 00000000 00000000_
→00000000 00000000 00000000 00000000
BLOCK3 ( ) [3 ] read_regs: 00000000 00000000 00000000_
→00000000 00000000 00000000 00000000

EFUSE_REG_DEC_STATUS 0x00000000

--- Run "dump" command ---

Header File

- components/efuse/esp32/include/esp_efuse_chip.h

Enumerations

eum esp_efuse_block_t

Type of eFuse blocks for ESP32.

Values:

enumerator EFUSE_BLK0

Number of eFuse block. Reserved.

enumerator EFUSE_BLK1

Number of eFuse block. Used for Flash Encryption. If not using that Flash Encryption feature, they can be used for another purpose.

enumerator EFUSE_BLK_KEY0

Number of eFuse block. Used for Flash Encryption. If not using that Flash Encryption feature, they can be used for another purpose.

enumerator EFUSE_BLK_ENCRYPT_FLASH

Number of eFuse block. Used for Flash Encryption. If not using that Flash Encryption feature, they can be used for another purpose.
enumerator **EFUSE_BLK2**
   Number of eFuse block. Used for Secure Boot. If not using that Secure Boot feature, they can be used for another purpose.

enumerator **EFUSE_BLK_KEY1**
   Number of eFuse block. Used for Secure Boot. If not using that Secure Boot feature, they can be used for another purpose.

enumerator **EFUSE_BLK_SECURE_BOOT**
   Number of eFuse block. Used for Secure Boot. If not using that Secure Boot feature, they can be used for another purpose.

enumerator **EFUSE_BLK3**
   Number of eFuse block. Uses for the purpose of the user.

enumerator **EFUSE_BLK_KEY2**
   Number of eFuse block. Uses for the purpose of the user.

enumerator **EFUSE_BLK_KEY_MAX**

enumerator **EFUSE_BLK_MAX**

enum **esp_efuse_coding_scheme_t**
   Type of coding scheme.
   **Values:**

   enumerator **EFUSE_CODING_SCHEME_NONE**
      None

   enumerator **EFUSE_CODING_SCHEME_3_4**
      3/4 coding

   enumerator **EFUSE_CODING_SCHEME_REPEAT**
      Repeat coding

enum **esp_efuse_purpose_t**
   Type of key purpose (virtual because ESP32 has only fixed purposes for blocks)
   **Values:**

   enumerator **ESP_EFUSE_KEY_PURPOSE_USER**
      BLOCK3

   enumerator **ESP_EFUSE_KEY_PURPOSE_SYSTEM**
      BLOCK0

   enumerator **ESP_EFUSE_KEY_PURPOSE_FLASH_ENCRYPTION**
      BLOCK1
Chapter 2. API Reference

enumerator ESP_EFUSE_KEY_PURPOSE_SECURE_BOOT_V2
    BLOCK2

enumerator ESP_EFUSE_KEY_PURPOSE_MAX
    MAX PURPOSE

Header File

- components/efuse/include/esp_efuse.h

Functions

```c
esp_err_t esp_efuse_read_field_blob(const esp_efuse_desc_t *field[], void* dst, size_t dst_size_bits)
```

Reads bits from EFUSE field and writes it into an array. The number of read bits will be limited to the minimum value from the description of the bits in “field” structure or “dst_size_bits” required size. Use “esp_efuse_get_field_size()” function to determine the length of the field.

**Note:** Please note that reading in the batch mode does not show uncommitted changes.

**Parameters**
- `field` [in] A pointer to the structure describing the fields of efuse.
- `dst` [out] A pointer to array that will contain the result of reading.
- `dst_size_bits` [in] The number of bits required to read. If the requested number of bits is greater than the field, the number will be limited to the field size.

**Returns**
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.

```c
bool esp_efuse_read_field_bit(const esp_efuse_desc_t *field[])
```

Read a single bit eFuse field as a boolean value.

**Note:** The value must exist and must be a single bit wide. If there is any possibility of an error in the provided arguments, call `esp_efuse_read_field_blob()` and check the returned value instead.

**Note:** If assertions are enabled and the parameter is invalid, execution will abort

**Note:** Please note that reading in the batch mode does not show uncommitted changes.

**Parameters**
- `field` [in] A pointer to the structure describing the fields of efuse.

**Returns**
- `true`: The field parameter is valid and the bit is set.
- `false`: The bit is not set, or the parameter is invalid and assertions are disabled.

```c
esp_err_t esp_efuse_read_field_cnt(const esp_efuse_desc_t *field[], size_t *out_cnt)
```

Reads bits from EFUSE field and returns number of bits programmed as “1”. If the bits are set not sequentially, they will still be counted.
Chapter 2. API Reference

Note: Please note that reading in the batch mode does not show uncommitted changes.

Parameters
- **field** - [in] A pointer to the structure describing the fields of efuse.
- **out_cnt** - [out] A pointer that will contain the number of programmed as “1” bits.

Returns
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.

`esp_err_t esp_efuse_write_field_blob` (const `esp_efuse_desc_t *field[]`, const void *src, size_t src_size_bits)

Writes array to EFUSE field.

The number of write bits will be limited to the minimum value from the description of the bits in “field” structure or “src_size_bits” required size. Use “esp_efuse_get_field_size()” function to determine the length of the field. After the function is completed, the writing registers are cleared.

Parameters
- **field** - [in] A pointer to the structure describing the fields of efuse.
- **src** - [in] A pointer to array that contains the data for writing.
- **src_size_bits** - [in] The number of bits required to write.

Returns
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.
- ESP_ERR_EFUSE_CNT_IS_FULL: Not all requested cnt bits is set.

`esp_err_t esp_efuse_write_field_cnt` (const `esp_efuse_desc_t *field[]`, size_t cnt)

Writes a required count of bits as “1” to EFUSE field.

If there are no free bits in the field to set the required number of bits to “1”, ESP_ERR_EFUSE_CNT_IS_FULL error is returned, the field will not be partially recorded. After the function is completed, the writing registers are cleared.

Parameters
- **field** - [in] A pointer to the structure describing the fields of efuse.
- **cnt** - [in] Required number of programmed as “1” bits.

Returns
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_EFUSE_CNT_IS_FULL: Not all requested cnt bits is set.

`esp_err_t esp_efuse_write_field_bit` (const `esp_efuse_desc_t *field[]`)

Write a single bit eFuse field to 1.

For use with eFuse fields that are a single bit. This function will write the bit to value 1 if it is not already set, or does nothing if the bit is already set.

This is equivalent to calling esp_efuse_write_field_cnt() with the cnt parameter equal to 1, except that it will return ESP_OK if the field is already set to 1.

Parameters **field** - [in] Pointer to the structure describing the eFuse field.

Returns
- ESP_OK: The operation was successfully completed, or the bit was already set to value 1.
- ESP_ERR_INVALID_ARG: Error in the passed arguments, including if the eFuse field is not 1 bit wide.

`esp_err_t esp_efuse_set_write_protect` (esp_efuse_block_t blk)

Sets a write protection for the whole block.
After that, it is impossible to write to this block. The write protection does not apply to block 0.

**Parameters**
- `blk` - [in] Block number of eFuse. (EFUSE_BLK1, EFUSE_BLK2 and EFUSE_BLK3)

**Returns**
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_EFUSE_CNT_IS_FULL: Not all requested cnt bits is set.
- ESP_ERR_NOT_SUPPORTED: The block does not support this command.

```c
esp_err_t esp_efuse_set_read_protect(esp_efuse_block_t blk)
```

Sets a read protection for the whole block.

After that, it is impossible to read from this block. The read protection does not apply to block 0.

**Parameters**
- `blk` - [in] Block number of eFuse. (EFUSE_BLK1, EFUSE_BLK2 and EFUSE_BLK3)

**Returns**
- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_EFUSE_CNT_IS_FULL: Not all requested cnt bits is set.
- ESP_ERR_NOT_SUPPORTED: The block does not support this command.

```c
int esp_efuse_get_field_size(const esp_efuse_desc_t *field[])
```

Returns the number of bits used by field.

**Parameters**
- `field` - [in] A pointer to the structure describing the fields of efuse.

**Returns**
Returns the number of bits used by field.

```c
uint32_t esp_efuse_read_reg(esp_efuse_block_t blk, unsigned int num_reg)
```

Returns value of efuse register.

This is a thread-safe implementation. Example: EFUSE_BLK2_RDATA3_REG where (blk=2, num_reg=3)

**Note:** Please note that reading in the batch mode does not show uncommitted changes.

```c
esp_err_t esp_efuse_write_reg(esp_efuse_block_t blk, unsigned int num_reg, uint32_t val)
```

Write value to efuse register.

Apply a coding scheme if necessary. This is a thread-safe implementation. Example: EFUSE_BLK3_WDATA0_REG where (blk=3, num_reg=0)

**Parameters**
- `blk` - [in] Block number of eFuse.
- `num_reg` - [in] The register number in the block.

**Returns**
- ESP_OK: The operation was successfully completed.
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.

```c
esp_efuse_coding_scheme_t esp_efuse_get_coding_scheme(esp_efuse_block_t blk)
```

Return efuse coding scheme for blocks.

**Note:** The coding scheme is applicable only to 1, 2 and 3 blocks. For 0 block, the coding scheme is always NONE.
**Parameters**  
 blk – [in] Block number of eFuse.  

**Returns**  
 Return efuse coding scheme for blocks

```c
esp_err_t esp_efuse_read_block(esp_efuse_block_t blk, void *dst_key, size_t offset_in_bits, size_t size_bits)
```

Read key to efuse block starting at the offset and the required size.

**Note:** Please note that reading in the batch mode does not show uncommitted changes.

**Parameters**
• blk – [in] Block number of eFuse.
• dst_key – [in] A pointer to array that will contain the result of reading.
• size_bits – [in] The number of bits required to read.

**Returns**
• ESP_OK: The operation was successfully completed.
• ESP_ERR_INVALID_ARG: Error in the passed arguments.
• ESP_ERR_CODING: Error range of data does not match the coding scheme.

```c
esp_err_t esp_efuse_write_block(esp_efuse_block_t blk, const void *src_key, size_t offset_in_bits, size_t size_bits)
```

Write key to efuse block starting at the offset and the required size.

**Parameters**
• blk – [in] Block number of eFuse.
• src_key – [in] A pointer to array that contains the key for writing.
• size_bits – [in] The number of bits required to write.

**Returns**
• ESP_OK: The operation was successfully completed.
• ESP_ERR_INVALID_ARG: Error in the passed arguments.
• ESP_ERR_CODING: Error range of data does not match the coding scheme.
• ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits

```c
uint32_t esp_efuse_get_pkg_ver(void)
```

Returns chip package from efuse.

**Returns**  
 chip package

```c
void esp_efuse_reset(void)
```

Reset efuse write registers.

Efuse write registers are written to zero, to negate any changes that have been staged here.

**Note:** This function is not threadsafe, if calling code updates efuse values from multiple tasks then this is caller’s responsibility to serialise.

```c
void esp_efuse_disable_basic_rom_console(void)
```

Disable BASIC ROM Console via efuse.

By default, if booting from flash fails the ESP32 will boot a BASIC console in ROM.

Call this function (from bootloader or app) to permanently disable the console on this chip.

```c
esp_err_t esp_efuse_disable_rom_download_mode(void)
```

Disable ROM Download Mode via eFuse.
Permanently disables the ROM Download Mode feature. Once disabled, if the SoC is booted with strapping pins set for ROM Download Mode then an error is printed instead.

**Note:** Not all SoCs support this option. An error will be returned if called on an ESP32 with a silicon revision lower than 3, as these revisions do not support this option.

**Note:** If ROM Download Mode is already disabled, this function does nothing and returns success.

### Returns
- ESP_OK If the eFuse was successfully burned, or had already been burned.
- ESP_ERR_NOT_SUPPORTED (ESP32 only) This SoC is not capable of disabling UART download mode
- ESP_ERR_INVALID_STATE (ESP32 only) This eFuse is write protected and cannot be written

```c
esp_err_t esp_efuse_set_rom_log_scheme (esp_efuse_rom_log_scheme_t log_scheme)
```

Set boot ROM log scheme via eFuse.

**Note:** By default, the boot ROM will always print to console. This API can be called to set the log scheme only once per chip, once the value is changed from the default it can’t be changed again.

### Parameters
- **log_scheme** – Supported ROM log scheme

### Returns
- ESP_OK If the eFuse was successfully burned, or had already been burned.
- ESP_ERR_NOT_SUPPORTED (ESP32 only) This SoC is not capable of setting ROM log scheme
- ESP_ERR_INVALID_STATE This eFuse is write protected or has been burned already

```c
uint32_t esp_efuse_read_secure_version (void)
```

Return secure_version from efuse field.

**Returns** Secure version from efuse field

```c
bool esp_efuse_check_secure_version (uint32_t secure_version)
```

Check secure_version from app and secure_version and from efuse field.

**Parameters**
- **secure_version** – Secure version from app.

**Returns**
- True: If version of app is equal or more then secure_version from efuse.

```c
esp_err_t esp_efuse_update_secure_version (uint32_t secure_version)
```

Write efuse field by secure_version value.

Update the secure_version value is available if the coding scheme is None. Note: Do not use this function in your applications. This function is called as part of the other API.

**Parameters**
- **secure_version** – [in] Secure version from app.

**Returns**
- ESP_OK: Successful.
- ESP_FAIL: secure version of app cannot be set to efuse field.
- ESP_ERR_NOT_SUPPORTED: Anti rollback is not supported with the 3/4 and Repeat coding scheme.
**esp_err_t** esp_efuse_batch_write_begin (void)

Set the batch mode of writing fields.

This mode allows you to write the fields in the batch mode when need to burn several efuses at one time. To enable batch mode call begin() then perform as usually the necessary operations read and write and at the end call commit() to actually burn all written efuses. The batch mode can be used nested. The commit will be done by the last commit() function. The number of begin() functions should be equal to the number of commit() functions.

Note: If batch mode is enabled by the first task, at this time the second task cannot write/read efuses. The second task will wait for the first task to complete the batch operation.

```c
// Example of using the batch writing mode.

// set the batch writing mode
esp_efuse_batch_write_begin();

// use any writing functions as usual
esp_efuse_write_field_blob(ESP_EFUSE_...);
esp_efuse_write_field_cnt(ESP_EFUSE_...);
esp_efuse_set_write_protect(EFUSE_BLKx);
esp_efuse_write_reg(EFUSE_BLKx, ...);
esp_efuse_write_block(EFUSE_BLKx, ...);
esp_efuse_write(ESP_EFUSE_1, 3);    // ESP_EFUSE_1 == 1, here we write a new
    --> value = 3. The changes will be burn by the commit() function.
esp_efuse_read...(ESP_EFUSE_1);    // this function returns ESP_EFUSE_1 == 1
    --> because uncommitted changes are not readable, it will be available only
        --> after commit.
...

// esp_efuse_batch_write APIs can be called recursively.

esp_efuse_batch_write_begin();
esp_efuse_set_write_protect(EFUSE_BLKx);
esp_efuse_batch_write_commit();    // the burn will be skipped here, it will be...
                                    --> done in the last commit().
...

// Write all of these fields to the efuse registers

esp_efuse_batch_write_commit();
esp_efuse_read...(ESP_EFUSE_1);    // this function returns ESP_EFUSE_1 == 3.
```

**Note:** Please note that reading in the batch mode does not show uncommitted changes.

**Returns**

- ESP_OK: Successful.

**esp_err_t** esp_efuse_batch_write_cancel (void)

Reset the batch mode of writing fields.

It will reset the batch writing mode and any written changes.

**Returns**

- ESP_OK: Successful.
- ESP_ERR_INVALID_STATE: Tha batch mode was not set.
### `esp_err_t esp_efuse_batch_write_commit(void)`

Writes all prepared data for the batch mode.

Must be called to ensure changes are written to the Efuse registers. After this the batch writing mode will be reset.

**Returns**
- ESP_OK: Successful.
- ESP_ERR_INVALID_STATE: The deferred writing mode was not set.

### `bool esp_efuse_block_is_empty(esp_efuse_block_t block)`

Checks that the given block is empty.

**Returns**
- True: The block is empty.
- False: The block is not empty or was an error.

### `bool esp_efuse_get_key_dis_read(esp_efuse_block_t block)`

Returns a read protection for the key block.

**Parameters**
- `block` [in] A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**Returns**
- True: The key block is read protected
- False: The key block is readable.

### `esp_err_t esp_efuse_set_key_dis_read(esp_efuse_block_t block)`

Sets a read protection for the key block.

**Parameters**
- `block` [in] A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**Returns**
- ESP_OK: Successful.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.
- ESP_ERR_CODING: Error range of data does not match the coding scheme.

### `bool esp_efuse_get_key_dis_write(esp_efuse_block_t block)`

Returns a write protection for the key block.

**Parameters**
- `block` [in] A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**Returns**
- True: The key block is write protected
- False: The key block is writeable.

### `esp_err_t esp_efuse_set_key_dis_write(esp_efuse_block_t block)`

Sets a write protection for the key block.

**Parameters**
- `block` [in] A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**Returns**
- ESP_OK: Successful.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.
- ESP_ERR_CODING: Error range of data does not match the coding scheme.

### `bool esp_efuse_key_block_unused(esp_efuse_block_t block)`

Returns true if the key block is unused, false otherwise.

An unused key block is all zero content, not read or write protected, and has purpose 0 (ESP_EFUSE_KEY_PURPOSE_USER)

**Parameters**
- `block` [key block to check.

**Returns**
- True if key block is unused.
- False if key block is used or the specified block index is not a key block.

### `bool esp_efuse_find_purpose(esp_efuse_purpose_t purpose, esp_efuse_block_t *block)`

Find a key block with the particular purpose set.
Chapter 2. API Reference

Parameters

- **purpose**  
  *in* Purpose to search for.
- **block**  
  *out* Pointer in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX which will be set to the key block if found. Can be NULL, if only need to test the key block exists.

Returns

- True: If found,
- False: If not found (value at block pointer is unchanged).

```
bool esp_efuse_get_keypurpose_dis_write(esp_efuse_block_t block)
```

Returns a write protection of the key purpose field for an efuse key block.

Note: For ESP32: no keypurpose, it returns always True.

Parameters **block**  
*in* A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

Returns True: The key purpose is write protected. False: The key purpose is writeable.

```
esp_efuse_purpose_t esp_efuse_get_key_purpose(esp_efuse_block_t block)
```

Returns the current purpose set for an efuse key block.

Parameters **block**  
*in* A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

Returns

- Value: If Successful, it returns the value of the purpose related to the given key block.
- ESP_EFUSE_KEY_PURPOSE_MAX: Otherwise.

```
esp_err_t esp_efuse_write_key(esp_efuse_block_t block, esp_efuse_purpose_t purpose, const void* key, size_t key_size_bytes)
```

Program a block of key data to an efuse block.

The burn of a key, protection bits, and a purpose happens in batch mode.

Parameters

- **block**  
  *in* Block to read purpose for. Must be in range EFUSE_BLK_KEY0 to EFUSE_BLK_KEY_MAX. Key block must be unused (esp_efuse_key_block_unused).
- **purpose**  
  *in* Purpose to set for this key. Purpose must be already unset.
- **key**  
  *in* Pointer to data to write.
- **key_size_bytes**  
  *in* Bytes length of data to write.

Returns

- ESP_OK: Successful.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
- ESP_ERR_INVALID_STATE: Error in efuses state, unused block not found.
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.
- ESP_ERR_CODING: Error range of data does not match the coding scheme.

```
esp_err_t esp_efuse_write_keys(const esp_efuse_purpose_t purposes[], uint8_t keys[][32], unsigned number_of_keys)
```

Program keys to unused efuse blocks.

The burn of keys, protection bits, and purposes happens in batch mode.

Parameters

- **purposes**  
  *in* Array of purposes (purpose[number_of_keys]).
- **keys**  
  *in* Array of keys (uint8_t keys[number_of_keys][32]). Each key is 32 bytes long.
- **number_of_keys**  
  *in* The number of keys to write (up to 6 keys).

Returns

- ESP_OK: Successful.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.
Chapter 2. API Reference

- ESP_ERR_INVALID_STATE: Error in efuses state, unused block not found.
- ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS: Error not enough unused key blocks available
- ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.
- ESP_ERR_CODING: Error range of data does not match the coding scheme.

`esp_err_t esp_efuse_check_errors (void)`

Checks eFuse errors in BLOCK0.

It does a BLOCK0 check if eFuse EFUSE_ERR_RST_ENABLE is set. If BLOCK0 has an error, it prints the error and returns ESP_FAIL, which should be treated as esp_restart.

**Note:** Refers to ESP32-C3 only.

**Returns**
- ESP_OK: No errors in BLOCK0.
- ESP_FAIL: Error in BLOCK0 requiring reboot.

**Structures**

```c
struct esp_efuse_desc_t
```
Type definition for an eFuse field.

**Public Members**

```c
esp_efuse_block_t efuse_block
```
Block of eFuse

```c
uint8_t bit_start
```
Start bit [0..255]

```c
uint16_t bit_count
```
Length of bit field [1-]

**Macros**

`ESP_ERR_EFUSE`
Base error code for efuse api.

`ESP_OK_EFUSE_CNT`
OK the required number of bits is set.

`ESP_ERR_EFUSE_CNT_IS_FULL`
Error field is full.

`ESP_ERR_EFUSE_REPEATED_PROG`
Error repeated programming of programmed bits is strictly forbidden.
Chapter 2. API Reference

ESP_ERR_CODING
Error while a encoding operation.

ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS
Error not enough unused key blocks available

ESP_ERR_DAMAGED_READING
Error. Burn or reset was done during a reading operation leads to damage read data. This error is internal to the efuse component and not returned by any public API.

Enumerations
enum esp_efuse_rom_log_scheme_t
Type definition for ROM log scheme.

Values:

enumerator ESP_EFUSE_ROM_LOG_ALWAYS_ON
    Always enable ROM logging

enumerator ESP_EFUSE_ROM_LOG_ON_GPIO_LOW
    ROM logging is enabled when specific GPIO level is low during start up

enumerator ESP_EFUSE_ROM_LOG_ON_GPIO_HIGH
    ROM logging is enabled when specific GPIO level is high during start up

enumerator ESP_EFUSE_ROM_LOG_ALWAYS_OFF
    Disable ROM logging permanently

2.10.7 Error Codes and Helper Functions

This section lists definitions of common ESP-IDF error codes and several helper functions related to error handling.

For general information about error codes in ESP-IDF, see Error Handling.

For the full list of error codes defined in ESP-IDF, see Error Code Reference.

API Reference

Header File

• components/esp_common/include/esp_check.h

Macros

ESP_RETURN_ON_ERROR(x, log_tag, format, ...)
Macro which can be used to check the error code. If the code is not ESP_OK, it prints the message and returns. In the future, we want to switch to C++20. We also want to become compatible with clang. Hence, we provide two versions of the following macros. The first one is using the GNU extension ##__VA_ARGS__. The second one is using the C++20 feature VA_OPT(.). This allows users to compile their code with standard C++20 enabled instead of the GNU extension. Below C++20, we haven’t found any good alternative to using ##__VA_ARGS__. Macro which can be used to check the error code. If the code is not ESP_OK, it prints the message and returns.
ESP_RETURN_ON_ERROR_ISR(x, log_tag, format, ...)
A version of ESP_RETURN_ON_ERROR() macro that can be called from ISR.

ESP_GOTO_ON_ERROR(x, goto_tag, log_tag, format, ...)
Macro which can be used to check the error code. If the code is not ESP_OK, it prints the message, sets the
local variable ‘ret’ to the code, and then exits by jumping to ‘goto_tag’.

ESP_GOTO_ON_ERROR_ISR(x, goto_tag, log_tag, format, ...)
A version of ESP_GOTO_ON_ERROR() macro that can be called from ISR.

ESP_RETURN_ON_FALSE(a, err_code, log_tag, format, ...)
Macro which can be used to check the condition. If the condition is not ‘true’, it prints the message and
returns with the supplied ‘err_code’.

ESP_RETURN_ON_FALSE_ISR(a, err_code, goto_tag, log_tag, format, ...)
A version of ESP_RETURN_ON_FALSE() macro that can be called from ISR.

ESP_GOTO_ON_FALSE(a, err_code, goto_tag, log_tag, format, ...)
Macro which can be used to check the condition. If the condition is not ‘true’, it prints the message, sets
the local variable ‘ret’ to the supplied ‘err_code’ and then exits by jumping to ‘goto_tag’.

ESP_GOTO_ON_FALSE_ISR(a, err_code, goto_tag, log_tag, format, ...)
A version of ESP_GOTO_ON_FALSE() macro that can be called from ISR.

Header File

- components/esp_common/include/esp_err.h

Functions

const char *esp_err_to_name(esp_err_t code)
Returns string for esp_err_t error codes.

This function finds the error code in a pre-generated lookup-table and returns its string representation.
The function is generated by the Python script tools/gen_esp_err_to_name.py which should be run each time
an esp_err_t error is modified, created or removed from the IDF project.

Parameters
code – esp_err_t error code

Returns string error message

const char *esp_err_to_name_r(esp_err_t code, char *buf, size_t buflen)
Returns string for esp_err_t and system error codes.

This function finds the error code in a pre-generated lookup-table of esp_err_t errors and returns its string
representation. If the error code is not found then it is attempted to be found among system errors.
The function is generated by the Python script tools/gen_esp_err_to_name.py which should be run each time
an esp_err_t error is modified, created or removed from the IDF project.

Parameters
code – esp_err_t error code
buf – [out] buffer where the error message should be written
buflen – Size of buffer buf. At most buflen bytes are written into the buf buffer (including
the terminating null byte).

Returns buf containing the string error message

Macros

ESP_OK
esp_err_t value indicating success (no error)
**ESP_FAIL**
Generic esp_err_t code indicating failure

**ESP_ERR_NO_MEM**
Out of memory

**ESP_ERR_INVALID_ARG**
Invalid argument

**ESP_ERR_INVALID_STATE**
Invalid state

**ESP_ERR_INVALID_SIZE**
Invalid size

**ESP_ERR_NOT_FOUND**
Requested resource not found

**ESP_ERR_NOT_SUPPORTED**
Operation or feature not supported

**ESP_ERR_TIMEOUT**
Operation timed out

**ESP_ERR_INVALID_RESPONSE**
Received response was invalid

**ESP_ERR_INVALID_CRC**
CRC or checksum was invalid

**ESP_ERR_INVALID_VERSION**
Version was invalid

**ESP_ERR_INVALID_MAC**
MAC address was invalid

**ESP_ERR_NOT_FINISHED**
There are items remained to retrieve

**ESP_ERR_WIFI_BASE**
Starting number of WiFi error codes

**ESP_ERR_MESH_BASE**
Starting number of MESH error codes

**ESP_ERR_FLASH_BASE**
Starting number of flash error codes
Chapter 2. API Reference

ESP_ERR_HW_CRYPTO_BASE
Starting number of HW cryptography module error codes

ESP_ERR_MEMPROT_BASE
Starting number of Memory Protection API error codes

ESP_ERROR_CHECK(x)
Macro which can be used to check the error code, and terminate the program in case the code is not ESP_OK. Prints the error code, error location, and the failed statement to serial output. Disabled if assertions are disabled.

ESP_ERROR_CHECK_WITHOUT_ABORT(x)
Macro which can be used to check the error code. Prints the error code, error location, and the failed statement to serial output. In comparison with ESP_ERROR_CHECK(), this prints the same error message but isn’t terminating the program.

Type Definitions
typedef int esp_err_t

2.10.8 ESP HTTPS OTA

Overview

esp_https_ota provides simplified APIs to perform firmware upgrades over HTTPS. It’s an abstraction layer over existing OTA APIs.

Application Example

```c
esp_err_t do_firmware_upgrade()
{
    esp_http_client_config_t config = {
        .url = CONFIG_FIRMWARE_UPGRADE_URL,
        .cert_pem = (char *)server_cert_pem_start,
    };
    esp_https_ota_config_t ota_config = {
        .http_config = &config,
    };
    esp_err_t ret = esp_https_ota(&ota_config);
    if (ret == ESP_OK) {
        esp_restart();
    } else {
        return ESP_FAIL;
    }
    return ESP_OK;
}
```

Server Verification

Please refer to ESP-TLS: TLS Server Verification for more information on server verification. The root certificate (in PEM format) needs to be provided to the esp_http_client_config_t::cert_pem member.

**Note:** The server-endpoint root certificate should be used for verification instead of any intermediate ones from the certificate chain. The reason being that the root certificate has the maximum validity
and usually remains the same for a long period of time. Users can also use the ESP x509 Certificate Bundle feature for verification, which covers most of the trusted root certificates (using the esp_http_client_config_t::crt_bundle_attach member).

**Partial Image Download over HTTPS**

To use partial image download feature, enable `partial_http_download` configuration in esp_https_ota_config_t. When this configuration is enabled, firmware image will be downloaded in multiple HTTP requests of specified size. Maximum content length of each request can be specified by setting `max_http_request_size` to required value.

This option is useful while fetching image from a service like AWS S3, where mbedTLS Rx buffer size (`CONFIG_MBEDTLS_SSL_IN_CONTENT_LEN`) can be set to lower value which is not possible without enabling this configuration.

Default value of mbedTLS Rx buffer size is set to 16K. By using partial_http_download with `max_http_request_size` of 4K, size of mbedTLS Rx buffer can be reduced to 4K. With this configuration, memory saving of around 12K is expected.

**Signature Verification**

For additional security, signature of OTA firmware images can be verified. For that, refer *Secure OTA Updates Without Secure boot*

**Advanced APIs**

`esp_https_ota` also provides advanced APIs which can be used if more information and control is needed during the OTA process.

Example that uses advanced ESP_HTTPS_OTA APIs: `system/ota/advanced_https_ota`.

**OTA Upgrades with Pre-Encrypted Firmware**

To perform OTA upgrades with Pre-Encrypted Firmware, please enable `CONFIG_ESP_HTTPS_OTA_DECRYPT_CB` in component menuconfig.

Example that performs OTA upgrade with Pre-Encrypted Firmware: `system/ota/pre_encrypted_ota`.

**OTA System Events**

ESP HTTPS OTA has various events for which a handler can be triggered by the Event Loop library when the particular event occurs. The handler has to be registered using `esp_event_handler_register()`. This helps in event handling for ESP HTTPS OTA. `esp_https_ota_event_t` has all the events which can happen when performing OTA upgrade using ESP HTTPS OTA.

**Event Handler Example**

```c
/* Event handler for catching system events */
static void event_handler(void* arg, esp_event_base_t event_base, int32_t event_id, void* event_data) {
    if (event_base == ESP_HTTPS_OTA_EVENT) {
        switch (event_id) {
            case ESP_HTTPS_OTA_START:
                ESP_LOGI(TAG, "OTA started");
                break;
            // other cases...
        }
    }
}
```

(continues on next page)
break;
case ESP_HTTPS_OTA_CONNECTED:
    ESP_LOGI(TAG, "Connected to server");
    break;
case ESP_HTTPS_OTA_GET_IMG_DESC:
    ESP_LOGI(TAG, "Reading Image Description");
    break;
case ESP_HTTPS_OTA_VERIFY_CHIP_ID:
    ESP_LOGI(TAG, "Verifying chip id of new image: %d", *(esp_
        --chip_id_t *)event_data);
    break;
case ESP_HTTPS_OTA_DECRYPT_CB:
    ESP_LOGI(TAG, "Callback to decrypt function");
    break;
case ESP_HTTPS_OTA_WRITE_FLASH:
    ESP_LOGD(TAG, "Writing to flash: %d written", *(int_
        --*)event_data);
    break;
case ESP_HTTPS_OTA_UPDATE_BOOT_PARTITION:
    ESP_LOGI(TAG, "Boot partition updated. Next Partition: %d
    ", *(esp_partition_subtype_t *)event_data);
    break;
case ESP_HTTPS_OTA_FINISH:
    ESP_LOGI(TAG, "OTA finish");
    break;
case ESP_HTTPS_OTA_ABORT:
    ESP_LOGI(TAG, "OTA abort");
    break;
}
}

Expected data type for different ESP HTTPS OTA events in the system event loop:
- ESP_HTTPS_OTA_START: NULL
- ESP_HTTPS_OTA_CONNECTED: NULL
- ESP_HTTPS_OTA_GET_IMG_DESC: NULL
- ESP_HTTPS_OTA_VERIFY_CHIP_ID: esp_chip_id_t
- ESP_HTTPS_OTA_DECRYPT_CB: NULL
- ESP_HTTPS_OTA_WRITE_FLASH: int
- ESP_HTTPS_OTA_UPDATE_BOOT_PARTITION: esp_partition_subtype_t
- ESP_HTTPS_OTA_FINISH: NULL
- ESP_HTTPS_OTA_ABORT: NULL

API Reference

Header File
- components/esp_https_ota/include/esp_https_ota.h

Functions

`esp_err_t esp_https_ota (const esp_https_ota_config_t *ota_config)`

HTTPS OTA Firmware upgrade.

This function allocates HTTPS OTA Firmware upgrade context, establishes HTTPS connection, reads image
data from HTTP stream and writes it to OTA partition and finishes HTTPS OTA Firmware upgrade operation.
This API supports URL redirection, but if CA cert of URLs differ then it should be appended to cert_pem member of ota_config->http_config.
**Note:** This API handles the entire OTA operation, so if this API is being used then no other APIs from `esp_https_ota` component should be called. If more information and control is needed during the HTTPS OTA process, then one can use `esp_https_ota_begin` and subsequent APIs. If this API returns successfully, `esp_restart()` must be called to boot from the new firmware image.

**Parameters**

- `ota_config` - [in] pointer to `esp_https_ota_config_t` structure.

**Returns**

- `ESP_OK`: OTA data updated, next reboot will use specified partition.
- `ESP_FAIL`: For generic failure.
- `ESP_ERR_INVALID_ARG`: Invalid argument
- `ESP_ERR_OTA_VALIDATE_FAILED`: Invalid app image
- `ESP_ERR_NO_MEM`: Cannot allocate memory for OTA operation.
- `ESP_ERR_FLASH_OP_TIMEOUT` or `ESP_ERR_FLASH_OP_FAIL`: Flash write failed.
- For other return codes, refer OTA documentation in esp-idf’s `app_update` component.

```c
esp_err_t esp_https_ota_begin(const esp_https_ota_config_t *ota_config, esp_https_ota_handle_t *handle)
```

Start HTTPS OTA Firmware upgrade.

This function initializes ESP HTTPS OTA context and establishes HTTPS connection. This function must be invoked first. If this function returns successfully, then `esp_https_ota_perform` should be called to continue with the OTA process and there should be a call to `esp_https_ota_finish` on completion of OTA operation or on failure in subsequent operations. This API supports URL redirection, but if CA cert of URLs differ then it should be appended to `cert_pem` member of `http_config`, which is a part of `ota_config`. In case of error, this API explicitly sets `handle` to NULL.

**Note:** This API is blocking, so setting `is_async` member of `http_config` structure will result in an error.

**Parameters**

- `ota_config` - [in] pointer to `esp_https_ota_config_t` structure
- `handle` - [out] pointer to an allocated data of type `esp_https_ota_handle_t` which will be initialised in this function

**Returns**

- `ESP_ERR_HTTPS_OTA_IN_PROGRESS`: OTA update is in progress, call this API again to continue.
- `ESP_OK`: OTA update was successful
- `ESP_FAIL`: OTA update failed
- `ESP_ERR_INVALID_ARG`: Invalid argument
- `ESP_ERR_INVALID_VERSION`: Invalid chip revision in image header

```c
esp_err_t esp_https_ota_perform(esp_https_ota_handle_t https_ota_handle)
```

Read image data from HTTP stream and write it to OTA partition.

This function reads image data from HTTP stream and writes it to OTA partition. This function must be called only if `esp_https_ota_begin()` returns successfully. This function must be called in a loop since it returns after every HTTP read operation thus giving you the flexibility to stop OTA operation midway.

**Parameters**

- `https_ota_handle` - [in] pointer to `esp_https_ota_handle_t` structure

**Returns**

- `ESP_OK`: OTA update was successful
- `ESP_FAIL`: OTA update failed
- `ESP_ERR_HTTPS_OTA_IN_PROGRESS`: OTA update is in progress, call this API again to continue.
- `ESP_ERR_INVALID_ARG`: Invalid argument
- `ESP_ERR_INVALID_VERSION`: Invalid chip revision in image header
Chapter 2. API Reference

- ESP_ERR_OTA_VALIDATE_FAILED: Invalid app image
- ESP_ERR_NO_MEM: Cannot allocate memory for OTA operation.
- ESP_ERR_FLASH_OP_TIMEOUT or ESP_ERR_FLASH_OP_FAIL: Flash write failed.
- For other return codes, refer OTA documentation in esp-idf’s app_update component.

```c
bool esp_https_ota_is_complete_data_received(esp_https_ota_handle_t https_ota_handle)
```

Checks if complete data was received or not.

**Note:** This API can be called just before esp_https_ota_finish() to validate if the complete image was indeed received.

**Parameters**

- `https_ota_handle` - [in] pointer to esp_https_ota_handle_t structure

**Returns**

- false
- true

```c
esp_err_t esp_https_ota_finish(esp_https_ota_handle_t https_ota_handle)
```

Clean-up HTTPS OTA Firmware upgrade and close HTTPS connection.

This function closes the HTTP connection and frees the ESP HTTPS OTA context. This function switches the boot partition to the OTA partition containing the new firmware image.

**Note:** If this API returns successfully, esp_restart() must be called to boot from the new firmware image esp_https_ota_finish should not be called after calling esp_https_ota_abort

**Parameters**

- `https_ota_handle` - [in] pointer to esp_https_ota_handle_t structure

**Returns**

- ESP_OK: Clean-up successful
- ESP_ERR_INVALID_STATE
- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_ERR_OTA_VALIDATE_FAILED: Invalid app image

```c
esp_err_t esp_https_ota_abort(esp_https_ota_handle_t https_ota_handle)
```

Clean-up HTTPS OTA Firmware upgrade and close HTTPS connection.

This function closes the HTTP connection and frees the ESP HTTPS OTA context.

**Note:** esp_https_ota_abort should not be called after calling esp_https_ota_finish

**Parameters**

- `https_ota_handle` - [in] pointer to esp_https_ota_handle_t structure

**Returns**

- ESP_OK: Clean-up successful
- ESP_ERR_INVALID_STATE: Invalid ESP HTTPS OTA state
- ESP_FAIL: OTA not started
- ESP_ERR_NOT_FOUND: OTA handle not found
- ESP_ERR_INVALID_ARG: Invalid argument

```c
esp_err_t esp_https_ota_get_img_desc(esp_https_ota_handle_t https_ota_handle, esp_app_desc_t *new_app_info)
```

Reads app description from image header. The app description provides information like the “Firmware version” of the image.
Note: This API can be called only after esp_https_ota_begin() and before esp_https_ota_perform(). Calling this API is not mandatory.

Parameters
- **https_ota_handle** - [in] pointer to esp_https_ota_handle_t structure
- **new_app_info** - [out] pointer to an allocated esp_app_desc_t structure

Returns
- ESP_ERR_INVALID_ARG: Invalid arguments
- ESP_ERR_INVALID_STATE: Invalid state to call this API. esp_https_ota_begin() not called yet.
- ESP_FAIL: Failed to read image descriptor
- ESP_OK: Successfully read image descriptor

```c
int esp_https_ota_get_image_len_read(esp_https_ota_handle_t https_ota_handle)
```

This function returns OTA image data read so far.

Note: This API should be called only if esp_https_ota_perform() has been called at least once or if esp_https_ota_get_img_desc has been called before.

Parameters
- **https_ota_handle** - [in] pointer to esp_https_ota_handle_t structure

Returns
- -1 On failure
- total bytes read so far

```c
int esp_https_ota_get_image_size(esp_https_ota_handle_t https_ota_handle)
```

This function returns OTA image total size.

Note: This API should be called after esp_https_ota_begin() has been already called. This can be used to create some sort of progress indication (in combination with esp_https_ota_get_image_len_read())

Parameters
- **https_ota_handle** - [in] pointer to esp_https_ota_handle_t structure

Returns
- -1 On failure or chunked encoding
- total bytes of image

Structures

```c
struct esp_https_ota_config_t
```

ESP HTTPS OTA configuration.

Public Members

```c
const esp_http_client_config_t *http_config
```

ESP HTTP client configuration

```c
http_client_init_cb_t http_client_init_cb
```

Callback after ESP HTTP client is initialised
bool **bulk_flash_erase**
Erase entire flash partition during initialization. By default flash partition is erased during write operation and in chunk of 4K sector size

bool **partial_http_download**
Enable Firmware image to be downloaded over multiple HTTP requests

int **max_http_request_size**
Maximum request size for partial HTTP download

**Macros**

**ESP_ERR_HTTPS_OTA_BASE**

**ESP_ERR_HTTPS_OTA_IN_PROGRESS**

**Type Definitions**

typedef void *<code>espHttpsOtaHandle_t</code>

typedef <code>esp_err_t (*http_client_init_cb_t)</code>(<code>esp_http_client_handle_t</code>)

**Enumerations**

enum **espHttpsOtaEvent_t**
Events generated by OTA process.

*Values:*

enumerator **ESP_HTTPS_OTA_START**
OTA started

enumerator **ESP_HTTPS_OTA_CONNECTED**
Connected to server

enumerator **ESP_HTTPS_OTA_GET_IMG_DESC**
Read app description from image header

enumerator **ESP_HTTPS_OTA_VERIFY_CHIP_ID**
Verify chip id of new image

enumerator **ESP_HTTPS_OTA_DECRYPT_CB**
Callback to decrypt function

enumerator **ESP_HTTPS_OTA_WRITE_FLASH**
Flash write operation

enumerator **ESP_HTTPS_OTA_UPDATE_BOOT_PARTITION**
Boot partition update after successful ota update
enumerator ESP_HTTPS_OTA_FINISH
OTA finished

enumerator ESP_HTTPS_OTA_ABORT
OTA aborted

2.10.9 Event Loop Library

Overview

The event loop library allows components to declare events to which other components can register handlers – code which will execute when those events occur. This allows loosely coupled components to attach desired behavior to state changes of other components without application involvement. This also simplifies event processing by serializing and deferring code execution to another context.

One common use case is if a high level library is using the WiFi library: it may subscribe to events produced by the Wi-Fi subsystem directly and act on those events.

Note: Various modules of the Bluetooth stack deliver events to applications via dedicated callback functions instead of via the Event Loop Library.

Using esp_event APIs

There are two objects of concern for users of this library: events and event loops.

Events are occurrences of note. For example, for Wi-Fi, a successful connection to the access point may be an event. Events are referenced using a two part identifier which are discussed more here. Event loops are the vehicle by which events get posted by event sources and handled by event handler functions. These two appear prominently in the event loop library APIs.

Using this library roughly entails the following flow:

1. A user defines a function that should run when an event is posted to a loop. This function is referred to as the event handler. It should have the same signature as esp_event_handler_t.
2. An event loop is created using esp_event_loop_create(), which outputs a handle to the loop of type esp_event_loop_handle_t. Event loops created using this API are referred to as user event loops. There is, however, a special type of event loop called the default event loop which are discussed here.
3. Components register event handlers to the loop using esp_event_handler_register_with(). Handlers can be registered with multiple loops, more on that here.
4. Event sources post an event to the loop using esp_event_post_to().
5. Components wanting to remove their handlers from being called can do so by unregistering from the loop using esp_event_handler_unregister_with().
6. Event loops which are no longer needed can be deleted using esp_event_loop_delete().

In code, the flow above may look like as follows:

```c
// 1. Define the event handler
void run_on_event (void* handler_arg, esp_event_base_t base, int32_t id, void* _event_data)
{
   // Event handler logic
}

void app_main()
{
   // 2. A configuration structure of type esp_event_loop_args_t is needed to specify the properties of the loop to be
(continues on next page)```
// created. A handle of type esp_event_loop_handle_t is obtained, which is needed by the other APIs to reference the loop
// to perform their operations on.

esp_event_loop_args_t loop_args = {
    .queue_size = ...,
    .task_name = ...,
    .task_priority = ...,
    .task_stack_size = ...,
    .task_core_id = ...
};

esp_event_loop_handle_t loop_handle;

esp_event_loop_create(&loop_args, &loop_handle);

// 3. Register event handler defined in (1). MY_EVENT_BASE and MY_EVENT_ID specifies a hypothetical
// event that handler run_on_event should execute on when it gets posted to the loop.

esp_event_handler_register_with(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, run_on_event, ...);

...

// 4. Post events to the loop. This queues the event on the event loop. At some point in time
// the event loop executes the event handler registered to the posted event,
// in this case run_on_event.

esp_event_post_to(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, ...);

...

// 5. Unregistering an unneeded handler

esp_event_handler_unregister_with(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, run_on_event);

...

// 6. Deleting an unneeded event loop

esp_event_loop_delete(loop_handle);

}

### Declaring and defining events

As mentioned previously, events consists of two-part identifiers: the event base and the event ID. The event base identifies an independent group of events; the event ID identifies the event within that group. Think of the event base and event ID as a person’s last name and first name, respectively. A last name identifies a family, and the first name identifies a person within that family.

The event loop library provides macros to declare and define the event base easily.

**Event base declaration:**

```
ESP_EVENT_DECLARE_BASE(EVENT_BASE)
```

**Event base definition:**

None
Note: In IDF, the base identifiers for system events are uppercase and are postfixed with \_EVENT. For example, the base for Wi-Fi events is declared and defined as WIFI\_EVENT, the Ethernet event base ETHERNET\_EVENT, and so on. The purpose is to have event bases look like constants (although they are global variables considering the definitions of macros ESP\_EVENT\_DECLARE\_BASE and ESP\_EVENT\_DEFINE\_BASE).

For event ID’s, declaring them as enumerations is recommended. Once again, for visibility, these are typically placed in public header files.

Event ID:

```c
enum {
    EVENT\_ID\_1,
    EVENT\_ID\_2,
    EVENT\_ID\_3,
    ...
}
```

Default Event Loop

The default event loop is a special type of loop used for system events (Wi-Fi events, for example). The handle for this loop is hidden from the user. The creation, deletion, handler registration/unregistration and posting of events is done through a variant of the APIs for user event loops. The table below enumerates those variants, and the user event loops equivalent.

<table>
<thead>
<tr>
<th>User Event Loops</th>
<th>Default Event Loops</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_event_loop_create()</td>
<td>esp_event_loop_create_default()</td>
</tr>
<tr>
<td>esp_event_loop_delete()</td>
<td>esp_event_loop_delete_default()</td>
</tr>
<tr>
<td>esp_event_handler_register_with()</td>
<td>esp_event_handler_register()</td>
</tr>
<tr>
<td>esp_event_handler_unregister_with()</td>
<td>esp_event_handler_unregister()</td>
</tr>
<tr>
<td>esp_event_post_to()</td>
<td>esp_event_post()</td>
</tr>
</tbody>
</table>

If you compare the signatures for both, they are mostly similar except for the lack of loop handle specification for the default event loop APIs.

Other than the API difference and the special designation to which system events are posted to, there is no difference to how default event loops and user event loops behave. It is even possible for users to post their own events to the default event loop, should the user opt to not create their own loops to save memory.

Notes on Handler Registration

It is possible to register a single handler to multiple events individually, i.e. using multiple calls to esp\_event\_handler\_register\_with(). For those multiple calls, the specific event base and event ID can be specified with which the handler should execute.

However, in some cases it is desirable for a handler to execute on (1) all events that get posted to a loop or (2) all events of a particular base identifier. This is possible using the special event base identifier ESP\_EVENT\_ANY\_BASE and special event ID ESP\_EVENT\_ANY\_ID. These special identifiers may be passed as the event base and event ID arguments for esp\_event\_handler\_register\_with().

Therefore, the valid arguments to esp\_event\_handler\_register\_with() are:

1. <event base>, <event ID> - handler executes when the event with base <event base> and event ID <event ID> gets posted to the loop
2. <event base>, ESP\_EVENT\_ANY\_ID - handler executes when any event with base <event base> gets posted to the loop
3. ESP_EVENT_ANY_BASE, ESP_EVENT_ANY_ID - handler executes when any event gets posted to the loop

As an example, suppose the following handler registrations were performed:

```c
esp_event_handler_register_with(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, run_on_event_1, ...);
esp_event_handler_register_with(loop_handle, MY_EVENT_BASE, ESP_EVENT_ANY_ID, run_on_event_2, ...);
esp_event_handler_register_with(loop_handle, ESP_EVENT_ANY_BASE, ESP_EVENT_ANY_ID, ...
    run_on_event_3, ...);
```

If the hypothetical event MY_EVENT_BASE, MY_EVENT_ID is posted, all three handlers run_on_event_1, run_on_event_2, and run_on_event_3 would execute.

If the hypothetical event MY_EVENT_BASE, MY_OTHER_EVENT_ID is posted, only run_on_event_2 and run_on_event_3 would execute.

If the hypothetical event MY_OTHER_EVENT_BASE, MY_OTHER_EVENT_ID is posted, only run_on_event_3 would execute.

**Handler Un-registering Itself**  In general, an event handler run by an event loop is not allowed to do any (un)registering activity on that event loop. There is one exception, though: un-registering itself is allowed for the handler. E.g., it is possible to do the following:

```c
void run_on_event(void* handler_arg, esp_event_base_t base, int32_t id, void* event_data)
{
    esp_event_loop_handle_t *loop_handle = (esp_event_loop_handle_t*) handler_arg;
    esp_event_handler_unregister_with(*loop_handle, MY_EVENT_BASE, MY_EVENT_ID, ...
        run_on_event);
}
void app_main(void)
{
    esp_event_loop_handle_t loop_handle;
    esp_event_loop_create(&loop_args, &loop_handle);
    esp_event_handler_register_with(loop_handle, MY_EVENT_BASE, MY_EVENT_ID, run_on_event, &loop_handle);
    // ... post event MY_EVENT_BASE, MY_EVENT_ID and run loop at some point
}
```

**Handler Registration and Handler Dispatch Order**  The general rule is that for handlers that match a certain posted event during dispatch, those which are registered first also gets executed first. The user can then control which handlers get executed first by registering them before other handlers, provided that all registrations are performed using a single task. If the user plans to take advantage of this behavior, caution must be exercised if there are multiple tasks registering handlers. While the ‘first registered, first executed’ behavior still holds true, the task which gets executed first will also get their handlers registered first. Handlers registered one after the other by a single task will still be dispatched in the order relative to each other, but if that task gets pre-empted in between registration by another task which also registers handlers; then during dispatch those handlers will also get executed in between.

**Event loop profiling**

A configuration option `CONFIG_ESP_EVENT_LOOP_PROFILING` can be enabled in order to activate statistics collection for all event loops created. The function `esp_event_dump()` can be used to output the collected statistics to a file stream. More details on the information included in the dump can be found in the `esp_event_dump()` API Reference.
Application Example

Examples on using the esp_event library can be found in system/esp_event. The examples cover event declaration, loop creation, handler registration and unregistration and event posting.

Other examples which also adopt esp_event library:

• NMEA Parser, which will decode the statements received from GPS.

API Reference

Header File

• components/esp_event/include/esp_event.h

Functions

`esp_err_t esp_event_loop_create(const esp_event_loop_args_t *event_loop_args, esp_event_loop_handle_t *event_loop)`

Create a new event loop.

Parameters

• `event_loop_args` [in] configuration structure for the event loop to create
• `event_loop` [out] handle to the created event loop

Returns

• ESP_OK: Success
• ESP_ERR_INVALID_ARG: event_loop_args or event_loop was NULL
• ESP_ERR_NO_MEM: Cannot allocate memory for event loops list
• ESP_FAIL: Failed to create task loop
• Others: Fail

`esp_err_t esp_event_loop_delete(esp_event_loop_handle_t event_loop)`

Delete an existing event loop.

Parameters `event_loop` [in] event loop to delete, must not be NULL

Returns

• ESP_OK: Success
• Others: Fail

`esp_err_t esp_event_loop_create_default(void)`

Create default event loop.

Returns

• ESP_OK: Success
• ESP_ERR_NO_MEM: Cannot allocate memory for event loops list
• ESP_ERR_INVALID_STATE: Default event loop has already been created
• ESP_FAIL: Failed to create task loop
• Others: Fail

`esp_err_t esp_event_loop_delete_default(void)`

Delete the default event loop.

Returns

• ESP_OK: Success
• Others: Fail

`esp_err_t esp_event_loop_run(esp_event_loop_handle_t event_loop, TickType_t ticks_to_run)`

Dispatch events posted to an event loop.

This function is used to dispatch events posted to a loop with no dedicated task, i.e. task name was set to NULL in event_loop_args argument during loop creation. This function includes an argument to limit the amount of time it runs, returning control to the caller when that time expires (or some time afterwards). There is no guarantee that a call to this function will exit at exactly the time of expiry. There is also no guarantee that
events have been dispatched during the call, as the function might have spent all the allotted time waiting on
the event queue. Once an event has been dequeued, however, it is guaranteed to be dispatched. This guarantee
contributes to not being able to exit exactly at time of expiry as (1) blocking on internal mutexes is necessary
for dispatching the dequeued event, and (2) during dispatch of the dequeued event there is no way to control the
time occupied by handler code execution. The guaranteed time of exit is therefore the allotted time + amount
of time required to dispatch the last dequeued event.

In cases where waiting on the queue times out, ESP_OK is returned and not ESP_ERR_TIMEOUT, since it
is normal behavior.

---

Note: encountering an unknown event that has been posted to the loop will only generate a warning, not an
error.

---

**Parameters**

- **event_loop** [in] event loop to dispatch posted events from, must not be NULL
- **ticks_to_run** [in] number of ticks to run the loop

**Returns**

- ESP_OK: Success
- Others: Fail

```c
esp_err_t esp_event_handler_register(esp_event_base_t event_base, int32_t event_id, 
                                   esp_event_handler_t event_handler, void *event_handler_arg)
```

Register an event handler to the system event loop (legacy).

This function can be used to register a handler for either: (1) specific events, (2) all events of a certain event
base, or (3) all events known by the system event loop.

- specific events: specify exact event_base and event_id
- all events of a certain base: specify exact event_base and use ESP_EVENT_ANY_ID as the event_id
- all events known by the loop: use ESP_EVENT_ANY_BASE for event_base and
  ESP_EVENT_ANY_ID as the event_id

Registering multiple handlers to events is possible. Registering a single handler to multiple events is also
possible. However, registering the same handler to the same event multiple times would cause the previous
registrations to be overwritten.

---

Note: the event loop library does not maintain a copy of event_handler_arg, therefore the user should ensure
that event_handler_arg still points to a valid location by the time the handler gets called

---

**Parameters**

- **event_base** [in] the base ID of the event to register the handler for
- **event_id** [in] the ID of the event to register the handler for
- **event_handler** [in] the handler function which gets called when the event is dis-
  patched
- **event_handler_arg** [in] data, aside from event data, that is passed to the handler
  when it is called

**Returns**

- ESP_OK: Success
- ESP_ERR_NO_MEM: Cannot allocate memory for the handler
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

```c
esp_err_t esp_event_handler_register_with(esp_event_loop_handle_t event_loop, esp_event_base_t 
                                          event_base, int32_t event_id, esp_event_handler_t 
                                          event_handler, void *event_handler_arg)
```
Register an event handler to a specific loop (legacy).

This function behaves in the same manner as esp_event_handler_register, except the additional specification of the event loop to register the handler to.

**Note:** the event loop library does not maintain a copy of event_handler_arg, therefore the user should ensure that event_handler_arg still points to a valid location by the time the handler gets called.

**Parameters**

- **event_loop** - [in] the event loop to register this handler function to, must not be NULL
- **event_base** - [in] the base ID of the event to register the handler for
- **event_id** - [in] the ID of the event to register the handler for
- **event_handler** - [in] the handler function which gets called when the event is dispatched
- **event_handler_arg** - [in] data, aside from event data, that is passed to the handler when it is called

**Returns**

- ESP_OK: Success
- ESP_ERR_NO_MEM: Cannot allocate memory for the handler
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

```c
esp_err_t esp_event_handler_instance_register_with(const esp_event_loop_handle_t *event_loop,
                                                  const esp_event_base_t event_base,
                                                  int32_t event_id,
                                                  const esp_event_handler_t *event_handler,
                                                  void *event_handler_arg,
                                                  esp_event_handler_instance_t *instance)
```

Register an instance of event handler to a specific loop.

This function can be used to register a handler for either: (1) specific events, (2) all events of a certain event base, or (3) all events known by the system event loop.

- specific events: specify exact event_base and event_id
- all events of a certain base: specify exact event_base and use ESP_EVENT_ANY_ID as the event_id
- all events known by the loop: use ESP_EVENT_ANY_BASE for event_base and ESP_EVENT_ANY_ID as the event_id

Besides the error, the function returns an instance object as output parameter to identify each registration. This is necessary to remove (unregister) the registration before the event loop is deleted.

Registering multiple handlers to events, registering a single handler to multiple events as well as registering the same handler to the same event multiple times is possible. Each registration yields a distinct instance object which identifies it over the registration lifetime.

**Note:** the event loop library does not maintain a copy of event_handler_arg, therefore the user should ensure that event_handler_arg still points to a valid location by the time the handler gets called.

**Parameters**

- **event_loop** - [in] the event loop to register this handler function to, must not be NULL
- **event_base** - [in] the base ID of the event to register the handler for
- **event_id** - [in] the ID of the event to register the handler for
- **event_handler** - [in] the handler function which gets called when the event is dispatched
- **event_handler_arg** - [in] data, aside from event data, that is passed to the handler when it is called
• **instance** [out] An event handler instance object related to the registered event handler and data, can be NULL. This needs to be kept if the specific callback instance should be unregistered before deleting the whole event loop. Registering the same event handler multiple times is possible and yields distinct instance objects. The data can be the same for all registrations. If no unregistration is needed, but the handler should be deleted when the event loop is deleted, instance can be NULL.

**Returns**
- ESP_OK: Success
- ESP_ERR_NO_MEM: Cannot allocate memory for the handler
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID or instance is NULL
- Others: Fail

```c
esp_err_t esp_event_handler_instance_register(esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler, void *event_handler_arg, esp_event_handler_instance_t *instance)
```

Register an instance of event handler to the default loop.

This function does the same as esp_event_handler_instance_register_with, except that it registers the handler to the default event loop.

**Note:** the event loop library does not maintain a copy of event_handler_arg, therefore the user should ensure that event_handler_arg still points to a valid location by the time the handler gets called

**Parameters**
- **event_base** [in] the base ID of the event to register the handler for
- **event_id** [in] the ID of the event to register the handler for
- **event_handler** [in] the handler function which gets called when the event is dispatched
- **event_handler_arg** [in] data, aside from event data, that is passed to the handler when it is called
- **instance** [out] An event handler instance object related to the registered event handler and data, can be NULL. This needs to be kept if the specific callback instance should be unregistered before deleting the whole event loop. Registering the same event handler multiple times is possible and yields distinct instance objects. The data can be the same for all registrations. If no unregistration is needed, but the handler should be deleted when the event loop is deleted, instance can be NULL.

**Returns**
- ESP_OK: Success
- ESP_ERR_NO_MEM: Cannot allocate memory for the handler
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID or instance is NULL
- Others: Fail

```c
esp_err_t esp_event_handler_unregister(esp_event_base_t event_base, int32_t event_id, esp_event_handler_t event_handler)
```

Unregister a handler with the system event loop (legacy).

Unregisters a handler, so it will no longer be called during dispatch. Handlers can be unregistered for any combination of event_base and event_id which were previously registered. To unregister a handler, the event_base and event_id arguments must match exactly the arguments passed to esp_event_handler_register() when that handler was registered. Passing ESP_EVENT_ANY_BASE and/or ESP_EVENT_ANY_ID will only unregister handlers that were registered with the same wildcard arguments.

**Note:** When using ESP_EVENT_ANY_ID, handlers registered to specific event IDs using the same base
will not be unregistered. When using ESP_EVENT_ANY_BASE, events registered to specific bases will also not be unregistered. This avoids accidental unregistration of handlers registered by other users or components.

**Parameters**

- **event_base** [in] the base of the event with which to unregister the handler
- **event_id** [in] the ID of the event with which to unregister the handler
- **event_handler** [in] the handler to unregister

**Returns**

- ESP_OK success
- ESP_ERR_INVALID_ARG invalid combination of event base and event ID
- Others fail

```c
esp_err_t esp_event_handler_unregister_with(esp_event_loop_handle_t event_loop,
                                          esp_event_base_t event_base,
                                          int32_t event_id,
                                          esp_event_handler_t event_handler)
```

Unregister a handler from a specific event loop (legacy).

This function behaves in the same manner as esp_event_handler_unregister, except the additional specification of the event loop to unregister the handler with.

**Parameters**

- **event_loop** [in] the event loop with which to unregister this handler function, must not be NULL
- **event_base** [in] the base of the event with which to unregister the handler
- **event_id** [in] the ID of the event with which to unregister the handler
- **event_handler** [in] the handler to unregister

**Returns**

- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

```c
esp_err_t esp_event_handler_instance_unregister_with(esp_event_loop_handle_t event_loop,
                                                   esp_event_base_t event_base,
                                                   int32_t event_id,
                                                   esp_event_handler_instance_t instance)
```

Unregister a handler instance from a specific event loop.

Unregisters a handler instance, so it will no longer be called during dispatch. Handler instances can be unregistered for any combination of event_base and event_id which were previously registered. To unregister a handler instance, the event_base and event_id arguments must match exactly the arguments passed to esp_event_handler_instance_register() when that handler instance was registered. Passing ESP_EVENT_ANY_BASE and/or ESP_EVENT_ANY_ID will only unregister handler instances that were registered with the same wildcard arguments.

**Note:** When using ESP_EVENT_ANY_ID, handlers registered to specific event IDs using the same base will not be unregistered. When using ESP_EVENT_ANY_BASE, events registered to specific bases will also not be unregistered. This avoids accidental unregistration of handlers registered by other users or components.

**Parameters**

- **event_loop** [in] the event loop with which to unregister this handler function, must not be NULL
- **event_base** [in] the base of the event with which to unregister the handler
- **event_id** [in] the ID of the event with which to unregister the handler
- **instance** [in] the instance object of the registration to be unregistered

**Returns**

- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail
**esp_err_t esp_event_handler_instance_unregister**

Unregister a handler from the system event loop.

This function does the same as esp_event_handler_instance_unregister_with, except that it unregisters the handler instance from the default event loop.

**Parameters**
- `event_base` [in] the base of the event with which to unregister the handler
- `event_id` [in] the ID of the event with which to unregister the handler
- `instance` [in] the instance object of the registration to be unregistered

**Returns**
- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

**esp_err_t esp_event_post**

Posts an event to the system default event loop. The event loop library keeps a copy of event data and manages the copy’s lifetime automatically (allocation + deletion); this ensures that the data the handler receives is always valid.

**Parameters**
- `event_base` [in] the event base that identifies the event
- `event_id` [in] the event ID that identifies the event
- `event_data` [in] the data, specific to the event occurrence, that gets passed to the handler
- `event_data_size` [in] the size of the event data
- `ticks_to_wait` [in] number of ticks to block on a full event queue

**Returns**
- ESP_OK: Success
- ESP_ERR_TIMEOUT: Time to wait for event queue to unblock expired, queue full when posting from ISR
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

**esp_err_t esp_event_post_to**

Posts an event to the specified event loop. The event loop library keeps a copy of event data and manages the copy’s lifetime automatically (allocation + deletion); this ensures that the data the handler receives is always valid.

This function behaves in the same manner as esp_event_post_to, except the additional specification of the event loop to post the event to.

**Parameters**
- `event_loop` [in] the event loop to post to, must not be NULL
- `event_base` [in] the event base that identifies the event
- `event_id` [in] the event ID that identifies the event
- `event_data` [in] the data, specific to the event occurrence, that gets passed to the handler
- `event_data_size` [in] the size of the event data
- `ticks_to_wait` [in] number of ticks to block on a full event queue

**Returns**
- ESP_OK: Success
- ESP_ERR_TIMEOUT: Time to wait for event queue to unblock expired, queue full when posting from ISR
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail
**esp_err_t esp_event_isr_post**

(esp_event_base_t event_base, int32_t event_id, const void *event_data, size_t event_data_size, BaseType_t *task_unblocked)

Special variant of *esp_event_post* for posting events from interrupt handlers.

**Note:** this function is only available when CONFIG_ESP_EVENT_POST_FROM_ISR is enabled

**Note:** when this function is called from an interrupt handler placed in IRAM, this function should be placed in IRAM as well by enabling CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR

### Parameters
- **event_base** [in] the event base that identifies the event
- **event_id** [in] the event ID that identifies the event
- **event_data** [in] the data, specific to the event occurrence, that gets passed to the handler
- **event_data_size** [in] the size of the event data; max is 4 bytes
- **task_unblocked** [out] an optional parameter (can be NULL) which indicates that an event task with higher priority than currently running task has been unblocked by the posted event; a context switch should be requested before the interrupt is exited.

### Returns
- ESP_OK: Success
- ESP_FAIL: Event queue for the default event loop full
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID, data size of more than 4 bytes
- Others: Fail

**esp_err_t esp_event_isr_post_to**

(esp_event_loop_handle_t event_loop, esp_event_base_t event_base, int32_t event_id, const void *event_data, size_t event_data_size, BaseType_t *task_unblocked)

Special variant of *esp_event_post_to* for posting events from interrupt handlers.

**Note:** this function is only available when CONFIG_ESP_EVENT_POST_FROM_ISR is enabled

**Note:** when this function is called from an interrupt handler placed in IRAM, this function should be placed in IRAM as well by enabling CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR

### Parameters
- **event_loop** [in] the event loop to post to, must not be NULL
- **event_base** [in] the event base that identifies the event
- **event_id** [in] the event ID that identifies the event
- **event_data** [in] the data, specific to the event occurrence, that gets passed to the handler
- **event_data_size** [in] the size of the event data
- **task_unblocked** [out] an optional parameter (can be NULL) which indicates that an event task with higher priority than currently running task has been unblocked by the posted event; a context switch should be requested before the interrupt is exited.

### Returns
- ESP_OK: Success
- ESP_FAIL: Event queue for the loop full
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID, data size of more than 4 bytes
- Others: Fail
\texttt{esp_err_t \ esp\_event\_dump (FILE* \textbar file)}

Dumps statistics of all event loops.

Dumps event loop info in the format:

\begin{verbatim}
event loop
  handler
  handler
...
  event loop
  handler
  handler
...

where:

  event loop
    format: address, name \ rx:total\_received \ \ dr:total\_dropped
    where:
      address - memory address of the event loop
      name - name of the event loop, 'none' if no dedicated task
      total\_received - number of successfully posted events
      total\_dropped - number of events unsuccessfully posted due to queue being full

  handler
    format: address \ ev:base, id \ inv:total\_invoked \ run:total\_runtime
    where:
      address - address of the handler function
      base, id - the event specified by event base and ID this handler executes
      total\_invoked - number of times this handler has been invoked
      total\_runtime - total amount of time used for invoking this handler
\end{verbatim}

\textbf{Note:} this function is a noop when \texttt{CONFIG\_ESP\_EVENT\_LOOP\_PROFILING} is disabled

\textbf{Parameters} \texttt{file} \-[in]\, the file stream to output to

\textbf{Returns}

\begin{itemize}
  \item ESP_OK: Success
  \item ESP_ERR_NO_MEM: Cannot allocate memory for event loops list
  \item Others: Fail
\end{itemize}

\textbf{Structures}

\texttt{struct\ esp\_event\_loop\_args\_t}

Configuration for creating event loops.

\textbf{Public Members}

\begin{verbatim}
int32_t queue\_size
  \text{size of the event loop queue}

const char* task\_name
  \text{name of the event loop task; if NULL, a dedicated task is not created for event loop}
\end{verbatim}
Chapter 2. API Reference

```c
UBaseType_t task_priority
priority of the event loop task, ignored if task name is NULL
```

```c
uint32_t task_stack_size
stack size of the event loop task, ignored if task name is NULL
```

```c
BaseType_t task_core_id
core to which the event loop task is pinned to, ignored if task name is NULL
```

**Header File**
- `components/esp_event/include/esp_event_base.h`

**Macros**
- `ESP_EVENT_DECLARE_BASE(id)`
- `ESP_EVENT_DEFINE_BASE(id)`

```c
ESP_EVENT_ANY_BASE
register handler for any event base
```

```c
ESP_EVENT_ANY_ID
register handler for any event id
```

**Type Definitions**
- `typedef void *esp_event_loop_handle_t`
  - a number that identifies an event with respect to a base

```c
typedef void (*esp_event_handler_t)(void *event_handler_arg, esp_event_base_t event_base, int32_t event_id, void *event_data)
```
  - function called when an event is posted to the queue

- `typedef void *(esp_event_handler_instance_t)`
  - context identifying an instance of a registered event handler

**Related Documents**

2.10.10 FreeRTOS (Overview)

**Overview**

FreeRTOS is an open source real-time operating system kernel that acts as the operating system for ESP-IDF applications and is integrated into ESP-IDF as a component. The FreeRTOS component in ESP-IDF contains ports of the FreeRTOS kernel for all the CPU architectures used by ESP targets (i.e., Xtensa and RISC-V). Furthermore, ESP-IDF provides different implementations of FreeRTOS in order to support SMP (Symmetric Multiprocessing) on multi-core ESP targets. This document provides an overview of the FreeRTOS component, the FreeRTOS implementations offered by ESP-IDF, and the common aspects across all implementations.
Implementations

The official FreeRTOS (henceforth referred to as Vanilla FreeRTOS) is a single-core RTOS. In order to support the various multi-core ESP targets, ESP-IDF supports different FreeRTOS implementations, namely ESP-IDF FreeRTOS and Amazon SMP FreeRTOS.

ESP-IDF FreeRTOS  ESP-IDF FreeRTOS is a FreeRTOS implementation based on Vanilla FreeRTOS v10.4.3, but contains significant modifications to support SMP. ESP-IDF FreeRTOS only supports two cores at most (i.e., dual core SMP), but is more optimized for this scenario by design. For more details regarding ESP-IDF FreeRTOS and its modifications, please refer to the FreeRTOS (ESP-IDF) document.

Note:  ESP-IDF FreeRTOS is currently the default FreeRTOS implementation for ESP-IDF.

Amazon SMP FreeRTOS  Amazon SMP FreeRTOS is an SMP implementation of FreeRTOS that is officially supported by Amazon. Amazon SMP FreeRTOS is able to support N-cores (i.e., more than two cores). Amazon SMP FreeRTOS can be enabled via the CONFIG_FREERTOS_SMP option. For more details regarding Amazon SMP FreeRTOS, please refer to the official Amazon SMP FreeRTOS documentation.

Warning:  The Amazon SMP FreeRTOS implementation (and its port in ESP-IDF) are currently in experimental/beta state. Therefore, significant behavioral changes and breaking API changes can occur.

Configuration

Kernel Configuration  Vanilla FreeRTOS requires that ports and applications configure the kernel by adding various #define config... macros to FreeRTOSConfig.h. Vanilla FreeRTOS supports a list of kernel configuration options which allow various kernel behaviors and features to be enabled or disabled. However, for all FreeRTOS ports in ESP-IDF, the `"FreertosConfig.h"` file is considered private and must not be modified by users. A large number of kernel configuration options in FreeRTOSConfig.h are hard coded as they are either required or not supported in ESP-IDF. All kernel configuration options that are configurable by the user will be exposed via menuconfig under Component Config/FreeRTOS/Kernel.

For the full list of user configurable kernel options, see Project Configuration. The list below highlights some commonly used kernel configuration options:

- CONFIG_FREERTOS_UNICORE will run FreeRTOS only on CPU0. Note that this is not equivalent to running Vanilla FreeRTOS. Furthermore, this option may affect behavior of components other than freertos. For more details regarding the effects of running FreeRTOS on a single core, refer to ESP-IDF FreeRTOS Single Core (if using ESP-IDF FreeRTOS) or the official Amazon SMP FreeRTOS documentation. Alternatively, users can also search for occurrences of CONFIG_FREERTOS_UNICORE in the ESP-IDF components.
- CONFIG_FREERTOS_ENABLE_BACKWARD_COMPATIBILITY enables backward compatibility with some FreeRTOS macros/types/functions that were deprecated from v8.0 onwards.

Port Configuration  All other FreeRTOS related configuration options that are not part of the kernel configuration are exposed via menuconfig under Component Config/FreeRTOS/Port. These options configure aspects such as:

- The FreeRTOS ports themselves (e.g., tick timer selection, ISR stack size)
- Additional features added to the FreeRTOS implementation or ports
Using FreeRTOS

Application Entry Point  Unlike Vanilla FreeRTOS, users of FreeRTOS in ESP-IDF must never call \texttt{vTaskStartScheduler()} and \texttt{vTaskEndScheduler()}. Instead, ESP-IDF will start FreeRTOS automatically. Users must define a \texttt{void app\_main(void)} function which acts as the entry point for user’s application and is automatically called on ESP-IDF startup.

- Typically, users would spawn the rest of their application’s task from \texttt{app\_main}.
- The \texttt{app\_main} function is allowed to return at any point (i.e., before the application terminates).
- The \texttt{app\_main} function is called from the main task.

Background Tasks During startup, ESP-IDF and FreeRTOS will automatically create multiple tasks that run in the background (listed in the the table below).

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Description</th>
<th>Stack Size</th>
<th>Affinity</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle Tasks (IDLE\texttt{x})</td>
<td>An idle task (IDLE\texttt{x}) is created for (and pinned to) each CPU, where \texttt{x} is the CPU’s number.</td>
<td>\texttt{CONFIG_FREERTOS_IDLE_TASK_STACKSIZE}</td>
<td>CPU\texttt{x}</td>
<td>0</td>
</tr>
<tr>
<td>FreeRTOS Timer Task (Tmr Svc)</td>
<td>FreeRTOS will create the Timer Service/Daemon Task if any FreeRTOS Timer APIs are called by the application.</td>
<td>\texttt{CONFIG_FREERTOS_TIMER_TASK_STACK_SIZE}</td>
<td>CPU0</td>
<td>\texttt{CONFIG_FREERTOS_TIMER_TASK_PRIORITY}</td>
</tr>
<tr>
<td>Main Task (main)</td>
<td>Task that simply calls \texttt{app_main}. This task will self delete when \texttt{app_main} returns</td>
<td>\texttt{CONFIG_ESP_MAIN_TASK_STACK_SIZE}</td>
<td>CPU1</td>
<td>1</td>
</tr>
<tr>
<td>IPC Tasks (ipcx)</td>
<td>When \texttt{CONFIG_FREERTOS_UNICORE} is false, an IPC task (ipcx) is created for (and pinned to) each CPU. IPC tasks are used to implement the Inter-processor Call (IPC) feature.</td>
<td>\texttt{CONFIG_ESP_IPC_TASK_STACK_SIZE}</td>
<td>CPU\texttt{x}</td>
<td>24</td>
</tr>
<tr>
<td>ESP Timer Task (esp_timer)</td>
<td>ESP-IDF will create the ESP Timer Task used to process ESP Timer callbacks.</td>
<td>\texttt{CONFIG_ESP_TIMER_TASK_STACK_SIZE}</td>
<td>CPU0</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: Note that if an application uses other ESP-IDF features (e.g., WiFi or Bluetooth), those features may create their own background tasks in addition to the tasks listed in the table above.

FreeRTOS Additions

ESP-IDF provides some supplemental features to FreeRTOS such as Ring Buffers, ESP-IDF style Tick and Idle Hooks, and TLSP deletion callbacks. See \texttt{FreeRTOS (Supplemental Features)} for more details.

FreeRTOS Heap

Vanilla FreeRTOS provides its own selection of heap implementations. However, ESP-IDF already implements its own heap (see \texttt{Heap Memory Allocation}), thus ESP-IDF does not make use of the heap implementations provided by Vanilla FreeRTOS. All FreeRTOS ports in ESP-IDF map FreeRTOS memory allocation/free calls (e.g., \texttt{pvPortMalloc()} and \texttt{pvPortFree()}) to ESP-IDF heap API (i.e., \texttt{heap_caps_malloc()} and \texttt{heap_caps_free()}). However, the FreeRTOS ports ensure that all dynamic memory allocated by FreeRTOS is placed in internal memory.
Chapter 2. API Reference

Note: If users wish to place FreeRTOS tasks/objects in external memory, users can use the following methods:

- Allocate the task/object using one of the \(...\text{CreateWithCaps}()\) API such as \(\text{xTaskCreateWithCaps()}\) and \(\text{xQueueCreateWithCaps()}\) (see IDF Additional API for more details).
- Manually allocate external memory for those objects using \(\text{heap_caps_malloc()}\), then create the objects from the allocated memory using on of the \(...\text{CreateStatic}()\) FreeRTOS functions.

2.10.11 FreeRTOS (ESP-IDF)

Overview

The original FreeRTOS (hereinafter referred to as Vanilla FreeRTOS) is a small and efficient Real Time Operating System supported on many single-core MCUs and SoCs. However, to support numerous dual core ESP targets (such as the ESP32 and ESP32-S3), ESP-IDF provides a dual core SMP (Symmetric Multiprocessing) capable implementation of FreeRTOS, (hereinafter referred to as ESP-IDF FreeRTOS).

ESP-IDF FreeRTOS is based on Vanilla FreeRTOS v10.4.3, but contains significant modifications to both API and kernel behavior in order to support dual core SMP. This document describes the API and behavioral differences between Vanilla FreeRTOS and ESP-IDF FreeRTOS.

Note: This document assumes that the reader has a requisite understanding of Vanilla FreeRTOS (its features, behavior, and API usage). Refer to the Vanilla FreeRTOS documentation for more details.

Note: ESP-IDF FreeRTOS can be built for single core by enabling the \text{CONFIG_FREERTOS_UNICORE} configuration option. ESP targets that are single core will always have the \text{CONFIG_FREERTOS_UNICORE} option enabled. However, note that building with \text{CONFIG_FREERTOS_UNICORE} enabled does not equate to building with Vanilla FreeRTOS (i.e., some of the behavioral and API changes of ESP-IDF will still be present). For more details, see ESP-IDF FreeRTOS Single Core for more details.

This document is split into the following parts.

Contents

- FreeRTOS (ESP-IDF)
  - Overview
  - Symmetric Multiprocessing
  - Tasks
  - SMP Scheduler
  - Critical Sections
  - Misc
  - API Reference

Symmetric Multiprocessing

Basic Concepts SMP (Symmetric Multiprocessing) is a computing architecture where two or more identical CPUs (cores) are connected to a single shared main memory and controlled by a single operating system. In general, an SMP system:

- has multiple cores running independently. Each core has its own register file, interrupts, and interrupt handling.
- presents an identical view of memory to each core. Thus a piece of code that accesses a particular memory address will have the same effect regardless of which core it runs on.
The main advantages of an SMP system compared to single core or Asymmetric Multiprocessing systems are that...

- the presence of multiple CPUs allows for multiple hardware threads, thus increases overall processing throughput.
- having symmetric memory means that threads can switch cores during execution. This in general can lead to better CPU utilization.

Although an SMP system allows threads to switch cores, there are scenarios where a thread must/should only run on a particular core. Therefore, threads in an SMP systems will also have a core affinity that specifies which particular core the thread is allowed to run on.

- A thread that is pinned to a particular core will only be able to run on that core
- A thread that is unpinned will be allowed to switch between cores during execution instead of being pinned to a particular core.

**SMP on an ESP Target**  ESP targets (such as the ESP32, ESP32-S3) are dual core SMP SoCs. These targets have the following hardware features that make them SMP capable:

- Two identical cores known as CPU0 (i.e., Protocol CPU or PRO_CPU) and CPU1 (i.e., Application CPU or APP_CPU). This means that the execution of a piece of code is identical regardless of which core it runs on.
- Symmetric memory (with some small exceptions).
  - If multiple cores access the same memory address, their access will be serialized at the memory bus level.
  - True atomic access to the same memory address is achieved via an atomic compare-and-swap instruction provided by the ISA.
- Cross-core interrupts that allow one CPU to trigger and interrupt on another CPU. This allows cores to signal each other.

**Note:** The “PRO_CPU” and “APP_CPU” aliases for CPU0 and CPU1 exist in ESP-IDF as they reflect how typical IDF applications will utilize the two CPUs. Typically, the tasks responsible for handling wireless networking (e.g., WiFi or Bluetooth) will be pinned to CPU0 (thus the name PRO_CPU), whereas the tasks handling the remainder of the application will be pinned to CPU1 (thus the name APP_CPU).

**Tasks**

**Creation**  Vanilla FreeRTOS provides the following functions to create a task:

- `xTaskCreate()` creates a task. The task’s memory is dynamically allocated
- `xTaskCreateStatic()` creates a task. The task’s memory is statically allocated (i.e., provided by the user)

However, in an SMP system, tasks need to be assigned a particular affinity. Therefore, ESP-IDF provides a *Pinned-ToCore* version of Vanilla FreeRTOS’s task creation functions:

- `xTaskCreatePinnedToCore()` creates a task with a particular core affinity. The task’s memory is dynamically allocated.
- `xTaskCreateStaticPinnedToCore()` creates a task with a particular core affinity. The task’s memory is statically allocated (i.e., provided by the user)

The `PinnedToCore` versions of the task creation functions API differ from their vanilla counterparts by having an extra `xCoreID` parameter that is used to specify the created task’s core affinity. The valid values for core affinity are:

- 0 which pins the created task to CPU0
- 1 which pins the created task to CPU1
- `tskNO_AFFINITY` which allows the task to be run on both CPUs

Note that ESP-IDF FreeRTOS still supports the vanilla versions of the task creation functions. However, they have been modified to simply call their `PinnedToCore` counterparts with `tskNO_AFFINITY`. 
Note: ESP-IDF FreeRTOS also changes the units of `ulStackDepth` in the task creation functions. Task stack sizes in Vanilla FreeRTOS are specified in number of words, whereas in ESP-IDF FreeRTOS, the task stack sizes are specified in bytes.

**Execution** The anatomy of a task in ESP-IDF FreeRTOS is the same as Vanilla FreeRTOS. More specifically, ESP-IDF FreeRTOS tasks:

- Can only be in one of the following states: Running, Ready, Blocked, or Suspended.
- Task functions are typically implemented as an infinite loop
- Task functions should never return

**Deletion** Task deletion in Vanilla FreeRTOS is called via `vTaskDelete()`. The function allows deletion of another task or the currently running task (if the provided task handle is `NULL`). The actual freeing of the task’s memory is sometimes delegated to the idle task (if the task being deleted is the currently running task).

ESP-IDF FreeRTOS provides the same `vTaskDelete()` function. However, due to the dual core nature, there are some behavioral differences when calling `vTaskDelete()` in ESP-IDF FreeRTOS:

- When deleting a task that is pinned to the other core, that task’s memory is always freed by the idle task of the other core (due to the need to clear FPU registers).
- When deleting a task that is currently running on the other core, a yield is triggered on the other core and the task’s memory is freed by one of the idle tasks (depending on the task’s core affinity)
- A deleted task’s memory is freed immediately if:
  - The task is currently running on this core and is also pinned to this core
  - The task is not currently running and is not pinned to any core

Users should avoid calling `vTaskDelete()` on a task that is currently running on the other core. This is due to the fact that it is difficult to know what the task currently running on the other core is executing, thus can lead to unpredictable behavior such as:

- Deleting a task that is holding a mutex
- Deleting a task that has yet to free memory it previously allocated

Where possible, users should design their application such that `vTaskDelete()` is only ever called on tasks in a known state. For example:

- Tasks self deleting (via `vTaskDelete(NULL)`) when their execution is complete and have also cleaned up all resources used within the task.
- Tasks placing themselves in the suspend state (via `vTaskSuspend()`) before being deleted by another task.

**SMP Scheduler**

The Vanilla FreeRTOS scheduler is best described as a Fixed Priority Preemptive scheduler with Time Slicing meaning that:

- Each task is given a constant priority upon creation. The scheduler executes highest priority ready state task
- The scheduler can switch execution to another task without the cooperation of the currently running task
- The scheduler will periodically switch execution between ready state tasks of the same priority (in a round robin fashion). Time slicing is governed by a tick interrupt.

The ESP-IDF FreeRTOS scheduler supports the same scheduling features (i.e., Fixed Priority, Preemption, and Time Slicing) albeit with some small behavioral differences.

**Fixed Priority** In Vanilla FreeRTOS, when the scheduler selects a new task to run, it will always select the current highest priority ready state task. In ESP-IDF FreeRTOS, each core will independently schedule tasks to run. When a particular core selects a task, the core will select the highest priority ready state task that can be run by the core. A task can be run by the core if:
The task has a compatible affinity (i.e., is either pinned to that core or is unpinned)

The task is not currently being run by another core

However, users should not assume that the two highest priority ready state tasks are always run by the scheduler as a task’s core affinity must also be accounted for. For example, given the following tasks:

- Task A of priority 10 pinned to CPU0
- Task B of priority 9 pinned to CPU0
- Task C of priority 8 pinned to CPU1

The resulting schedule will have Task A running on CPU0 and Task C running on CPU1. Task B is not run even though it is the second highest priority task.

Preemption In Vanilla FreeRTOS, the scheduler can preempt the currently running task if a higher priority task becomes ready to execute. Likewise in ESP-IDF FreeRTOS, each core can be individually preempted by the scheduler if the scheduler determines that a higher priority task can run on that core.

However, there are some instances where a higher priority task that becomes ready can be run on multiple cores. In this case, the scheduler will only preempt one core. The scheduler always gives preference to the current core when multiple cores can be preempted. For example, given the following tasks:

- Task A of priority 8 currently running on CPU0
- Task B of priority 9 currently running on CPU1
- Task C of priority 10 that is unpinned and was unblocked by Task B

The resulting schedule will have Task A running on CPU0 and Task C preempting Task B given that the scheduler always gives preference to the current core.

Time Slicing The Vanilla FreeRTOS scheduler implements time slicing meaning that if current highest ready priority contains multiple ready tasks, the scheduler will switch between those tasks periodically in a round robin fashion.

However, in ESP-IDF FreeRTOS, it is not possible to implement perfect Round Robin time slicing due to the fact that a particular task may not be able to run on a particular core due to the following reasons:

- The task is pinned to the another core.
- For unpinned tasks, the task is already being run by another core.

Therefore, when a core searches the ready state task list for a task to run, the core may need to skip over a few tasks in the same priority list or drop to a lower priority in order to find a ready state task that the core can run.

The ESP-IDF FreeRTOS scheduler implements a Best Effort Round Robin time slicing for ready state tasks of the same priority by ensuring that tasks that have been selected to run will be placed at the back of the list, thus giving unselected tasks a higher priority on the next scheduling iteration (i.e., the next tick interrupt or yield).

The following example demonstrates the Best Effort Round Robin time slicing in action. Assume that:

- There are four ready state tasks of the same priority AX, B0, C1, D1 where: - The priority is the current highest priority with ready state tasks - The first character represents the task’s names (i.e., A, B, C, D) - And the second character represents the tasks core pinning (and X means unpinned)
- The task list is always searched from the head

---

1. Starting state. None of the ready state tasks have been selected to run

Head [ AX , B0 , C1 , D0 ] Tail

---

2. Core 0 has tick interrupt and searches for a task to run.
Task A is selected and is moved to the back of the list

Core0--|
Head [ AX , B0 , C1 , D0 ] Tail
0
Head [ B0 , C1 , D0 , AX ] Tail

--------------------------------------------------------------------------------

3. Core 1 has a tick interrupt and searches for a task to run.
   Task B cannot be run due to incompatible affinity, so core 1 skips to Task C.
   Task C is selected and is moved to the back of the list

Core1------| 0
Head [ B0 , C1 , D0 , AX ] Tail
0 1
Head [ B0 , D0 , AX , C1 ] Tail

--------------------------------------------------------------------------------

4. Core 0 has another tick interrupt and searches for a task to run.
   Task B is selected and moved to the back of the list

Core0--| 1
Head [ B0 , D0 , AX , C1 ] Tail
1 0
Head [ D0 , AX , C1 , B0 ] Tail

--------------------------------------------------------------------------------

5. Core 1 has another tick and searches for a task to run.
   Task D cannot be run due to incompatible affinity, so core 1 skips to Task A
   Task A is selected and moved to the back of the list

Core1------| 0
Head [ D0 , AX , C1 , B0 ] Tail
0 1
Head [ D0 , C1 , B0 , AX ] Tail

The implications to users regarding the Best Effort Round Robin time slicing:

- Users cannot expect multiple ready state tasks of the same priority to run sequentially (as is the case in Vanilla FreeRTOS). As demonstrated in the example above, a core may need to skip over tasks.
- However, given enough ticks, a task will eventually be given some processing time.
- If a core cannot find a task runnable task at the highest ready state priority, it will drop to a lower priority to search for tasks.
- To achieve ideal round robin time slicing, users should ensure that all tasks of a particular priority are pinned to the same core.

Tick Interrupts  
Vanilla FreeRTOS requires that a periodic tick interrupt occurs. The tick interrupt is responsible for:

- Incrementing the scheduler’s tick count
- Unblocking any blocked tasks that have timed out
- Checking if time slicing is required (i.e., triggering a context switch)
- Executing the application tick hook
In ESP-IDF FreeRTOS, each core will receive a periodic interrupt and independently run the tick interrupt. The tick interrupts on each core are of the same period but can be out of phase. However, the tick responsibilities listed above are not run by all cores:

- CPU0 will execute all of the tick interrupt responsibilities listed above
- CPU1 will only check for time slicing and execute the application tick hook

**Note:** CPU0 is solely responsible for keeping time in ESP-IDF FreeRTOS. Therefore anything that prevents CPU0 from incrementing the tick count (such as suspending the scheduler on CPU0) will cause the entire schedulers time keeping to lag behind.

**Idle Tasks**  Vanilla FreeRTOS will implicitly create an idle task of priority 0 when the scheduler is started. The idle task runs when no other task is ready to run, and it has the following responsibilities:

- Freeing the memory of deleted tasks
- Executing the application idle hook

In ESP-IDF FreeRTOS, a separate pinned idle task is created for each core. The idle tasks on each core have the same responsibilities as their vanilla counterparts.

**Scheduler Suspension**  Vanilla FreeRTOS allows the scheduler to be suspended/resumed by calling `vTaskSuspendAll()` and `xTaskResumeAll()` respectively. While the scheduler is suspended:

- Task switching is disabled but interrupts are left enabled.
- Calling any blocking/yielding function is forbidden, and time slicing is disabled.
- The tick count is frozen (but the tick interrupt will still occur to execute the application tick hook)

On scheduler resumption, `xTaskResumeAll()` will catch up all of the lost ticks and unblock any timed out tasks.

In ESP-IDF FreeRTOS, suspending the scheduler across multiple cores is not possible. Therefore when `vTaskSuspendAll()` is called on a particular core (e.g., core A):

- Task switching is disabled only on core A but interrupts for core A are left enabled
- Calling any blocking/yielding function on core A is forbidden. Time slicing is disabled on core A.
- If an interrupt on core A unblocks any tasks, tasks with affinity to core A will go into core A’s own pending ready task list. Unpinned tasks or tasks with affinity to other cores can be scheduled on cores with the scheduler running.
- In case the scheduler is suspended on all cores, tasks unblocked by an interrupt will go to the pending ready task lists of their pinned cores or to the pending ready list of the core on which the interrupt is called if the tasks are unpinned.
- If core A is CPU0, the tick count is frozen and a pended tick count is incremented instead. However, the tick interrupt will still occur in order to execute the application tick hook.

When `xTaskResumeAll()` is called on a particular core (e.g., core A):

- Any tasks added to core A’s pending ready task list will be resumed
- If core A is CPU0, the pended tick count is unwound to catch up the lost ticks.

**Warning:** Given that scheduler suspension on ESP-IDF FreeRTOS will only suspend scheduling on a particular core, scheduler suspension is NOT a valid method ensuring mutual exclusion between tasks when accessing shared data. Users should use proper locking primitives such as mutexes or spinlocks if they require mutual exclusion.

**Disabling Interrupts**  Vanilla FreeRTOS allows interrupts to be disabled and enabled by calling `taskDISABLE_INTERRUPTS` and `taskENABLE_INTERRUPTS` respectively.

ESP-IDF FreeRTOS provides the same API, however interrupts will only disabled or enabled on the current core.
**Warning:** Disabling interrupts is a valid method of achieve mutual exclusion in Vanilla FreeRTOS (and single core systems in general). However, in an SMP system, disabling interrupts is **NOT** a valid method ensuring mutual exclusion. Refer to Critical Sections for more details.

### Critical Sections

**API Changes**  
Vanilla FreeRTOS implements critical sections by disabling interrupts. This prevents preemptive context switches and the servicing of ISRs during a critical section. Thus a task/ISR that enters a critical section is guaranteed to be the sole entity to access a shared resource. Critical sections in Vanilla FreeRTOS have the following API:

- `taskENTER_CRITICAL()` enters a critical section by disabling interrupts
- `taskEXIT_CRITICAL()` exits a critical section by reenabling interrupts
- `taskENTER_CRITICAL_FROM_ISR()` enters a critical section from an ISR by disabling interrupt nesting
- `taskEXIT_CRITICAL_FROM_ISR()` exits a critical section from an ISR by reenabling interrupt nesting

However, in an SMP system, merely disabling interrupts does not constitute a critical section as the presence of other cores means that a shared resource can still be concurrently accessed. Therefore, critical sections in ESP-IDF FreeRTOS are implemented using spinlocks. To accommodate the spinlocks, the ESP-IDF FreeRTOS critical section APIs contain an additional spinlock parameter as shown below:

- Spinlocks are of `portMUX_TYPE` (**not to be confused to FreeRTOS mutexes**)
- `taskENTER_CRITICAL(&spinlock)` enters a critical section from a task context
- `taskEXIT_CRITICAL(&spinlock)` exits a critical section from a task context
- `taskENTER_CRITICAL_ISR(&spinlock)` enters a critical section from an interrupt context
- `taskEXIT_CRITICAL_ISR(&spinlock)` exits a critical section from an interrupt context

**Note:** The critical section API can be called recursively (i.e., nested critical sections). Entering a critical section multiple times recursively is valid so long as the critical section is exited the same number of times it was entered. However, given that critical sections can target different spinlocks, users should take care to avoid dead locking when entering critical sections recursively.

Spinlocks can be allocated statically or dynamically. As such, macros are provided for both static and dynamic initialization of spinlocks, as demonstrated by the following code snippets.

#### Allocating a static spinlock and initializing it using `portMUX_INITIALIZER_UNLOCKED`

```c
// Statically allocate and initialize the spinlock
static portMUX_TYPE my_spinlock = portMUX_INITIALIZER_UNLOCKED;

void some_function(void)
{
    taskENTER_CRITICAL(&my_spinlock);
    // We are now in a critical section
    taskEXIT_CRITICAL(&my_spinlock);
}
```

#### Allocating a dynamic spinlock and initializing it using `portMUX_INITIALIZE()`

```c
// Allocate the spinlock dynamically
portMUX_TYPE *my_spinlock = malloc(sizeof(portMUX_TYPE));
// Initialize the spinlock dynamically
portMUX_INITIALIZE(my_spinlock);
...

    taskENTER_CRITICAL(my_spinlock);
    // Access the resource
    taskEXIT_CRITICAL(my_spinlock);
```
**Implementation**  
In ESP-IDF FreeRTOS, the process of a particular core entering and exiting a critical section is as follows:

- For `taskENTER_CRITICAL(&spinlock)` (or `taskENTER_CRITICAL_ISR(&spinlock)`)
  1. The core disables its interrupts (or interrupt nesting) up to `configMAX_SYSCALL_INTERRUPT_PRIORITY`
  2. The core then spins on the spinlock using an atomic compare-and-set instruction until it acquires the lock.
  3. Once the spinlock is acquired, the function returns. The remainder of the critical section runs with interrupts (or interrupt nesting) disabled.
- For `taskEXIT_CRITICAL(&spinlock)` (or `taskEXIT_CRITICAL_ISR(&spinlock)`)
  1. The core releases the spinlock by clearing the spinlock’s owner value
  2. The core re-enables interrupts (or interrupt nesting)

**Restrictions and Considerations**  
Given that interrupts (or interrupt nesting) are disabled during a critical section, there are multiple restrictions regarding what can be done within a critical sections. During a critical section, users should keep the following restrictions and considerations in mind:

- Critical sections should be as short as possible
  - The longer the critical section lasts, the longer a pending interrupt can be delayed.
  - A typical critical section should only access a few data structures and/or hardware registers
  - If possible, defer as much processing and/or event handling to the outside of critical sections.
- FreeRTOS API should not be called from within a critical section
- Users should never call any blocking or yielding functions within a critical section

**Misc**

**Floating Point Usage**  
Usually, when a context switch occurs:

- the current state of a CPU’s registers are saved to the stack of task being switch out
- the previously saved state of the CPU’s registers are loaded from the stack of the task being switched in

However, ESP-IDF FreeRTOS implements Lazy Context Switching for the FPU (Floating Point Unit) registers of a CPU. In other words, when a context switch occurs on a particular core (e.g., CPU0), the state of the core’s FPU registers are not immediately saved to the stack of the task getting switched out (e.g., Task A). The FPU’s registers are left untouched until:

- A different task (e.g., Task B) runs on the same core and uses the FPU. This will trigger an exception that will save the FPU registers to Task A’s stack.
- Task A gets scheduled to the same core and continues execution. Saving and restoring the FPU’s registers is not necessary in this case.

However, given that tasks can be unpinned thus can be scheduled on different cores (e.g., Task A switches to CPU1), it is unfeasible to copy and restore the FPU’s registers across cores. Therefore, when a task utilizes the FPU (by using a `float` type in its call flow), ESP-IDF FreeRTOS will automatically pin the task to the current core it is running on. This ensures that all tasks that uses the FPU are always pinned to a particular core.

Furthermore, ESP-IDF FreeRTOS by default does not support the usage of the FPU within an interrupt context given that the FPU’s register state is tied to a particular task.

**Note:** ESP targets that contain an FPU do not support hardware acceleration for double precision floating point arithmetic (`double`). Instead `double` is implemented via software hence the behavioral restrictions regarding the `float` type do not apply to `double`. Note that due to the lack of hardware acceleration, `double` operations may consume significantly more CPU time in comparison to `float`.

**ESP-IDF FreeRTOS Single Core**  
Although ESP-IDF FreeRTOS is an SMP scheduler, some ESP targets are single core (such as the ESP32-S2 and ESP32-C3). When building ESP-IDF applications for these targets, ESP-IDF...
FreeRTOS is still used but the number of cores will be set to 1 (i.e., the `CONFIG_FREERTOS_UNICORE` will always be enabled for single core targets).

For multicore targets (such as the ESP32 and ESP32-S3), `CONFIG_FREERTOS_UNICORE` can also be set. This will result in ESP-IDF FreeRTOS only running on CPU0, and all other cores will be inactive.

**Note:** Users should bear in mind that enabling `CONFIG_FREERTOS_UNICORE` is NOT equivalent to running Vanilla FreeRTOS. The additional API of ESP-IDF FreeRTOS can still be called, and the behavior changes of ESP-IDF FreeRTOS will incur a small amount of overhead even when compiled for only a single core.

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**API Reference**

This section contains documentation of FreeRTOS types, functions, and macros. It is automatically generated from FreeRTOS header files.

**Task API**

**Header File**

- components/freertos/FreeRTOS-Kernel/include/freertos/task.h

**Functions**

```c
BaseType_t xTaskCreatePinnedToCore(TaskFunction_t pxTaskCode, const char*const pcName, const configSTACK_DEPTH_TYPE usStackDepth, void*const pvParameters, UBaseType_t uxPriority, TaskHandle_t *const pvCreatedTask, const BaseType_t xCoreID)
```

Create a new task with a specified affinity and add it to the list of tasks that are ready to run.

This function is similar to `xTaskCreate`, but allows setting task affinity in SMP system.

Example usage:

```c
// Task to be created.
void vTaskCode( void * pvParameters )
{
    for( ;; )
    {
        // Task code goes here.
    }
}

// Function that creates a task.
void vOtherFunction( void )
{
    static uint8_t ucParameterToPass;
    TaskHandle_t xHandle = NULL;

    // Create the task pinned to core 0, storing the handle. Note that the
    // passed parameter ucParameterToPass
    // must exist for the lifetime of the task, so in this case is declared
    // static. If it was just an
    // an automatic stack variable it might no longer exist, or at least have
    // been corrupted, by the time
    // the new task attempts to access it.
    xTaskCreatePinnedToCore( vTaskCode, "NAME", STACK_SIZE, &ucParameterToPass,
    tskIDLE_PRIORITY, &xHandle, 0 );
}
```

(continues on next page)
configASSERT( xHandle );

// Use the handle to delete the task.
if( xHandle !=- NULL )
{
  vTaskDelete( xHandle );
}

Note: If program uses thread local variables (ones specified with "__thread" keyword) then storage for them will be allocated on the task’s stack.

Parameters

- **pxTaskCode** - Pointer to the task entry function. Tasks must be implemented to never return (i.e. continuous loop), or should be terminated using vTaskDelete function.
- **pcName** -A descriptive name for the task. This is mainly used to facilitate debugging. Max length defined by configMAX_TASK_NAME_LEN - default is 16.
- **usStackDepth** -The size of the task stack specified as the number of bytes. Note that this differs from vanilla FreeRTOS.
- **pvParameters** -Pointer that will be used as the parameter for the task being created.
- **uxPriority** -The priority at which the task should run. Systems that include MPU support can optionally create tasks in a privileged (system) mode by setting bit portPRIVILEGE_BIT of the priority parameter. For example, to create a privileged task at priority 2 the uxPriority parameter should be set to ( 2 | portPRIVILEGE_BIT ).
- **pvCreatedTask** -[out] Used to pass back a handle by which the created task can be referenced.
- **xCOREID** -If the value is tskNO_AFFINITY, the created task is not pinned to any CPU, and the scheduler can run it on any core available. Values 0 or 1 indicate the index number of the CPU which the task should be pinned to. Specifying values larger than (configNUM_CORES - 1) will cause the function to fail.

Returns pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

`TaskHandle_t xTaskCreateStaticPinnedToCore( TaskFunction_t pxTaskCode, const char* const pcName, const uint32_t ulStackDepth, void *const pvParameters, UBaseType_t uxPriority, StackType_t *const pxStackBuffer, StaticTask_t *const pxTaskBuffer, const BaseType_t xCoreID )`

Create a new task with a specified affinity and add it to the list of tasks that are ready to run. This function is similar to xTaskCreateStatic, but allows specifying task affinity in an SMP system.

Example usage:

```c
// Dimensions the buffer that the task being created will use as its stack.
// NOTE: This is the number of words the stack will hold, not the number of
// bytes. For example, if each stack item is 32-bits, and this is set to 100,
// then 400 bytes (100 * 32-bits) will be allocated.
#define STACK_SIZE 200

// Structure that will hold the TCB of the task being created.
StaticTask_t xTaskBuffer;

// Buffer that the task being created will use as its stack. Note this is
// an array of StackType_t variables. The size of StackType_t is dependent on
// the RTOS port.
```

(continues on next page)
StackType_t xStack[ STACK_SIZE ];

// Function that implements the task being created.
void vTaskCode( void * pvParameters )
{
    // The parameter value is expected to be 1 as 1 is passed in the
    // pvParameters value in the call to xTaskCreateStaticPinnedToCore().
    configASSERT( ( uint32_t ) pvParameters == 1UL );

    for( ;; )
    {
        // Task code goes here.
    }
}

// Function that creates a task.
void vOtherFunction( void )
{
    TaskHandle_t xHandle = NULL;

    // Create the task pinned to core 0 without using any dynamic memory
    // allocation.
    xHandle = xTaskCreateStaticPinnedToCore( 
        vTaskCode, // Function that implements the task.
        "NAME", // Text name for the task.
        STACK_SIZE, // Stack size in bytes, not words.
        ( void * ) 1, // Parameter passed into the task.
        tskIDLE_PRIORITY, // Priority at which the task is created.
        &xStack, // Array to use as the task's stack.
        &xTaskBuffer, // Variable to hold the task's data
        0 ); // Specify the task's core affinity

    // puxStackBuffer and pxTaskBuffer were not NULL, so the task will have
    // been created, and xHandle will be the task's handle. Use the handle
    // to suspend the task.
    vTaskSuspend( xHandle );
}

Parameters

- **pxTaskCode** - Pointer to the task entry function. Tasks must be implemented to never return (i.e. continuous loop), or should be terminated using vTaskDelete function.
- **pcName** - A descriptive name for the task. This is mainly used to facilitate debugging. The maximum length of the string is defined by configMAX_TASK_NAME_LEN in FreeRTOSConfig.h.
- **ulStackDepth** - The size of the task stack specified as the number of bytes. Note that this differs from vanilla FreeRTOS.
- **pvParameters** - Pointer that will be used as the parameter for the task being created.
- **uxPriority** - The priority at which the task will run.
- **pxStackBuffer** - Must point to a StackType_t array that has at least ulStackDepth indexes - the array will then be used as the task’s stack, removing the need for the stack to be allocated dynamically.
- **pxTaskBuffer** - Must point to a variable of type StaticTask_t, which will then be used to hold the task’s data structures, removing the need for the memory to be allocated dynamically.
- **xCoreID** - If the value is tskNO_AFFINITY, the created task is not pinned to any CPU, and the scheduler can run it on any core available. Values 0 or 1 indicate the index number of the CPU which the task should be pinned to. Specifying values larger than (configNUM_CORES - 1) will cause the function to fail.
Returns If neither pxStackBuffer or pxTaskBuffer are NULL, then the task will be created and pdPASS is returned. If either pxStackBuffer or pxTaskBuffer are NULL then the task will not be created and errCANNOTALLOCATEREQUIREDMEMORY is returned.

static inline BaseType_t xTaskCreate(TaskFunction_t pxTaskCode, const char *const pcName, const configSTACK_DEPTH_TYPE usStackDepth, void *const pvParameters, UBaseType_t uxPriority, TaskHandle_t *const pxCreatedTask)

Create a new task and add it to the list of tasks that are ready to run.

Internally, within the FreeRTOS implementation, tasks use two blocks of memory. The first block is used to hold the task’s data structures. The second block is used by the task as its stack. If a task is created using xTaskCreate() then both blocks of memory are automatically dynamically allocated inside the xTaskCreate() function. (see https://www.FreeRTOS.org/a00111.html). If a task is created using xTaskCreateStatic() then the application writer must provide the required memory. xTaskCreateStatic() therefore allows a task to be created without using any dynamic memory allocation.

See xTaskCreateStatic() for a version that does not use any dynamic memory allocation.

xTaskCreate() can only be used to create a task that has unrestricted access to the entire microcontroller memory map. Systems that include MPU support can alternatively create an MPU constrained task using xTaskCreateRestricted().

Example usage:

```c
// Task to be created.
void vTaskCode( void * pvParameters )
{
    for( ;; )
    {
        // Task code goes here.
    }
}

// Function that creates a task.
void vOtherFunction( void )
{
    static uint8_t ucParameterToPass;
    TaskHandle_t xHandle = NULL;

    // Create the task, storing the handle. Note that the passed parameter...
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, &ucParameterToPass, tskIDLE_PRIORITY, &xHandle );
    configASSERT( xHandle );

    // Use the handle to delete the task.
    if( xHandle != NULL )
    {
        vTaskDelete( xHandle );
    }
}
```

Note: If program uses thread local variables (ones specified with "__thread" keyword) then storage for them
will be allocated on the task’s stack.

**Parameters**

- **pxTaskCode** - Pointer to the task entry function. Tasks must be implemented to never return (i.e. continuous loop), or should be terminated using vTaskDelete function.
- **pcName** - A descriptive name for the task. This is mainly used to facilitate debugging. Max length defined by configMAX_TASK_NAME_LEN - default is 16.
- **usStackDepth** - The size of the task stack specified as the number of bytes. Note that this differs from vanilla FreeRTOS.
- **pvParameters** - Pointer that will be used as the parameter for the task being created.
- **uxPriority** - The priority at which the task should run. Systems that include MPU support can optionally create tasks in a privileged (system) mode by setting bit portPRIVILEGE_BIT of the priority parameter. For example, to create a privileged task at priority 2 the uxPriority parameter should be set to (2 | portPRIVILEGE_BIT).
- **pxCreatedTask** - Used to pass back a handle by which the created task can be referenced.

**Returns** pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

```
static inline TaskHandle_t xTaskCreateStatic(TaskFunction_t pxTaskCode, const char* const pcName,
                                           const uint32_t ulStackDepth, void *const pvParameters,
                                           UBaseType_t uxPriority, StackType_t *const puxStackBuffer, StaticTask_t *const pxTaskBuffer)
```

Create a new task and add it to the list of tasks that are ready to run.

Internally, within the FreeRTOS implementation, tasks use two blocks of memory. The first block is used to hold the task’s data structures. The second block is used by the task as its stack. If a task is created using xTaskCreate() then both blocks of memory are automatically dynamically allocated inside the xTaskCreate() function. (see https://www.FreeRTOS.org/a00111.html). If a task is created using xTaskCreateStatic() then the application writer must provide the required memory. xTaskCreateStatic() therefore allows a task to be created without using any dynamic memory allocation.

**Example usage:**

```c
// Dimensions the buffer that the task being created will use as its stack.
// NOTE: This is the number of bytes the stack will hold, not the number of
// words as found in vanilla FreeRTOS.
#define STACK_SIZE 200

// Structure that will hold the TCB of the task being created.
StaticTask_t xTaskBuffer;

// Buffer that the task being created will use as its stack. Note this is
// an array of StackType_t variables. The size of StackType_t is dependent on
// the RTOS port.
StackType_t xStack[ STACK_SIZE ];

// Function that implements the task being created.
void vTaskCode( void * pvParameters )
{
    // The parameter value is expected to be 1 as 1 is passed in the
    // pvParameters value in the call to xTaskCreateStatic().
    configASSERT( ( uint32_t ) pvParameters == 1UL );

    for( ;; )
    {
        // Task code goes here.
    }
```

(continues on next page)
// Function that creates a task.
void vOtherFunction( void )
{
    TaskHandle_t xHandle = NULL;

    // Create the task without using any dynamic memory allocation.
    xHandle = xTaskCreateStatic(
        vTaskCode,          // Function that implements the task.
        "NAME",            // Text name for the task.
        STACK_SIZE,        // Stack size in bytes, not words.
        ( void * ) 1,      // Parameter passed into the task.
        tskIDLE_PRIORITY,  // Priority at which the task is created.
        xStack,            // Array to use as the task's stack.
        &xTaskBuffer );    // Variable to hold the task's data...

    // puxStackBuffer and pxTaskBuffer were not NULL, so the task will have
    // been created, and xHandle will be the task's handle. Use the handle
    // to suspend the task.
    vTaskSuspend( xHandle );
}

Note: If program uses thread local variables (ones specified with "__thread" keyword) then storage for them
will be allocated on the task’s stack.

Parameters
- pxTaskCode - Pointer to the task entry function. Tasks must be implemented to never
  return (i.e. continuous loop), or should be terminated using vTaskDelete function.
- pcName - A descriptive name for the task. This is mainly used to facilitate debugging.
  The maximum length of the string is defined by configMAX_TASK_NAME_LEN in
  FreeRTOSConfig.h.
- ulStackDepth - The size of the task stack specified as the number of bytes. Note that
  this differs from vanilla FreeRTOS.
- pvParameters - Pointer that will be used as the parameter for the task being created.
- uxPriority - The priority at which the task will run.
- puxStackBuffer - Must point to a StackType_t array that has at least ulStackDepth
  indexes - the array will then be used as the task’s stack, removing the need for the stack
to be allocated dynamically.
- pxTaskBuffer - Must point to a variable of type StaticTask_t, which will then be used
to hold the task’s data structures, removing the need for the memory to be allocated
dynamically.

Returns If neither pxStackBuffer or pxTaskBuffer are NULL, then the task will be created and
pdPASS is returned. If either pxStackBuffer or pxTaskBuffer are NULL then the task will not
be created and errCOULD_NOT_ALLOCATE_REQUIRED_MEMORY is returned.

void vTaskAllocateMPURegions ( TaskHandle_t xTask, const MemoryRegion_t *const pxRegions)

Only available when configSUPPORT_DYNAMIC_ALLOCATION is set to 1.

xTaskCreateRestricted() should only be used in systems that include an MPU implementation.

Create a new task and add it to the list of tasks that are ready to run. The function parameters define the
memory regions and associated access permissions allocated to the task.

See xTaskCreateRestrictedStatic() for a version that does not use any dynamic memory allocation.
Example usage:

```c
// Create an TaskParameters_t structure that defines the task to be created.
static const TaskParameters_t xCheckTaskParameters = {
    vATask,       // pvTaskCode - the function that implements the task.
    "ATask",     // pcName - just a text name for the task to assist debugging.
    100,         // usStackDepth - the stack size DEFINED IN WORDS.
    NULL,        // pvParameters - passed into the task function as the function parameters.
    &xCheckTaskParameters,
    1UL | portPRIVILEGE_BIT,  // uxPriority - task priority, set the...
    cStackBuffer, // puxStackBuffer - the buffer to be used as the task stack.
    // xRegions - Allocate up to three separate memory regions for access by...
    // the task, with appropriate access permissions. Different processors have
    // different memory alignment requirements - refer to the FreeRTOS...
    // documentation
    // for full information.
    {
        cReadWriteArray, 32, portMPU_REGION_READ_WRITE },
    {
        cReadOnlyArray, 32, portMPU_REGION_READ_ONLY },
    {
        cPrivilegedOnlyAccessArray, 128, portMPU_REGION_PRIVILEGED_READ_WRITE }
};

int main( void )
{
    TaskHandle_t xHandle;

    // Create a task from the const structure defined above. The task handle
    // is requested (the second parameter is not NULL) but in this case just for
    // demonstration purposes as its not actually used.
    xTaskCreateRestricted( &xRegTest1Parameters, &xHandle );

    // Start the scheduler.
    vTaskStartScheduler();

    // Will only get here if there was insufficient memory to create the idle
    // and/or timer task.
    for( ;; );
}
```

Only available when configSUPPORT_STATIC_ALLOCATION is set to 1.

xTaskCreateRestrictedStatic() should only be used in systems that include an MPU implementation.

Internally, within the FreeRTOS implementation, tasks use two blocks of memory. The first block is used to hold the task’s data structures. The second block is used by the task as its stack. If a task is created using xTaskCreateRestricted() then the stack is provided by the application writer, and the memory used to hold the task’s data structure is automatically dynamically allocated inside the xTaskCreateRestricted() function. If a task is created using xTaskCreateRestrictedStatic() then the application writer must provide the memory used to hold the task’s data structures too. xTaskCreateRestrictedStatic() therefore allows a memory protected task to be created without using any dynamic memory allocation.

Example usage:

```c
// Create an TaskParameters_t structure that defines the task to be created.
// The StaticTask_t variable is only included in the structure when
(continues on next page)
```
// configSUPPORT_STATIC_ALLOCATION is set to 1. The PRIVILEGED_DATA macro can be used to force the variable into the RTOS kernel's privileged data area.

```c
static PRIVILEGED_DATA StaticTask_t xTaskBuffer;
static const TaskParameters_t xCheckTaskParameters = {
    vATask,  // pvTaskCode - the function that implements the task.
    "vATask",  // pcName - just a text name for the task to assist debugging.
    100,    // usStackDepth - the stack size DEFINED IN BYTES.
    NULL,   // pvParameters - passed into the task function as the function parameters.
    1UL | portPRIVILEGE_BIT, // uxPriority - task priority, set the portPRIVILEGE_BIT if the task should run in a privileged state.
    cStackBuffer, // puxStackBuffer - the buffer to be used as the task stack.
};
```

Memory regions are assigned to a restricted task when the task is created by a call to `xTaskCreateRestricted()`. These regions can be redefined using `vTaskAllocateMPURegions()`.

Example usage:

```c
int main( void )
{
    TaskHandle_t xHandle;

    // Create a task from the const structure defined above. The task handle is requested (the second parameter is not NULL) but in this case just for demonstration purposes as its not actually used.
    xTaskCreateRestricted( &xRegTest1Parameters, &xHandle );

    // Start the scheduler.
    vTaskStartScheduler();

    // Will only get here if there was insufficient memory to create the idle task.
    for( ;; );
}
```

(continues on next page)
void vATask( void *pvParameters )
{
    // This task was created such that it has access to certain regions of
    // memory as defined by the MPU configuration. At some point it is
    // desired that these MPU regions are replaced with that defined in the
    // xAltRegions const struct above. Use a call to vTaskAllocateMPURegions()
    // for this purpose. NULL is used as the task handle to indicate that this
    // function should modify the MPU regions of the calling task.
    vTaskAllocateMPURegions( NULL, xAltRegions );

    // Now the task can continue its function, but from this point on can only
    // access its stack and the ucOneKByte array (unless any other statically
    // defined or shared regions have been declared elsewhere).
}

Parameters

- **pxTaskDefinition** – Pointer to a structure that contains a member for each of the
  normal xTaskCreate() parameters (see the xTaskCreate() API documentation) plus an
  optional stack buffer and the memory region definitions.

- **pxCreatedTask** – Used to pass back a handle by which the created task can be refer-
  enced.

- **pxTaskDefinition** – Pointer to a structure that contains a member for each of
  the normal xTaskCreate() parameters (see the xTaskCreate() API documentation)
  plus an optional stack buffer and the memory region definitions. If configSUP-
  PORT_STATIC_ALLOCATION is set to 1 the structure contains an additional member,
  which is used to point to a variable of type StaticTask_t - which is then used to hold the
  task’s data structure.

- **pxCreatedTask** – Used to pass back a handle by which the created task can be refer-
  enced.

- **xTask** – The handle of the task being updated.

- **pxRegions** – A pointer to an MemoryRegion_t structure that contains the new memory
  region definitions.

Returns pdPASS if the task was successfully created and added to a ready list, otherwise an error
code defined in the file projdefs.h

Returns pdPASS if the task was successfully created and added to a ready list, otherwise an error
code defined in the file projdefs.h

void vTaskDelete( TaskHandle_t xTaskToDelete )

INCLUDE_vTaskDelete must be defined as 1 for this function to be available. See the configuration section
for more information.

Remove a task from the RTOS real time kernel’s management. The task being deleted will be removed from
all ready, blocked, suspended and event lists.

NOTE: The idle task is responsible for freeing the kernel allocated memory from tasks that have been deleted.
It is therefore important that the idle task is not starved of microcontroller processing time if your application
makes any calls to vTaskDelete(). Memory allocated by the task code is not automatically freed, and should
be freed before the task is deleted.

See the demo application file death.c for sample code that utilises vTaskDelete().

Example usage:
```c
void vOtherFunction( void )
{
    TaskHandle_t xHandle;

    // Create the task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle );

    // Use the handle to delete the task.
    vTaskDelete( xHandle );
}
```

**Parameters xTaskToDelete** – The handle of the task to be deleted. Passing NULL will cause the calling task to be deleted.

```c
void vTaskDelay( const TickType_t xTicksToDelay )
```

Delay a task for a given number of ticks. The actual time that the task remains blocked depends on the tick rate. The constant portTICK_PERIOD_MS can be used to calculate real time from the tick rate - with the resolution of one tick period.

INCLUDE_vTaskDelay must be defined as 1 for this function to be available. See the configuration section for more information.

vTaskDelay() specifies a time at which the task wishes to unblock relative to the time at which vTaskDelay() is called. For example, specifying a block period of 100 ticks will cause the task to unblock 100 ticks after vTaskDelay() is called. vTaskDelay() does not therefore provide a good method of controlling the frequency of a periodic task as the path taken through the code, as well as other task and interrupt activity, will effect the frequency at which vTaskDelay() gets called and therefore the time at which the task next executes. See xTaskDelayUntil() for an alternative API function designed to facilitate fixed frequency execution. It does this by specifying an absolute time (rather than a relative time) at which the calling task should unblock.

```c
void vTaskFunction( void *pvParameters )
{
    // Block for 500ms.
    const TickType_t xDelay = 500 / portTICK_PERIOD_MS;

    for( ;; )
    {
        // Simply toggle the LED every 500ms, blocking between each toggle.
        vToggleLED();
        vTaskDelay( xDelay );
    }
}
```

**Parameters xTicksToDelay** – The amount of time, in tick periods, that the calling task should block.

```c
BaseType_t xTaskDelayUntil( TickType_t *const pxPreviousWakeTime, const TickType_t xTimeIncrement )
```

INCLUDE_xTaskDelayUntil must be defined as 1 for this function to be available. See the configuration section for more information.

Delay a task until a specified time. This function can be used by periodic tasks to ensure a constant execution frequency.

This function differs from vTaskDelay() in one important aspect: vTaskDelay() will cause a task to block for the specified number of ticks from the time vTaskDelay() is called. It is therefore difficult to use vTaskDelay
by itself to generate a fixed execution frequency as the time between a task starting to execute and that task calling vTaskDelay() may not be fixed [the task may take a different path though the code between calls, or may get interrupted or preempted a different number of times each time it executes].

Whereas vTaskDelay() specifies a wake time relative to the time at which the function is called, xTaskDelayUntil() specifies the absolute (exact) time at which it wishes to unblock.

The macro pdMS_TO_TICKS() can be used to calculate the number of ticks from a time specified in milliseconds with a resolution of one tick period.

Example usage:

```c
// Perform an action every 10 ticks.
void vTaskFunction( void * pvParameters )
{
    TickType_t xLastWakeTime;
    const TickType_t xFrequency = 10;
    BaseType_t xWasDelayed;

    // Initialise the xLastWakeTime variable with the current time.
    xLastWakeTime = xTaskGetTickCount();
    for(;; )
    {
        // Wait for the next cycle.
        xWasDelayed = xTaskDelayUntil( &xLastWakeTime, xFrequency );

        // Perform action here. xWasDelayed value can be used to determine // whether a deadline was missed if the code here took too long.
    }
}
```

Parameters

- **pxPreviousWakeTime**  – Pointer to a variable that holds the time at which the task was last unblocked. The variable must be initialized with the current time prior to its first use (see the example below). Following this the variable is automatically updated within xTaskDelayUntil().
- **xTimeIncrement**  – The cycle time period. The task will be unblocked at time *pxPreviousWakeTime + xTimeIncrement*. Calling xTaskDelayUntil with the same xTimeIncrement parameter value will cause the task to execute with a fixed interface period.

Returns  Value which can be used to check whether the task was actually delayed. Will be pdTRUE if the task way delayed and pdFALSE otherwise. A task will not be delayed if the next expected wake time is in the past.

BaseType_t xTaskAbortDelay(TaskHandle_t xTask)

INCLUDE_xTaskAbortDelay must be defined as 1 in FreeRTOSConfig.h for this function to be available.

A task will enter the Blocked state when it is waiting for an event. The event it is waiting for can be a temporal event (waiting for a time), such as when vTaskDelay() is called, or an event on an object, such as when xQueueReceive() or ulTaskNotifyTake() is called. If the handle of a task that is in the Blocked state is used in a call to xTaskAbortDelay() then the task will leave the Blocked state, and return from whichever function call placed the task into the Blocked state.

There is no ‘FromISR’ version of this function as an interrupt would need to know which object a task was blocked on in order to know which actions to take. For example, if the task was blocked on a queue the interrupt handler would then need to know if the queue was locked.

Parameters **xTask**  – The handle of the task to remove from the Blocked state.

Returns  If the task referenced by xTask was not in the Blocked state then pdFAIL is returned. Otherwise pdPASS is returned.
Chapter 2. API Reference

**UBaseType_t** `uxTaskPriorityGet` (const `TaskHandle_t` `xTask`)

INCLUDE `_uxTaskPriorityGet` must be defined as 1 for this function to be available. See the configuration section for more information.

Obtain the priority of any task.

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle_--);

    // ...

    // Use the handle to obtain the priority of the created task.
    // It was created with tskIDLE_PRIORITY, but may have changed // it itself.
    if( uxTaskPriorityGet( xHandle ) != tskIDLE_PRIORITY )
    {
        // The task has changed it's priority.
    }

    // ...

    // Is our priority higher than the created task?
    if( uxTaskPriorityGet( xHandle ) < uxTaskPriorityGet( NULL ) )
    {
        // Our priority (obtained using NULL handle) is higher.
    }
}
```

**Parameters**
- `xTask` – Handle of the task to be queried. Passing a NULL handle results in the priority of the calling task being returned.

**Returns**
The priority of `xTask`.

**UBaseType_t** `uxTaskPriorityGetFromISR` (const `TaskHandle_t` `xTask`)

A version of `uxTaskPriorityGet()` that can be used from an ISR.

**eTaskState** `eTaskGetState` (TaskHandle_t `xTask`)

INCLUDE `_eTaskGetState` must be defined as 1 for this function to be available. See the configuration section for more information.

Obtain the state of any task. States are encoded by the `eTaskState` enumerated type.

**Parameters**
- `xTask` – Handle of the task to be queried.

**Returns**
The state of `xTask` at the time the function was called. Note the state of the task might change between the function being called, and the functions return value being tested by the calling task.

**void** `vTaskGetInfo` (TaskHandle_t `xTask`, TaskStatus_t *pxTaskStatus, BaseType_t `xGetFreeStackSpace`, eTaskState `eState`)

`configUSE_TRACE_FACILITY` must be defined as 1 for this function to be available. See the configuration section for more information.

Populates a `TaskStatus_t` structure with information about a task.
Example usage:

```c
void vAFunction( void )
{
  TaskHandle_t xHandle;
  TaskStatus_t xTaskDetails;

  // Obtain the handle of a task from its name.
  xHandle = xTaskGetHandle( "Task_Name" );

  // Check the handle is not NULL.
  configASSERT( xHandle );

  // Use the handle to obtain further information about the task.
  vTaskGetInfo( xHandle,
               &xTaskDetails,
               pdTRUE, // Include the high water mark in xTaskDetails.
               eInvalid ); // Include the task state in xTaskDetails.
}
```

**Parameters**

- **xTask** – Handle of the task being queried. If xTask is NULL then information will be returned about the calling task.
- **pxTaskStatus** – A pointer to the TaskStatus_t structure that will be filled with information about the task referenced by the handle passed using the xTask parameter.
- **xGetFreeStackSpace** – The TaskStatus_t structure contains a member to report the stack high water mark of the task being queried. Calculating the stack high water mark takes a relatively long time, and can make the system temporarily unresponsive - so the xGetFreeStackSpace parameter is provided to allow the high water mark checking to be skipped. The high watermark value will only be written to the TaskStatus_t structure if xGetFreeStackSpace is not set to pdFALSE;
- **eState** – The TaskStatus_t structure contains a member to report the state of the task being queried. Obtaining the task state is not as fast as a simple assignment - so the eState parameter is provided to allow the state information to be omitted from the TaskStatus_t structure. To obtain state information then set eState to eInvalid - otherwise the value passed in eState will be reported as the task state in the TaskStatus_t structure.

void vTaskPrioritySet ( TaskHandle_t xTask, UBaseType_t uxNewPriority )

INCLUDE_vTaskPrioritySet must be defined as 1 for this function to be available. See the configuration section for more information.

Set the priority of any task.

A context switch will occur before the function returns if the priority being set is higher than the currently executing task.

Example usage:

```c
void vAFunction( void )
{
  TaskHandle_t xHandle;

  // Create a task, storing the handle.
  xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle_~);

  // ...

  // Use the handle to raise the priority of the created task.
```
vTaskPrioritySet( xHandle, tskIDLE_PRIORITY + 1 );

// ...

// Use a NULL handle to raise our priority to the same value.
vTaskPrioritySet( NULL, tskIDLE_PRIORITY + 1 );

Parameters

- **xTask** – Handle to the task for which the priority is being set. Passing a NULL handle results in the priority of the calling task being set.
- **uxNewPriority** – The priority to which the task will be set.

void vTaskSuspend( TaskHandle_t xTaskToSuspend )

INCLUDE_vTaskSuspend must be defined as 1 for this function to be available. See the configuration section for more information.

Suspend any task. When suspended a task will never get any microcontroller processing time, no matter what its priority.

Calls to vTaskSuspend are not accumulative - i.e. calling vTaskSuspend() twice on the same task still only requires one call to vTaskResume() to ready the suspended task.

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle);

    // ...

    // Use the handle to suspend the created task.
    vTaskSuspend( xHandle );

    // ...

    // The created task will not run during this period, unless
    // another task calls vTaskResume( xHandle ).
    // ...

    // Suspend ourselves.
    vTaskSuspend( NULL );

    // We cannot get here unless another task calls vTaskResume
    // with our handle as the parameter.
}
```

Parameters **xTaskToSuspend** – Handle to the task being suspended. Passing a NULL handle will cause the calling task to be suspended.

void vTaskResume( TaskHandle_t xTaskToResume )

INCLUDE_vTaskSuspend must be defined as 1 for this function to be available. See the configuration section for more information.
Resumes a suspended task.

A task that has been suspended by one or more calls to vTaskSuspend() will be made available for running again by a single call to vTaskResume().

Example usage:

```c
void vAFunction( void )
{
    TaskHandle_t xHandle;

    // Create a task, storing the handle.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle );

    // ...

    // Use the handle to suspend the created task.
    vTaskSuspend( xHandle );

    // ...

    // The created task will not run during this period, unless
    // another task calls vTaskResume( xHandle ).

    // ...

    // Resume the suspended task ourselves.
    vTaskResume( xHandle );

    // The created task will once again get microcontroller processing
    // time in accordance with its priority within the system.
}
```

**Parameters**

- xTaskToResume – Handle to the task being readied.

**BaseType_t xTaskResumeFromISR (TaskHandle_t xTaskToResume)**

INCLUDE_xTaskResumeFromISR must be defined as 1 for this function to be available. See the configuration section for more information.

An implementation of vTaskResume() that can be called from within an ISR.

A task that has been suspended by one or more calls to vTaskSuspend() will be made available for running again by a single call to xTaskResumeFromISR().

xTaskResumeFromISR() should not be used to synchronise a task with an interrupt if there is a chance that the interrupt could arrive prior to the task being suspended - as this can lead to interrupts being missed. Use of a semaphore as a synchronisation mechanism would avoid this eventuality.

**Parameters**

- xTaskToResume – Handle to the task being readied.

**Returns**

pdTRUE if resuming the task should result in a context switch, otherwise pdFALSE. This is used by the ISR to determine if a context switch may be required following the ISR.

void vTaskStartScheduler (void)

Starts the real time kernel tick processing. After calling the kernel has control over which tasks are executed and when.

See the demo application file main.c for an example of creating tasks and starting the kernel.

Example usage:
Chapter 2. API Reference

```c
void vAFuntion( void )
{
    // Create at least one task before starting the kernel.
    xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, NULL );

    // Start the real time kernel with preemption.
    vTaskStartScheduler();

    // Will not get here unless a task calls vTaskEndScheduler ()
}
```

**Note:** In ESP-IDF the scheduler is started automatically during application startup, vTaskStartScheduler() should not be called from ESP-IDF applications.

```c
void vTaskEndScheduler( void )
{
    NOTE: At the time of writing only the x86 real mode port, which runs on a PC in place of DOS, implements this function.

    Stops the real time kernel tick. All created tasks will be automatically deleted and multitasking (either pre-emptive or cooperative) will stop. Execution then resumes from the point where vTaskStartScheduler () was called, as if vTaskStartScheduler () had just returned.

    See the demo application file main. c in the demo/PC directory for an example that uses vTaskEndScheduler ()

    vTaskEndScheduler () requires an exit function to be defined within the portable layer (see vPortEndScheduler () in port. c for the PC port). This performs hardware specific operations such as stopping the kernel tick.

    vTaskEndScheduler () will cause all of the resources allocated by the kernel to be freed - but will not free resources allocated by application tasks.

    Example usage:

    ```c
    void vTaskCode( void * pvParameters )
    {
        for( ;; )
        {
            // Task code goes here.
            // At some point we want to end the real time kernel processing
            // so call ....
            vTaskEndScheduler();
        }
    }
    ```

    ```c
    void vAFuntion( void )
    {
        // Create at least one task before starting the kernel.
        xTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, NULL );

        // Start the real time kernel with preemption.
        vTaskStartScheduler();

        // Will only get here when the vTaskCode () task has called
        // vTaskEndScheduler (). When we get here we are back to single task
        // execution.
    }
    ```

void vTaskSuspendAll ( void )

Suspends the scheduler without disabling interrupts. Context switches will not occur while the scheduler is suspended.
After calling vTaskSuspendAll() the calling task will continue to execute without risk of being swapped out until a call to xTaskResumeAll() has been made.

API functions that have the potential to cause a context switch (for example, vTaskDelayUntil(), xQueueSend(), etc.) must not be called while the scheduler is suspended.

Example usage:

```c
void vTask1( void * pvParameters )
{
    for(;; )
    {
        // Task code goes here.
        // ...

        // At some point the task wants to perform a long operation during
        // which it does not want to get swapped out. It cannot use
        // taskENTER_CRITICAL() / taskEXIT_CRITICAL() as the length of the
        // operation may cause interrupts to be missed - including the
        // ticks.

        // Prevent the real time kernel swapping out the task.
        vTaskSuspendAll();

        // Perform the operation here. There is no need to use critical
        // sections as we have all the microcontroller processing time.
        // During this time interrupts will still operate and the kernel
        // tick count will be maintained.

        // ...

        // The operation is complete. Restart the kernel.
        xTaskResumeAll();
    }
}
```

BaseType_t xTaskResumeAll( void )
Resumes scheduler activity after it was suspended by a call to vTaskSuspendAll().

xTaskResumeAll() only resumes the scheduler. It does not unsuspend tasks that were previously suspended by a call to vTaskSuspend().

Example usage:

```c
void vTask1( void * pvParameters )
{
    for(;; )
    {
        // Task code goes here.
        // ...

        // At some point the task wants to perform a long operation during
        // which it does not want to get swapped out. It cannot use
        // taskENTER_CRITICAL() / taskEXIT_CRITICAL() as the length of the
        // operation may cause interrupts to be missed - including the
        // ticks.

        // Prevent the real time kernel swapping out the task.
        vTaskSuspendAll();
    }
}
```
// Perform the operation here. There is no need to use critical
// sections as we have all the microcontroller processing time.
// During this time interrupts will still operate and the real
// time kernel tick count will be maintained.

// ...

// The operation is complete. Restart the kernel. We want to force
// a context switch - but there is no point if resuming the scheduler
// caused a context switch already.
if (!xTaskResumeAll ( ) )
{
    taskYIELD ( );
}

Returns  If resuming the scheduler caused a context switch then pdTRUE is returned, otherwise
pdFALSE is returned.

TickType_t xTaskGetTickCount ( void )

Returns  The count of ticks since vTaskStartScheduler was called.

TickType_t xTaskGetTickCountFromISR ( void )

This is a version of xTaskGetTickCount() that is safe to be called from an ISR - provided that TickType_t is
the natural word size of the microcontroller being used or interrupt nesting is either not supported or not being
used.

Returns  The count of ticks since vTaskStartScheduler was called.

UBaseType_t uxTaskGetNumberOfTasks ( void )

Returns  The number of tasks that the real time kernel is currently managing. This includes all
ready, blocked and suspended tasks. A task that has been deleted but not yet freed by the idle
task will also be included in the count.

char *pcTaskGetName ( TaskHandle_t xTaskToQuery )

Returns  The text (human readable) name of the task referenced by the handle xTaskToQuery. A
task can query its own name by either passing in its own handle, or by setting xTaskToQuery
to NULL.

TaskHandle_t xTaskGetHandle ( const char *pcNameToQuery )

NOTE: This function takes a relatively long time to complete and should be used sparingly.

Returns  The handle of the task that has the human readable name pcNameToQuery. NULL
is returned if no matching name is found. INCLUDE_xTaskGetHandle must be set to 1 in
FreeRTOSConfig.h for pcTaskGetHandle() to be available.

BaseType_t xTaskGetStaticBuffers ( TaskHandle_t xTask, StackType_t **ppuxStackBuffer, StaticTask_t **ppxTaskBuffer )

UBaseType_t uxTaskGetStackHighWaterMark ( TaskHandle_t xTask )

Returns  the high water mark of the stack associated with xTask.

INCLUDE_uxTaskGetStackHighWaterMark must be set to 1 in FreeRTOSConfig.h for this function to be available.

Returns  the high water mark of the stack associated with xTask. That is, the minimum free stack space there
has been (in bytes not words, unlike vanilla FreeRTOS) since the task started. The smaller the returned number
the closer the task has come to overflowing its stack.
uxTaskGetStackHighWaterMark() and uxTaskGetStackHighWaterMark2() are the same except for their return type. Using configSTACK_DEPTH_TYPE allows the user to determine the return type. It gets around the problem of the value overflowing on 8-bit types without breaking backward compatibility for applications that expect an 8-bit return type.

**Parameters**
- **xTask** – Handle of the task associated with the stack to be checked. Set xTask to NULL to check the stack of the calling task.

**Returns**
- The smallest amount of free stack space there has been (in bytes not words, unlike vanilla FreeRTOS) since the task referenced by xTask was created.

```c
configSTACK_DEPTH_TYPE uxTaskGetStackHighWaterMark2 (TaskHandle_t xTask)
```

- Returns the start of the stack associated with xTask.

**Parameters**
- **xTask** – Handle of the task associated with the stack to be checked. Set xTask to NULL to check the stack of the calling task.

**Returns**
- The smallest amount of free stack space there has been (in bytes not words, unlike vanilla FreeRTOS) since the task referenced by xTask was created.

```c
uint8_t* pxTaskGetStackStart (TaskHandle_t xTask)
```

- Returns the start of the stack associated with xTask.

**Parameters**
- **xTask** – Handle of the task associated with the stack returned. Set xTask to NULL to return the stack of the calling task.

**Returns**
- A pointer to the start of the stack.

```c
void vTaskSetApplicationTaskTag (TaskHandle_t xTask, TaskHookFunction_t pxHookFunction)
```

- Sets pxHookFunction to be the task hook function used by the task xTask.

**Parameters**
- **xTask** – Handle of the task to set the hook function for. Passing xTask as NULL has the effect of setting the calling tasks hook function.
- **pxHookFunction** – Pointer to the hook function.

```c
TaskHookFunction_t xTaskGetApplicationTaskTag (TaskHandle_t xTask)
```

- Returns the pxHookFunction value assigned to the task xTask. Do not call from an interrupt service routine - call xTaskGetApplicationTaskTagFromISR() instead.

```c
TaskHookFunction_t xTaskGetApplicationTaskTagFromISR (TaskHandle_t xTask)
```

- Returns the pxHookFunction value assigned to the task xTask. Can be called from an interrupt service routine.

```c
void vTaskSetThreadLocalStoragePointer (TaskHandle_t xTaskToSet, BaseType_t xIndex, void *pvValue)
```

- Set local storage pointer specific to the given task.

Each task contains an array of pointers that is dimensioned by the configNUM_THREAD_LOCAL_STORAGE_POINTERS setting in FreeRTOSConfig.h. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

**Parameters**
• **xTaskToSet** - Task to set thread local storage pointer for
• **xIndex** - The index of the pointer to set, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.
• **pvValue** - Pointer value to set.

```c
void *pvTaskGetThreadLocalStoragePointer (TaskHandle_t xTaskToQuery, BaseType_t xIndex)
```

Get local storage pointer specific to the given task.

Each task contains an array of pointers that is dimensioned by the configNUM_THREAD_LOCAL_STORAGE_POINTERS setting in FreeRTOSConfig.h. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

**Parameters**

- **xTaskToQuery** - Task to get thread local storage pointer for
- **xIndex** - The index of the pointer to get, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.

**Returns** - Pointer value

```c
void vTaskSetThreadLocalStoragePointerAndDelCallback (TaskHandle_t xTaskToSet,
          BaseType_t xIndex, void *pvValue,
          TlsDeleteCallbackFunction_t pvDelCallback)
```

Set local storage pointer and deletion callback.

Each task contains an array of pointers that is dimensioned by the configNUM_THREAD_LOCAL_STORAGE_POINTERS setting in FreeRTOSConfig.h. The kernel does not use the pointers itself, so the application writer can use the pointers for any purpose they wish.

Local storage pointers set for a task can reference dynamically allocated resources. This function is similar to vTaskSetThreadLocalStoragePointer, but provides a way to release these resources when the task gets deleted. For each pointer, a callback function can be set. This function will be called when task is deleted, with the local storage pointer index and value as arguments.

**Parameters**

- **xTaskToSet** - Task to set thread local storage pointer for
- **xIndex** - The index of the pointer to set, from 0 to configNUM_THREAD_LOCAL_STORAGE_POINTERS - 1.
- **pvValue** - Pointer value to set.
- **pvDelCallback** - Function to call to dispose of the local storage pointer when the task is deleted.

```c
void vApplicationGetIdleTaskMemory (StaticTask_t **ppxIdleTaskTCBBuffer, StackType_t **pxxIdleTaskStackBuffer, uint32_t *pulIdleTaskStackSize)
```

This function is used to provide a statically allocated block of memory to FreeRTOS to hold the Idle Task TCB. This function is required when configSUPPORT_STATIC_ALLOCATION is set. For more information see this URI: [https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION](https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION)

**Parameters**

- **ppxIdleTaskTCBBuffer** - A handle to a statically allocated TCB buffer
- **pxxIdleTaskStackBuffer** - A handle to a statically allocated Stack buffer for the idle task
- **pulIdleTaskStackSize** - A pointer to the number of elements that will fit in the allocated stack buffer

```c
BaseType_t xTaskCallApplicationTaskHook (TaskHandle_t xTask, void *pvParameter)
```

Calls the hook function associated with xTask. Passing xTask as NULL has the effect of calling the Running tasks (the calling task) hook function.

**Parameters**

- **xTask** - Handle of the task to call the hook for.
- **pvParameter** - Parameter passed to the hook function for the task to interpret as it wants. The return value is the value returned by the task hook function registered by the user.
xTaskGetIdleTaskHandle() is only available if INCLUDE_xTaskGetIdleTaskHandle is set to 1 in FreeRTOSConfig.h.

Simply returns the handle of the idle task. It is not valid to call xTaskGetIdleTaskHandle() before the scheduler has been started.

uxTaskGetSystemState() populates an TaskStatus_t structure for each task in the system. TaskStatus_t structures contain, among other things, members for the task handle, task name, task priority, task state, and total amount of run time consumed by the task. See the TaskStatus_t structure definition in this file for the full member list.

Example usage:

```c
// This example demonstrates how a human readable table of run time stats
// information is generated from raw data provided by uxTaskGetSystemState().
// The human readable table is written to pcWriteBuffer.
void vTaskGetRunTimeStats( char *pcWriteBuffer )
{
    TaskStatus_t *pxTaskStatusArray;
    volatile UBaseType_t uxArraySize, x;
    uint32_t ulTotalRunTime, ulStatsAsPercentage;

    // Make sure the write buffer does not contain a string.
    *pcWriteBuffer = 0x00;

    // Take a snapshot of the number of tasks in case it changes while this
    // function is executing.
    uxArraySize = uxTaskGetNumberOfTasks();

    // Allocate a TaskStatus_t structure for each task. An array could be
    // allocated statically at compile time.
    pxTaskStatusArray = pvPortMalloc( uxArraySize * sizeof( TaskStatus_t ) );
    if( pxTaskStatusArray ! = NULL )
    {
        // Generate raw status information about each task.
        uxArraySize = uxTaskGetSystemState( pxTaskStatusArray, uxArraySize,  &ulTotalRunTime );

        // For percentage calculations.
        ulTotalRunTime /= 100UL;

        // Avoid divide by zero errors.
        if( ulTotalRunTime > 0 )
        {
            // For each populated position in the pxTaskStatusArray array,
            // format the raw data as human readable ASCII data
            for( x = 0; x < uxArraySize; x++ )
            {
                // What percentage of the total run time has the task used?
                // This will always be rounded down to the nearest integer.
                // ulTotalRunTimeDiv100 has already been divided by 100.
                ulStatsAsPercentage = pxTaskStatusArray[x].ulRunTimeCounter / ulTotalRunTime;
            }
        }
    }
}
```
if ( ulStatsAsPercentage > 0UL )
{
  sprintf( pcWriteBuffer, "%s\t%lu\t%lu\t%lu\n",
  &pxTaskStatusArray[ x ].pcTaskName, pxTaskStatusArray[ x ].ulRunTimeCounter,
  &ulStatsAsPercentage );
} else
{
  // If the percentage is zero here then the task has
  // consumed less than 1% of the total run time.
  sprintf( pcWriteBuffer, "%s\t%lu\t<1\%\n",
  &pxTaskStatusArray[ x ].pcTaskName, pxTaskStatusArray[ x ].ulRunTimeCounter );
}

pcWriteBuffer += strlen( ( char * ) pcWriteBuffer );

// The array is no longer needed, free the memory it consumes.
vPortFree( pxTaskStatusArray );

Note: This function is intended for debugging use only as its use results in the scheduler remaining suspended for an extended period.

Parameters

• pxTaskStatusArray – A pointer to an array of TaskStatus_t structures. The array must contain at least one TaskStatus_t structure for each task that is under the control of the RTOS. The number of tasks under the control of the RTOS can be determined using the uxTaskGetNumberOfTasks() API function.

• uxArraySize – The size of the array pointed to by the pxTaskStatusArray parameter. The size is specified as the number of indexes in the array, or the number of TaskStatus_t structures contained in the array, not by the number of bytes in the array.

• pulTotalRunTime – If configGENERATE_RUN_TIME_STATS is set to 1 in FreeRTOSConfig.h then *pulTotalRunTime is set by uxTaskGetSystemState() to the total run time (as defined by the run time stats clock, see https://www.FreeRTOS.org/rtos-run-time-stats.html) since the target booted. pulTotalRunTime can be set to NULL to omit the total run time information.

Returns The number of TaskStatus_t structures that were populated by uxTaskGetSystemState(). This should equal the number returned by the uxTaskGetNumberOfTasks() API function, but will be zero if the value passed in the uxArraySize parameter was too small.

void vTaskList (char *pcWriteBuffer)
List all the current tasks.

configUSE_TRACE_FACILITY and configUSE_STATS_FORMATTING_FUNCTIONS must both be defined as 1 for this function to be available. See the configuration section of the FreeRTOS.org website for more information.

NOTE 1: This function will disable interrupts for its duration. It is not intended for normal application runtime use but as a debug aid.

Lists all the current tasks, along with their current state and stack usage high water mark.

Tasks are reported as blocked (‘B’), ready (‘R’), deleted (‘D’) or suspended (‘S’).

PLEASE NOTE:
This function is provided for convenience only, and is used by many of the demo applications. Do not consider it to be part of the scheduler.

vTaskList() calls uxTaskGetSystemState(), then formats part of the uxTaskGetSystemState() output into a human readable table that displays task names, states and stack usage.

vTaskList() has a dependency on the sprintf() C library function that might bloat the code size, use a lot of stack, and provide different results on different platforms. An alternative, tiny, third party, and limited functionality implementation of sprintf() is provided in many of the FreeRTOS/Demo sub-directories in a file called printf-stdarg.c (note printf-stdarg.c does not provide a full snprintf() implementation!).

It is recommended that production systems call uxTaskGetSystemState() directly to get access to raw stats data, rather than indirectly through a call to vTaskList().

**Parameters**

- `pcWriteBuffer` – A buffer into which the above mentioned details will be written, in ASCII form. This buffer is assumed to be large enough to contain the generated report. Approximately 40 bytes per task should be sufficient.

```c
void vTaskGetRunTimeStats(char* pcWriteBuffer)
```

Get the state of running tasks as a string

- `configGENERATE_RUN_TIME_STATS` and `configUSE_STATS_FORMATTING_FUNCTIONS` must both be defined as 1 for this function to be available. The application must also then provide definitions for `portCONFIGURE_TIMER_FOR_RUN_TIME_STATS()` and `portGET_RUN_TIME_COUNTER_VALUE()` to configure a peripheral timer/counter and return the timers current count value respectively. The counter should be at least 10 times the frequency of the tick count.

**NOTE 1:** This function will disable interrupts for its duration. It is not intended for normal application runtime use but as a debug aid.

Setting `configGENERATE_RUN_TIME_STATS` to 1 will result in a total accumulated execution time being stored for each task. The resolution of the accumulated time value depends on the frequency of the timer configured by the `portCONFIGURE_TIMER_FOR_RUN_TIME_STATS()` macro. Calling `vTaskGetRunTimeStats()` writes the total execution time of each task into a buffer, both as an absolute count value and as a percentage of the total system execution time.

**NOTE 2:** This function is provided for convenience only, and is used by many of the demo applications. Do not consider it to be part of the scheduler.

vTaskGetRunTimeStats() calls uxTaskGetSystemState(), then formats part of the uxTaskGetSystemState() output into a human readable table that displays the amount of time each task has spent in the Running state in both absolute and percentage terms.

vTaskGetRunTimeStats() has a dependency on the sprintf() C library function that might bloat the code size, use a lot of stack, and provide different results on different platforms. An alternative, tiny, third party, and limited functionality implementation of sprintf() is provided in many of the FreeRTOS/Demo sub-directories in a file called printf-stdarg.c (note printf-stdarg.c does not provide a full snprintf() implementation!).

It is recommended that production systems call uxTaskGetSystemState() directly to get access to raw stats data, rather than indirectly through a call to vTaskGetRunTimeStats().

**Parameters**

- `pcWriteBuffer` – A buffer into which the execution times will be written, in ASCII form. This buffer is assumed to be large enough to contain the generated report. Approximately 40 bytes per task should be sufficient.

```c
uint32_t ulTaskGetIdleRunTimeCounter(void)
```

- `configGENERATE_RUN_TIME_STATS` and `configUSE_STATS_FORMATTING_FUNCTIONS` must both be defined as 1 for this function to be available. The application must also then provide definitions for `portCONFIGURE_TIMER_FOR_RUN_TIME_STATS()` and `portGET_RUN_TIME_COUNTER_VALUE()` to configure a peripheral timer/counter and return the timers current count value respectively. The counter should be at least 10 times the frequency of the tick count.
Setting config\_GENERATE\_RUN\_TIME\_STATS to 1 will result in a total accumulated execution time being stored for each task. The resolution of the accumulated time value depends on the frequency of the timer configured by the port\_CONFIGURE\_TIMER\_FOR\_RUN\_TIME\_STATS() macro. While uxTaskGetSystemState() and vTaskGetRunTimeStats() writes the total execution time of each task into a buffer, ulTaskGetIdleRunTimeCounter() returns the total execution time of just the idle task.

**Returns** The total run time of the idle task. This is the amount of time the idle task has actually been executing. The unit of time is dependent on the frequency configured using the port\_CONFIGURE\_TIMER\_FOR\_RUN\_TIME\_STATS() and port\_GET\_RUN\_TIME\_COUNTER\_VALUE() macros.

**BaseType**\_t xTaskGenericNotify (TaskHandle\_t xTaskToNotify, UBaseType\_t uXIndexToNotify, uint32\_t ulValue, eNotifyAction eAction, uint32\_t *pulPreviousNotificationValue)


configUSE\_TASK\_NOTIFICATIONS must be undefined or defined as 1 for these functions to be available.

Sends a direct to task notification to a task, with an optional value and action.

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit unsigned integer (uint32\_t). The constant config\_TASK\_NOTIFICATION\_ARRAY\_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.

A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.

A task can use xTaskNotifyWaitIndexed() to [optionally] block to wait for a notification to be pending, or ulTaskNotifyTakeIndexed() to [optionally] block to wait for a notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.

A notification sent to a task will remain pending until it is cleared by the task calling xTaskNotifyWaitIndexed() or ulTaskNotifyTakeIndexed() (or their un-indexed equivalents). If the task was already in the Blocked state to wait for a notification when the notification arrives then the task will automatically be removed from the Blocked state (unblocked) and the notification cleared.

**NOTE** Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotify() is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling xTaskNotify() is equivalent to calling xTaskNotifyIndexed() with the uxIndexToNotify parameter set to 0.

**eSetBits** - The target notification value is bitwise ORed with ulValue. xTaskNotifyIndexed() always returns pdPASS in this case.

**eIncrement** - The target notification value is incremented. ulValue is not used and xTaskNotifyIndexed() always returns pdPASS in this case.

**eSetValueWithOverwrite** - The target notification value is set to the value of ulValue, even if the task being notified had not yet processed the previous notification at the same array index (the task already had a notification pending at that index). xTaskNotifyIndexed() always returns pdPASS in this case.

**eSetValueWithoutOverwrite** - If the task being notified did not already have a notification pending at the same array index then the target notification value is set to ulValue and xTaskNotifyIndexed() will return pdPASS.
If the task being notified already had a notification pending at the same array index then no action is performed and pdFAIL is returned.

eNoAction - The task receives a notification at the specified array index without the notification value at that index being updated. ulValue is not used and xTaskNotifyIndexed() always returns pdPASS in this case.

**Parameters**

- **xTaskToNotify** – The handle of the task being notified. The handle to a task can be returned from the xTaskCreate() API function used to create the task, and the handle of the currently running task can be obtained by calling xTaskGetCurrentTaskHandle().
- **uxIndexToNotify** – The index within the target task’s array of notification values to which the notification is to be sent. uxIndexToNotify must be less than config-TASK_NOTIFICATION_ARRAY_ENTRIES. xTaskNotify() does not have this parameter and always sends notifications to index 0.
- **ulValue** – Data that can be sent with the notification. How the data is used depends on the value of the eAction parameter.
- **eAction** – Specifies how the notification updates the task’s notification value, if at all. Valid values for eAction are as follows:

**pulPreviousNotificationValue** -- Can be used to pass out the subject task’s notification value before any bits are modified by the notify function.

**Returns**

Dependent on the value of eAction. See the description of the eAction parameter.

```c
BaseType_t xTaskGenericNotifyFromISR(
  TaskHandle_t xTaskToNotify,
  UBaseType_t uxIndexToNotify, uint32_t ulValue,
  eNotifyAction eAction,
  uint32_t *pulPreviousNotificationValue, BaseType_t *pxHigherPriorityTaskWoken)
```


configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for these functions to be available.

A version of xTaskNotifyIndexed() that can be used from an interrupt service routine (ISR).

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit unsigned integer (uint32_t). The constant config-TASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.

A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.

A task can use xTaskNotifyWaitIndexed() to [optionally] block to wait for a notification to be pending, or ulTaskNotifyTakeIndexed() to [optionally] block to wait for a notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.

A notification sent to a task will remain pending until it is cleared by the task calling xTaskNotifyWaitIndexed() or ulTaskNotifyTakeIndexed() (or their un-indexed equivalents). If the task was already in the Blocked state to wait for a notification when the notification arrives then the task will automatically be removed from the Blocked state (unblocked) and the notification cleared.

**NOTE** Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotifyFromISR() is the original API function, and remains backward compatible by always operating on the notification value at index 0 within the array. Calling xTaskNotifyFromISR() is equivalent to calling xTaskNotifyIndexedFromISR() with the uxIndexToNotify parameter set to 0.
eSetBits - The task’s notification value is bitwise ORed with ulValue. xTaskNotify() always returns pdPASS in this case.

eIncrement - The task’s notification value is incremented. ulValue is not used and xTaskNotify() always returns pdPASS in this case.

eSetValueWithOverwrite - The task’s notification value is set to the value of ulValue, even if the task being notified had not yet processed the previous notification (the task already had a notification pending). xTaskNotify() always returns pdPASS in this case.

eSetValueWithoutOverwrite - If the task being notified did not already have a notification pending then the task’s notification value is set to ulValue and xTaskNotify() will return pdPASS. If the task being notified already had a notification pending then no action is performed and pdFAIL is returned.

eNoAction - The task receives a notification without its notification value being updated. ulValue is not used and xTaskNotify() always returns pdPASS in this case.

Parameters

- **uxIndexToNotify** – The index within the target task’s array of notification values to which the notification is to be sent. uxIndexToNotify must be less than configTASK_NOTIFICATION_ARRAY_ENTRIES. xTaskNotifyFromISR() does not have this parameter and always sends notifications to index 0.
- **xTaskToNotify** – The handle of the task being notified. The handle to a task can be returned from the xTaskCreate() API function used to create the task, and the handle of the currently running task can be obtained by calling xTaskGetCurrentTaskHandle().
- **ulValue** – Data that can be sent with the notification. How the data is used depends on the value of the eAction parameter.
- **eAction** – Specifies how the notification updates the task’s notification value, if at all. Valid values for eAction are as follows:
  - **pulPreviousNotificationValue** – Can be used to pass out the subject task’s notification value before any bits are modified by the notify function.
  - **pxHigherPriorityTaskWoken** – xTaskNotifyFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE if sending the notification caused the task to which the notification was sent to leave the Blocked state, and the unblocked task has a priority higher than the currently running task. If xTaskNotifyFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited. How a context switch is requested from an ISR is dependent on the port - see the documentation page for the port in use.

Returns  
Dependent on the value of eAction. See the description of the eAction parameter.

```c
BaseType_t xTaskGenericNotifyWait ( UBaseType_t uxIndexToWaitOn, uint32_t ulBitsToClearOnEntry, uint32_t ulBitsToClearOnExit, uint32_t *pulNotificationValue, TickType_t xTicksToWait )
```

Waits for a direct task notification to be pending at a given index within an array of direct to task notifications.


configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for this function to be available.

Each task has a private array of notification values (or notifications), each of which is a 32-bit unsigned integer (uint32_t). The constant configTASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.

A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.
A notification sent to a task will remain pending until it is cleared by the task calling `xTaskNotifyWaitIndexed()` or `ulTaskNotifyTakeIndexed()` (or their un-indexed equivalents). If the task was already in the Blocked state to wait for a notification when the notification arrives then the task will automatically be removed from the Blocked state (unblocked) and the notification cleared.

A task can use `xTaskNotifyWaitIndexed()` to [optionally] block to wait for a notification to be pending, or `ulTaskNotifyTakeIndexed()` to [optionally] block to wait for a notification value to have a non-zero value. The task does not consume any CPU time while it is in the Blocked state.

**NOTE** Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. `xTaskNotifyWait()` is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling `xTaskNotifyWait()` is equivalent to calling `xTaskNotifyWaitIndexed()` with the `uxIndexToWaitOn` parameter set to 0.

**Parameters**

- `uxIndexToWaitOn`: The index within the calling task’s array of notification values on which the calling task will wait for a notification to be received. `uxIndexToWaitOn` must be less than `configTASK_NOTIFICATION_ARRAY_ENTRIES`. `xTaskNotifyWait()` does not have this parameter and always waits for notifications on index 0.
- `ulBitsToClearOnEntry`: Bits that are set in `ulBitsToClearOnEntry` value will be cleared in the calling task’s notification value before the task is marked as waiting for a new notification (provided a notification is not already pending). Optionally blocks if no notifications are pending. Setting `ulBitsToClearOnEntry` to `U_LONG_MAX` (if `limits.h` is included) or `0xffffffffUL` (if `limits.h` is not included) will have the effect of resetting the task’s notification value to 0. Setting `ulBitsToClearOnEntry` to 0 will leave the task’s notification value unchanged.
- `ulBitsToClearOnExit`: If a notification is pending or received before the calling task exits the `xTaskNotifyWait()` function then the task’s notification value (see the `xTaskNotify()` API function) is passed out using the `pulNotificationValue` parameter. Then any bits that are set in `ulBitsToClearOnExit` will be cleared in the task’s notification value (note `pulNotificationValue` is set before any bits are cleared). Setting `ulBitsToClearOnExit` to `U_LONG_MAX` (if `limits.h` is included) or `0xffffffffUL` (if `limits.h` is not included) will have the effect of resetting the task’s notification value to 0 before the function exits. Setting `ulBitsToClearOnExit` to 0 will leave the task’s notification value unchanged when the function exits (in which case the value passed out in `pulNotificationValue` will match the task’s notification value).
- `pulNotificationValue`: Used to pass the task’s notification value out of the function. Note the value passed out will not be effected by the clearing of any bits caused by `ulBitsToClearOnExit` being non-zero.
- `xTicksToWait`: The maximum amount of time that the task should wait in the Blocked state for a notification to be received, should a notification not already be pending when `xTaskNotifyWait()` was called. The task will not consume any processing time while it is in the Blocked state. This is specified in kernel ticks, the macro `pdMS_TO_TICKS(value_in_ms)` can be used to convert a time specified in milliseconds to a time specified in ticks.

**Returns**

If a notification was received (including notifications that were already pending when `xTaskNotifyWait` was called) then `pdPASS` is returned. Otherwise `pdFAIL` is returned.

```c
void vTaskGenericNotifyGiveFromISR(TaskHandle_t xTaskToNotify, BaseType_t uxIndexToNotify, BaseType_t *pxHigherPriorityTaskWoken)
```

A version of `xTaskNotifyGiveIndexed()` that can be called from an interrupt service routine (ISR).


`configUSE_TASK_NOTIFICATIONS` must be undefined or defined as 1 for this macro to be available.

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit un-
signed integer (uint32_t). The constant configTASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.

A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.

vTaskNotifyGiveIndexedFromISR() is intended for use when task notifications are used as light weight and faster binary or counting semaphore equivalents. Actual FreeRTOS semaphores are given from an ISR using the xSemaphoreGiveFromISR() API function, the equivalent action that instead uses a task notification is vTaskNotifyGiveIndexedFromISR().

When task notifications are being used as a binary or counting semaphore equivalent then the task being notified should wait for the notification using the ulTaskNotificationTakeIndexed() API function rather than the xTaskNotifyWaitIndexed() API function.

**NOTE** Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotifyFromISR() is the original API function, and remains backward compatible by always operating on the notification value at index 0 within the array. Calling xTaskNotifyGiveFromISR() is equivalent to calling xTaskNotifyGiveIndexedFromISR() with the uxIndexToNotify parameter set to 0.

**Parameters**

- **xTaskToNotify** - The handle of the task being notified. The handle to a task can be returned from the xTaskCreate() API function used to create the task, and the handle of the currently running task can be obtained by calling xTaskGetCurrentTaskHandle().
- **uxIndexToNotify** - The index within the task’s array of notification values to which the notification is to be sent. uxIndexToNotify must be less than configTASK_NOTIFICATION_ARRAY_ENTRIES. xTaskNotifyGiveFromISR() does not have this parameter and always sends notifications to index 0.
- **pxHigherPriorityTaskWoken** - vTaskNotifyGiveFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE if sending the notification caused the task to which the notification was sent to leave the Blocked state, and the unblocked task has a priority higher than the currently running task. If vTaskNotifyGiveFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited. How a context switch is requested from an ISR is dependent on the port - see the documentation page for the port in use.

```c
uint32_t ulTaskGenericNotifyTake ( UBaseType_t uxIndexToWaitOn, BaseType_t xClearCountOnExit, TickType_t xTicksToWait)
```

Waits for a direct to task notification on a particular index in the calling task’s notification array in a manner similar to taking a counting semaphore.


**configUSE_TASK_NOTIFICATIONS** must be undefined or defined as 1 for this function to be available.

Each task has a private array of “notification values” (or “notifications”), each of which is a 32-bit unsigned integer (uint32_t). The constant configTASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.
A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.

\texttt{ulTaskNotifyTakeIndexed()} is intended for use when a task notification is used as a faster and lighter weight binary or counting semaphore alternative. Actual FreeRTOS semaphores are taken using the \texttt{xSemaphoreTake()} API function, the equivalent action that instead uses a task notification is \texttt{ulTaskNotifyTakeIndexed()}.

When a task is using its notification value as a binary or counting semaphore other tasks should send notifications to it using the \texttt{xTaskNotifyGiveIndexed()} macro, or \texttt{xTaskNotifyIndex()} function with the \texttt{eAction} parameter set to \texttt{eIncrement}.

\texttt{ulTaskNotifyTakeIndexed()} can either clear the task’s notification value at the array index specified by the \texttt{uxIndexToWaitOn} parameter to zero on exit, in which case the notification value acts like a binary semaphore, or decrement the notification value on exit, in which case the notification value acts like a counting semaphore.

A task can use \texttt{ulTaskNotifyTakeIndexed()} to [optionally] block to wait for the task’s notification value to be non-zero. The task does not consume any CPU time while it is in the Blocked state.

Where as \texttt{xTaskNotifyWaitIndexed()} will return when a notification is pending, \texttt{ulTaskNotifyTakeIndexed()} will return when the task’s notification value is not zero.

\textbf{NOTE} Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. \texttt{ulTaskNotifyTake()} is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling \texttt{ulTaskNotifyTake()} is equivalent to calling \texttt{ulTaskNotifyTakeIndexed()} with the \texttt{uxIndexToWaitOn} parameter set to 0.

\textbf{Parameters}
\begin{itemize}
  \item \texttt{uxIndexToWaitOn} – The index within the calling task’s array of notification values on which the calling task will wait for a notification to be non-zero. \texttt{uxIndexToWaitOn} must be less than \texttt{configTASK\_NOTIFICATION\_ARRAY\_ENTRIES}. \texttt{xTaskNotifyTake()} does not have this parameter and always waits for notifications on index 0.
  \item \texttt{xClearCountOnExit} – if \texttt{xClearCountOnExit} is \texttt{pdFALSE} then the task’s notification value is decremented when the function exits. In this way the notification value acts like a counting semaphore. If \texttt{xClearCountOnExit} is not \texttt{pdFALSE} then the task’s notification value is cleared to zero when the function exits. In this way the notification value acts like a binary semaphore.
  \item \texttt{xTicksToWait} – The maximum amount of time that the task should wait in the Blocked state for the task’s notification value to be greater than zero, should the count not already be greater than zero when \texttt{ulTaskNotifyTake()} was called. The task will not consume any processing time while it is in the Blocked state. This is specified in kernel ticks, the macro \texttt{pdMS\_TO\_TICKS}\(value\_in\_ms\) can be used to convert a time specified in milliseconds to a time specified in ticks.
\end{itemize}

\textbf{Returns} The task’s notification count before it is either cleared to zero or decremented (see the \texttt{xClearCountOnExit} parameter).

\texttt{BaseType}\_\texttt{xTaskGenericNotifyStateClear(TaskHandle_t xTask, UBaseType_t uxIndexToClear)}

See \url{https://www.FreeRTOS.org/RTOS-task-notifications.html} for details.

\texttt{configUSE\_TASK\_NOTIFICATIONS} must be undefined or defined as 1 for these functions to be available.

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit unsigned integer (\texttt{uint32\_t}). The constant \texttt{configTASK\_NOTIFICATION\_ARRAY\_ENTRIES} sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

If a notification is sent to an index within the array of notifications then the notification at that index is said to be ‘pending’ until it is read or explicitly cleared by the receiving task. \texttt{xTaskNotifyStateClearIndexed()} is
the function that clears a pending notification without reading the notification value. The notification value at the same array index is not altered. Set xTask to NULL to clear the notification state of the calling task.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value” and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotifyStateClear() is the original API function, and remains backward compatible by always operating on the notification value at index 0 within the array. Calling xTaskNotifyStateClear() is equivalent to calling xTaskNotifyStateClearIndexed() with the uxIndexToNotify parameter set to 0.

**Parameters**

- **xTask** – The handle of the RTOS task that will have a notification state cleared. Set xTask to NULL to clear a notification state in the calling task. To obtain a task’s handle create the task using xTaskCreate() and make use of the pxCreatedTask parameter, or create the task using xTaskCreateStatic() and store the returned value, or use the task’s name in a call to xTaskGetHandle().
- **uxIndexToClear** – The index within the target task’s array of notification values to act upon. For example, setting uxIndexToClear to 1 will clear the state of the notification at index 1 within the array. uxIndexToClear must be less than config-TASK_NOTIFICATION_ARRAY_ENTRIES. ulTaskNotifyStateClear() does not have this parameter and always acts on the notification at index 0.

**Returns** pdTRUE if the task’s notification state was set to eNotWaitingNotification, otherwise pdFALSE.

```c
uint32_t ulTaskGenericNotifyValueClear (TaskHandle_t xTask, UBaseType_t uxIndexToClear, uint32_t ulBitsToClear)
```


configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for these functions to be available.

Each task has a private array of “notification values” (or ‘notifications’), each of which is a 32-bit unsigned integer (uint32_t). The constant configTASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

ulTaskNotifyValueClearIndexed() clears the bits specified by the ulBitsToClear bit mask in the notification value at array index uxIndexToClear of the task referenced by xTask.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. ulTaskNotifyValueClear() is the original API function, and remains backward compatible by always operating on the notification value at index 0 within the array. Calling ulTaskNotifyValueClear() is equivalent to calling ulTaskNotifyValueClearIndexed() with the uxIndexToClear parameter set to 0.

**Parameters**

- **xTask** – The handle of the RTOS task that will have bits in one of its notification values cleared. Set xTask to NULL to clear bits in a notification value of the calling task. To obtain a task’s handle create the task using xTaskCreate() and make use of the pxCreatedTask parameter, or create the task using xTaskCreateStatic() and store the returned value, or use the task’s name in a call to xTaskGetHandle().
- **uxIndexToClear** – The index within the target task’s array of notification values in which to clear the bits. uxIndexToClear must be less than config-TASK_NOTIFICATION_ARRAY_ENTRIES. ulTaskNotifyValueClear() does not have this parameter and always clears bits in the notification value at index 0.
- **ulBitsToClear** – Bit mask of the bits to clear in the notification value of xTask. Set a bit to 1 to clear the corresponding bits in the task’s notification value. Set ulBitsToClear to 0xffffffff (UINT_MAX on 32-bit architectures) to clear the notification value to 0. Set ulBitsToClear to 0 to query the task’s notification value without clearing any bits.

**Returns** The value of the target task’s notification value before the bits specified by ulBitsToClear were cleared.
void vTaskSetTimeOutState(TimeOut_t *const pxTimeOut)

BaseType_t xTaskCheckForTimeOut(TimeOut_t *const pxTimeOut, TickType_t *const pxTicksToWait)

Determines if pxTicksToWait ticks has passed since a time was captured using a call to vTaskSetTimeOutState(). The captured time includes the tick count and the number of times the tick count has overflowed.

Example Usage:

```c
size_t xUART_Receive( uint8_t *pucBuffer, size_t uxWantedBytes )
{
    size_t uxReceived = 0;
    TickType_t xTicksToWait = MAX_TIME_TO_WAIT;
    TimeOut_t xTimeOut;

    // Initialize xTimeOut. This records the time at which this function
    // was entered.
    vTaskSetTimeOutState( &xTimeOut );

    // Loop until the buffer contains the wanted number of bytes, or a
    // timeout occurs.
    while( UART_bytes_in_rx_buffer( pxUARTInstance ) < uxWantedBytes )
    {
        // The buffer didn't contain enough data so this task is going to
        // enter the Blocked state. Adjusting xTicksToWait to account for
        // any time that has been spent in the Blocked state within this
        // function so far to ensure the total amount of time spent in the
        // Blocked state does not exceed MAX_TIME_TO_WAIT.
        if( xTaskCheckForTimeOut( &xTimeOut, &xTicksToWait ) != pdFALSE )
        {
            // Timed out before the wanted number of bytes were available,
            // exit the loop.
            break;
        }

        // Wait for a maximum of xTicksToWait ticks to be notified that the
        // receive interrupt has placed more data into the buffer.
        ulTaskNotifyTake( pdTRUE, xTicksToWait );
    }

    // Attempt to read uxWantedBytes from the receive buffer into pucBuffer.
    // The actual number of bytes read (which might be less than
    // uxWantedBytes) is returned.
    uxReceived = UART_read_from_receive_buffer( pxUARTInstance, pucBuffer, uxWantedBytes );

    return uxReceived;
}
```
See also:
https://www.FreeRTOS.org/xTaskCheckForTimeOut.html

Parameters

- **pxTimeOut** - The time status as captured previously using vTaskSetTimeOutState. If the timeout has not yet occurred, it is updated to reflect the current time status.
- **pxTicksToWait** - The number of ticks to check for timeout i.e. if pxTicksToWait ticks have passed since pxTimeOut was last updated (either by vTaskSetTimeOutState() or xTaskCheckForTimeOut()), the timeout has occurred. If the timeout has not occurred, pxTicksToWait is updated to reflect the number of remaining ticks.

Returns: If timeout has occurred, pdTRUE is returned. Otherwise pdFALSE is returned and pxTicksToWait is updated to reflect the number of remaining ticks.

BaseType_t xTaskCatchUpTicks (TickType_t xTicksToCatchUp)

Macros

tskKERNEL_VERSION_NUMBER

tskKERNEL_VERSION_MAJOR

tskKERNEL_VERSION_MINOR

tskKERNEL_VERSION_BUILD

tskMPU_REGION_READ_ONLY

tskMPU_REGION_READ_WRITE

tskMPU_REGION_EXECUTE_NEVER

tskMPU_REGION_NORMAL_MEMORY

tskMPU_REGION_DEVICE_MEMORY

tskDEFAULT_INDEX_TO_NOTIFY

tskNO_AFFINITY

tskIDLE_PRIORITY

Defines the priority used by the idle task. This must not be modified.

 taskYIELD ()

Macro for forcing a context switch.

taskENTER_CRITICAL (x)

Macro to mark the start of a critical code region. Preemptive context switches cannot occur when in a critical region.

**Note:** This may alter the stack (depending on the portable implementation) so must be used with care!
taskENTER_CRITICAL_FROM_ISR()

taskENTER_CRITICAL_ISR(x)

taskEXIT_CRITICAL(x)

Macro to mark the end of a critical code region. Preemptive context switches cannot occur when in a critical region.

Note: This may alter the stack (depending on the portable implementation) so must be used with care!

taskEXIT_CRITICAL_FROM_ISR(x)

taskEXIT_CRITICAL_ISR(x)

taskDISABLE_INTERRUPTS()

Macro to disable all maskable interrupts.

taskENABLE_INTERRUPTS()

Macro to enable microcontroller interrupts.

taskSCHEDULER_SUSPENDED

taskSCHEDULER_NOT_STARTED

taskSCHEDULER_RUNNING

vTaskDelayUntil(pxPreviousWakeTime, xTimeIncrement)

xTaskNotify(xTaskToNotify, ulValue, eAction)

xTaskNotifyIndexed(xTaskToNotify, uxIndexToNotify, ulValue, eAction)

xTaskNotifyAndQuery(xTaskToNotify, ulValue, eAction, pulPreviousNotifyValue)


xTaskNotifyAndQueryIndexed() performs the same operation as xTaskNotifyIndexed() with the addition that it also returns the subject task’s prior notification value (the notification value at the time the function is called rather than when the function returns) in the additional pulPreviousNotifyValue parameter.

xTaskNotifyAndQuery() performs the same operation as xTaskNotify() with the addition that it also returns the subject task’s prior notification value (the notification value as it was at the time the function is called, rather than when the function returns) in the additional pulPreviousNotifyValue parameter.

xTaskNotifyAndQueryIndexed(xTaskToNotify, uxIndexToNotify, ulValue, eAction, pulPreviousNotifyValue)

xTaskNotifyFromISR(xTaskToNotify, ulValue, eAction, pxHigherPriorityTaskWoken)

xTaskNotifyIndexedFromISR(xTaskToNotify, uxIndexToNotify, ulValue, eAction, pxHigherPriorityTaskWoken)

xTaskNotifyAndQueryIndexedFromISR(xTaskToNotify, uxIndexToNotify, ulValue, eAction, pulPreviousNotificationValue, pxHigherPriorityTaskWoken)


xTaskNotifyAndQueryIndexedFromISR() performs the same operation as xTaskNotifyIndexedFromISR() with the addition that it also returns the subject task’s prior notification value (the notification value at the time the function is called rather than at the time the function returns) in the additional pulPreviousNotificationValue parameter.
xTaskNotifyAndQueryFromISR() performs the same operation as xTaskNotifyFromISR() with the addition that it also returns the subject task’s prior notification value (the notification value at the time the function is called rather than at the time the function returns) in the additional pulPreviousNotifyValue parameter.

**xTaskNotifyAndQueryFromISR** (xTaskToNotify, ulValue, eAction, pulPreviousNotificationValue, pxHigherPriorityTaskWoken)

**xTaskNotifyWait** (ulBitsToClearOnEntry, ulBitsToClearOnExit, pulNotificationValue, xTicksToWait)

**xTaskNotifyWaitIndexed** (uxIndexToWaitOn, ulBitsToClearOnEntry, ulBitsToClearOnExit, pulNotificationValue, xTicksToWait)

**xTaskNotifyGiveIndexed** (xTaskToNotify, uxIndexToNotify)

Sends a direct task notification to a particular index in the target task’s notification array in a manner similar to giving a counting semaphore.


configUSE_TASK_NOTIFICATIONS must be undefined or defined as 1 for these macros to be available.

Each task has a private array of “notification values” (or “notifications”), each of which is a 32-bit unsigned integer (uint32_t). The constant configTASK_NOTIFICATION_ARRAY_ENTRIES sets the number of indexes in the array, and (for backward compatibility) defaults to 1 if left undefined. Prior to FreeRTOS V10.4.0 there was only one notification value per task.

Events can be sent to a task using an intermediary object. Examples of such objects are queues, semaphores, mutexes and event groups. Task notifications are a method of sending an event directly to a task without the need for such an intermediary object.

A notification sent to a task can optionally perform an action, such as update, overwrite or increment one of the task’s notification values. In that way task notifications can be used to send data to a task, or be used as light weight and fast binary or counting semaphores.

xTaskNotifyGiveIndexed() is a helper macro intended for use when task notifications are used as light weight and faster binary or counting semaphore equivalents. Actual FreeRTOS semaphores are given using the xSemaphoreGive() API function, the equivalent action that instead uses a task notification is xTaskNotifyGiveIndexed().

When task notifications are being used as a binary or counting semaphore equivalent then the task being notified should wait for the notification using the ulTaskNotificationTakeIndexed() API function rather than the xTaskNotifyWaitIndexed() API function.

**NOTE** Each notification within the array operates independently - a task can only block on one notification within the array at a time and will not be unblocked by a notification sent to any other array index.

Backward compatibility information: Prior to FreeRTOS V10.4.0 each task had a single “notification value”, and all task notification API functions operated on that value. Replacing the single notification value with an array of notification values necessitated a new set of API functions that could address specific notifications within the array. xTaskNotifyGive() is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling xTaskNotifyGive() is equivalent to calling xTaskNotifyGiveIndexed() with the uxIndexToNotify parameter set to 0.

**Parameters**

- **xTaskToNotify** – The handle of the task being notified. The handle to a task can be returned from the xTaskCreate() API function used to create the task, and the handle of the currently running task can be obtained by calling xTaskGetCurrentTaskHandle().
- **uxIndexToNotify** – The index within the target task’s array of notification values to which the notification is to be sent. uxIndexToNotify must be less than configTASK_NOTIFICATION_ARRAY_ENTRIES. xTaskNotifyGive() does not have this parameter and always sends notifications to index 0.

**Returns** xTaskNotifyGive() is a macro that calls xTaskNotify() with the eAction parameter set to eIncrement - so pdPASS is always returned.

xTaskNotifyGive (xTaskToNotify)
vTaskNotifyGiveFromISR (xTaskToNotify, pxHigherPriorityTaskWoken)

vTaskNotifyGiveIndexedFromISR (xTaskToNotify, uxIndexToNotify, pxHigherPriorityTaskWoken)

ulTaskNotifyTake (xClearCountOnExit, xTicksToWait)

ulTaskNotifyTakeIndexed (uxIndexToWaitOn, xClearCountOnExit, xTicksToWait)

xTaskNotifyStateClear (xTask)

xTaskNotifyStateClearIndexed (xTask, uxIndexToClear)

ulTaskNotifyValueClear (xTask, ulBitsToClear)

ulTaskNotifyValueClearIndexed (xTask, uxIndexToClear, ulBitsToClear)

Type Definitions

typedef struct tskTaskControlBlock *TaskHandle_t

typedef BaseType_t (*TaskHookFunction_t)(void*)

typedef void (*TlsDeleteCallbackFunction_t)(int, void*)

Prototype of local storage pointer deletion callback.

Enumerations

enum eTaskState
    Task states returned by eTaskGetState.
    Values:

    enumerator eRunning

    enumerator eReady

    enumerator eBlocked

    enumerator eSuspended

    enumerator eDeleted

    enumerator eInvalid

enum eNotifyAction
    Values:

    enumerator eNoAction

    enumerator eSetBits

    enumerator eIncrement
Chapter 2. API Reference

enumerator eSetValueWithOverwrite

enumerator eSetValueWithoutOverwrite

enum eSleepModeStatus
Possible return values for eTaskConfirmSleepModeStatus().
Values:

enumerator eAbortSleep

enumerator eStandardSleep

enumerator eNoTasksWaitingTimeout

Queue API

Header File

- components/freertos/FreeRTOS-Kernel/include/freertos/queue.h

Functions

BaseType_t xQueueGenericSend (QueueHandle_t xQueue, const void *const pvItemToQueue, TickType_t xTicksToWait, const BaseType_t xCopyPosition)

It is preferred that the macros xQueueSend(), xQueueSendToFront() and xQueueSendToBack() are used in place of calling this function directly.

Post an item on a queue. The item is queued by copy, not by reference. This function must not be called from an interrupt service routine. See xQueueSendFromISR () for an alternative which may be used in an ISR.

Example usage:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[ 20 ];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

    // ...
```

(continues on next page)
if( xQueue1 != 0 )
{
    // Send an uint32_t. Wait for 10 ticks for space to become
    // available if necessary.
    if( xQueueGenericSend( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10, _
        queueSEND_TO_BACK ) != pdPASS )
    {
        // Failed to post the message, even after 10 ticks.
    }
}

if( xQueue2 != 0 )
{
    // Send a pointer to a struct AMessage object. Don't block if the
    // queue is already full.
    pxMessage = & xMessage;
    xQueueGenericSend( xQueue2, ( void * ) pxMessage, ( TickType_t ) 0, _
        queueSEND_TO_BACK );
}

// ... Rest of task code.

Parameters

• xQueue - The handle to the queue on which the item is to be posted.
• pvItemToQueue - A pointer to the item that is to be placed on the queue. The size of
  the items the queue will hold was defined when the queue was created, so this many bytes
  will be copied from pvItemToQueue into the queue storage area.
• xTicksToWait - The maximum amount of time the task should block waiting for space
  to become available on the queue, should it already be full. The call will return immediately
  if this is set to 0 and the queue is full. The time is defined in tick periods so the constant
  portTICK_PERIOD_MS should be used to convert to real time if this is required.
• xCopyPosition - Can take the value queueSEND_TO_BACK to place the item at the
  back of the queue, or queueSEND_TO_FRONT to place the item at the front of the queue
  (for high priority messages).

Returns pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

BaseType_t xQueuePeek ( QueueHandle_t xQueue, void *const pvBuffer, TickType_t xTicksToWait )

Receive an item from a queue without removing the item from the queue. The item is received by copy so a
buffer of adequate size must be provided. The number of bytes copied into the buffer was defined when the
queue was created.

Successfully received items remain on the queue so will be returned again by the next call, or a call to
xQueueReceive().

This macro must not be used in an interrupt service routine. See xQueuePeekFromISR() for an alternative that
can be called from an interrupt service routine.

Example usage:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[ 20 ];
} xMessage;

QueueHandle_t xQueue;

// Task to create a queue and post a value.
```


```c
void vATask( void *pvParameters )
{
 struct AMessage *pxMessage;

 // Create a queue capable of containing 10 pointers to AMessage structures.
 // These should be passed by pointer as they contain a lot of data.
 xQueue = xQueueCreate( 10, sizeof( struct AMessage * ) );
 if( xQueue == 0 )
 {
 // Failed to create the queue.
 }

 // ... Send a pointer to a struct AMessage object. Don't block if the
 // queue is already full.
 pxMessage = & xMessage;
 xQueueSend( xQueue, ( void * ) &pxMessage, ( TickType_t ) 0 );
 // ... Rest of task code.
 }
}

task Task to peek the data from the queue.
void vADifferentTask( void *pvParameters )
{
 struct AMessage *pxRxedMessage;

 if( xQueue != 0 )
 {
 // Peek a message on the created queue. Block for 10 ticks if a
 // message is not immediately available.
 if( xQueuePeek( xQueue, & pxRxedMessage ), ( TickType_t ) 10 )
 {
 // pxRxedMessage now points to the struct AMessage variable posted
 // by vATask, but the item still remains on the queue.
 }
 }
 // ... Rest of task code.
 }
```

**Parameters**

- `xQueue` - The handle to the queue from which the item is to be received.
- `pvBuffer` - Pointer to the buffer into which the received item will be copied.
- `xTicksToWait` - The maximum amount of time the task should block waiting for an item to receive should the queue be empty at the time of the call. The time is defined in tick periods so the constant portTICK_PERIOD_MS should be used to convert to real time if this is required. xQueuePeek() will return immediately if xTicksToWait is 0 and the queue is empty.

**Returns**

- `pdTRUE` if an item was successfully received from the queue, otherwise `pdFALSE`.

**BaseType_t xQueuePeekFromISR (QueueHandle_t xQueue, void *const pvBuffer)**

A version of xQueuePeek() that can be called from an interrupt service routine (ISR).

Receive an item from a queue without removing the item from the queue. The item is received by copy so a buffer of adequate size must be provided. The number of bytes copied into the buffer was defined when the queue was created.

Successfully received items remain on the queue so will be returned again by the next call, or a call to xQueueReceive().
Chapter 2. API Reference

Parameters

• **xQueue** - The handle to the queue from which the item is to be received.

• **pvBuffer** - Pointer to the buffer into which the received item will be copied.

Returns

pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

BaseType_t xQueueReceive (QueueHandle_t xQueue, void *const pvBuffer, TickType_t xTicksToWait)

Receive an item from a queue. The item is received by copy so a buffer of adequate size must be provided. The number of bytes copied into the buffer was defined when the queue was created.

Successfully received items are removed from the queue.

This function must not be used in an interrupt service routine. See xQueueReceiveFromISR for an alternative that can.

Example usage:

```c
struct AMessage
{
  char ucMessageID;
  char ucData[20];
} xMessage;

QueueHandle_t xQueue;

// Task to create a queue and post a value.
void vATask( void *pvParameters )
{
  struct AMessage *pxMessage;

  // Create a queue capable of containing 10 pointers to AMessage structures.
  // These should be passed by pointer as they contain a lot of data.
  xQueue = xQueueCreate( 10, sizeof( struct AMessage * ) );
  if( xQueue == 0 )
  {
    // Failed to create the queue.
  }
  // ...

  // Send a pointer to a struct AMessage object. Don't block if the
  // queue is already full.
  pxMessage = &xMessage;
  xQueueSend( xQueue, ( void * ) &pxMessage, ( TickType_t ) 0 );

  // ... Rest of task code.
}

// Task to receive from the queue.
void vADifferentTask( void *pvParameters )
{
  struct AMessage *pxRxedMessage;

  if( xQueue != 0 )
  {
    // Receive a message on the created queue. Block for 10 ticks if a
    // message is not immediately available.
    if( xQueueReceive( xQueue, &pxRxedMessage, ( TickType_t ) 10 ) )
    {
      // pcRxedMessage now points to the struct AMessage variable posted
      // by vATask.
    }
  }
}
```

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Parameters

- **xQueue** - The handle to the queue from which the item is to be received.
- **pvBuffer** - Pointer to the buffer into which the received item will be copied.
- **xTicksToWait** - The maximum amount of time the task should block waiting for an item to receive should the queue be empty at the time of the call. xQueueReceive() will return immediately if xTicksToWait is zero and the queue is empty. The time is defined in tick periods so the constant portTICK_PERIOD_MS should be used to convert to real time if this is required.

Returns pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

```c
UBaseType_t uxQueueMessagesWaiting (const QueueHandle_t xQueue)

Return the number of messages stored in a queue.

Parameters xQueue - A handle to the queue being queried.

Returns The number of messages available in the queue.
```

```c
UBaseType_t uxQueueSpacesAvailable (const QueueHandle_t xQueue)

Return the number of free spaces available in a queue. This is equal to the number of items that can be sent to the queue before the queue becomes full if no items are removed.

Parameters xQueue - A handle to the queue being queried.

Returns The number of spaces available in the queue.
```

```c
void vQueueDelete (QueueHandle_t xQueue)

Delete a queue - freeing all the memory allocated for storing of items placed on the queue.

Parameters xQueue - A handle to the queue to be deleted.
```

```c
BaseType_t xQueueGenericSendFromISR (QueueHandle_t xQueue, const void*const pvItemToQueue,
   BaseType_t *const pxHigherPriorityTaskWoken, const BaseType_t xCopyPosition)

It is preferred that the macros xQueueSendFromISR(), xQueueSendToFrontFromISR() and xQueueSendToBackFromISR() be used in place of calling this function directly. xQueueGiveFromISR() is an equivalent for use by semaphores that don’t actually copy any data.

Post an item on a queue. It is safe to use this function from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR ( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWokenByPost;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWokenByPost = pdFALSE;

    // Loop until the buffer is empty.
    do
    {
        // Obtain a byte from the buffer.
        cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );
    } while (cIn != 0);

    // Process the bytes.

    // We have not woken a task at the end of the ISR.
    xHigherPriorityTaskWokenByPost = pdFALSE;
}
```

(continues on next page)
// Post each byte.
xQueueGenericSendFromISR( xRxQueue, &cIn, &xHigherPriorityTaskWokenByPost, - queueSEND_TO_BACK );
} while( portINPUT_BYTE( BUFFER_COUNT ) );

// Now the buffer is empty we can switch context if necessary. Note that the
// name of the yield function required is port specific.
if( xHigherPriorityTaskWokenByPost )
{
    taskYIELD_YIELD_FROM_ISR();
}

Parameters

- **xQueue** - The handle to the queue on which the item is to be posted.
- **pvItemToQueue** - A pointer to the item that is to be placed on the queue. The size of
  the items the queue will hold was defined when the queue was created, so this many bytes
  will be copied from pvItemToQueue into the queue storage area.
- **pxHigherPriorityTaskWoken** - [out] xQueueGenericSendFromISR() will set
  *pxHigherPriorityTaskWoken to pdTRUE if sending to the queue caused a task to un-
  block, and the unblocked task has a priority higher than the currently running task. If
  xQueueGenericSendFromISR() sets this value to pdTRUE then a context switch should
  be requested before the interrupt is exited.
- **xCopyPosition** - Can take the value queueSEND_TO_BACK to place the item at the
  back of the queue, or queueSEND_TO_FRONT to place the item at the front of the queue
  (for high priority messages).

Returns  pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

BaseType_t xQueueGiveFromISR (QueueHandle_t xQueue, BaseType_t*const pxHigherPriorityTaskWoken)

BaseType_t xQueueReceiveFromISR (QueueHandle_t xQueue, void*const pvBuffer, BaseType_t*const
                                       pxHigherPriorityTaskWoken)

Receive an item from a queue. It is safe to use this function from within an interrupt service routine.

Example usage:

```c
QueueHandle_t xQueue;

// Function to create a queue and post some values.
void vAFunction( void *pvParameters )
{
    char cValueToPost;
    const TickType_t xTicksToWait = ( TickType_t )0xff;

    // Create a queue capable of containing 10 characters.
    xQueue = xQueueCreate( 10, sizeof( char ) );
    if( xQueue == 0 )
    {
        // Failed to create the queue.
    }
    // ...

    // Post some characters that will be used within an ISR. If the queue
    // is full then this task will block for xTicksToWait ticks.
    cValueToPost = 'a';
```

(continues on next page)
xQueueSend( xQueue, ( void * ) &cValueToPost, xTicksToWait );
cValueToPost = 'b';
xQueueSend( xQueue, ( void * ) &cValueToPost, xTicksToWait );

// ... keep posting characters ... this task may block when the queue
// becomes full.
cValueToPost = 'c';
xQueueSend( xQueue, ( void * ) &cValueToPost, xTicksToWait );

// ISR that outputs all the characters received on the queue.
void vISR_Routine( void )
{
    BaseType_t xTaskWokenByReceive = pdFALSE;
    char cRxedChar;

    while( xQueueReceiveFromISR( xQueue, ( void * ) &cRxedChar, &
                           xTaskWokenByReceive) )
    {
        // A character was received. Output the character now.
        vOutputCharacter( cRxedChar );

        // If removing the character from the queue woke the task that was
        // posting onto the queue cTaskWokenByReceive will have been set to
        // pdTRUE. No matter how many times this loop iterates only one
        // task will be woken.
    }

    if( cTaskWokenByPost != ( char ) pdFALSE; }
    { taskYIELD ();
    }
}

Parameters

- xQueue - The handle to the queue from which the item is to be received.
- pvBuffer - Pointer to the buffer into which the received item will be copied.
- pxHigherPriorityTaskWoken - [out] A task may be blocked waiting for space to
  become available on the queue. If xQueueReceiveFromISR causes such a task to unblock
  *pxTaskWoken will get set to pdTRUE, otherwise *pxTaskWoken will remain unchanged.

Returns pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

BaseType_t xQueueIsQueueEmptyFromISR (const QueueHandle_t xQueue)
BaseType_t xQueueIsQueueFullFromISR (const QueueHandle_t xQueue)
UBaseType_t uxQueueMessagesWaitingFromISR (const QueueHandle_t xQueue)

void vQueueAddToRegistry (QueueHandle_t xQueue, const char *pcQueueName)

The registry is provided as a means for kernel aware debuggers to locate queues, semaphores and mutexes. Call
vQueueAddToRegistry() add a queue, semaphore or mutex handle to the registry if you want the handle to be
available to a kernel aware debugger. If you are not using a kernel aware debugger then this function can be
ignored.

configQUEUE_REGISTRY_SIZE defines the maximum number of handles the registry can hold. configQUEUE_REGISTRY_SIZE
must be greater than 0 within FreeRTOSConfig.h for the registry to be available.
Its value does not effect the number of queues, semaphores and mutexes that can be created - just the
number that the registry can hold.

Parameters
• **xQueue** – The handle of the queue being added to the registry. This is the handle returned by a call to xQueueCreate(). Semaphore and mutex handles can also be passed in here.

• **pcQueueName** – The name to be associated with the handle. This is the name that the kernel aware debugger will display. The queue registry only stores a pointer to the string - so the string must be persistent (global or preferably in ROM/Flash), not on the stack.

```c
void vQueueUnregisterQueue(QueueHandle_t xQueue)
```

The registry is provided as a means for kernel aware debuggers to locate queues, semaphores and mutexes. Call vQueueAddToRegistry() add a queue, semaphore or mutex handle to the registry if you want the handle to be available to a kernel aware debugger, and vQueueUnregisterQueue() to remove the queue, semaphore or mutex from the register. If you are not using a kernel aware debugger then this function can be ignored.

**Parameters**

• **xQueue** – The handle of the queue being removed from the registry.

```c
const char* pcQueueGetName(QueueHandle_t xQueue)
```

The queue registry is provided as a means for kernel aware debuggers to locate queues, semaphores and mutexes. Call pcQueueGetName() to look up and return the name of a queue in the queue registry from the queue’s handle.

**Parameters**

• **xQueue** – The handle of the queue the name of which will be returned.

**Returns**

If the queue is in the registry then a pointer to the name of the queue is returned. If the queue is not in the registry then NULL is returned.

```c
QueueHandle_t xQueueGenericCreate(UBaseType_t uxQueueLength, const UBaseType_t uxItemSize, uxcQueueType)
```

Generic version of the function used to create a queue using dynamic memory allocation. This is called by other functions and macros that create other RTOS objects that use the queue structure as their base.

```c
QueueHandle_t xQueueGenericCreateStatic(UBaseType_t uxQueueLength, const UBaseType_t uxItemSize, uint8_t*pucQueueStorage, StaticQueue_t pxStaticQueue, uxcQueueType)
```

Generic version of the function used to create a queue using dynamic memory allocation. This is called by other functions and macros that create other RTOS objects that use the queue structure as their base.

```c
BaseType_t xQueueGenericGetStaticBuffers(QueueHandle_t xQueue, uint8_t **ppucQueueStorage, StaticQueue_t **ppxStaticQueue)
```

```c
QueueSetHandle_t xQueueCreateSet(UBaseType_t uxEventQueueLength)
```

Queue sets provide a mechanism to allow a task to block (pend) on a read operation from multiple queues or semaphores simultaneously.

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

A queue set must be explicitly created using a call to xQueueCreateSet() before it can be used. Once created, standard FreeRTOS queues and semaphores can be added to the set using calls to xQueueAddToSet(). xQueueSelectFromSet() is then used to determine which, if any, of the queues or semaphores contained in the set is in a state where a queue read or semaphore take operation would be successful.

Note 1: See the documentation on https://www.FreeRTOS.org/RTOS-queue-sets.html for reasons why queue sets are very rarely needed in practice as there are simpler methods of blocking on multiple objects.

Note 2: Blocking on a queue set that contains a mutex will not cause the mutex holder to inherit the priority of the blocked task.

Note 3: An additional 4 bytes of RAM is required for each space in a every queue added to a queue set. Therefore counting semaphores that have a high maximum count value should not be added to a queue set.

Note 4: A receive (in the case of a queue) or take (in the case of a semaphore) operation must not be performed on a member of a queue set unless a call to xQueueSelectFromSet() has first returned a handle to that set member.

**Parameters**

• **uxEventQueueLength** – Queue sets store events that occur on the queues and semaphores contained in the set. uxEventQueueLength specifies the maximum number of
events that can be queued at once. To be absolutely certain that events are not lost uxEventQueueLength should be set to the total sum of the length of the queues added to the set, where binary semaphores and mutexes have a length of 1, and counting semaphores have a length set by their maximum count value. Examples:

- If a queue set is to hold a queue of length 5, another queue of length 12, and a binary semaphore, then uxEventQueueLength should be set to $(5 + 12 + 1)$, or 18.
- If a queue set is to hold three binary semaphores then uxEventQueueLength should be set to $(1 + 1 + 1)$, or 3.
- If a queue set is to hold a counting semaphore that has a maximum count of 5, and a counting semaphore that has a maximum count of 3, then uxEventQueueLength should be set to $(5 + 3)$, or 8.

**Returns**: If the queue set is created successfully then a handle to the created queue set is returned. Otherwise NULL is returned.

`BaseType_t xQueueAddToSet(QueueSetMemberHandle_t xQueueOrSemaphore, QueueSetHandle_t xQueueSet)`

Adds a queue or semaphore to a queue set that was previously created by a call to xQueueCreateSet().

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

**Parameters**

- `xQueueOrSemaphore` – The handle of the queue or semaphore being added to the queue set (cast to an QueueSetMemberHandle_t type).
- `xQueueSet` – The handle of the queue set to which the queue or semaphore is being added.

**Returns**: If the queue or semaphore was successfully added to the queue set then pdPASS is returned. If the queue could not be successfully added to the queue set because it is already a member of a different queue set then pdFAIL is returned.

`BaseType_t xQueueRemoveFromSet(QueueSetMemberHandle_t xQueueOrSemaphore, QueueSetHandle_t xQueueSet)`

Removes a queue or semaphore from a queue set. A queue or semaphore can only be removed from a set if the queue or semaphore is empty.

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

**Parameters**

- `xQueueOrSemaphore` – The handle of the queue or semaphore being removed from the queue set (cast to an QueueSetMemberHandle_t type).
- `xQueueSet` – The handle of the queue set in which the queue or semaphore is included.

**Returns**: If the queue or semaphore was successfully removed from the queue set then pdPASS is returned. If the queue was not in the queue set, or the queue (or semaphore) was not empty, then pdFAIL is returned.

`QueueSetMemberHandle_t xQueueSelectFromSet(QueueSetHandle_t xQueueSet, const TickType_t xTicksToWait)`

xQueueSelectFromSet() selects from the members of a queue set a queue or semaphore that either contains data (in the case of a queue) or is available to take (in the case of a semaphore). xQueueSelectFromSet() effectively allows a task to block (pend) on a read operation on all the queues and semaphores in a queue set simultaneously.

See FreeRTOS/Source/Demo/Common/Minimal/QueueSet.c for an example using this function.

**Note 1**: See the documentation on [https://www.FreeRTOS.org/RTOS-queue-sets.html](https://www.FreeRTOS.org/RTOS-queue-sets.html) for reasons why queue sets are very rarely needed in practice as there are simpler methods of blocking on multiple objects.

**Note 2**: Blocking on a queue set that contains a mutex will not cause the mutex holder to inherit the priority of the blocked task.
Note 3: A receive (in the case of a queue) or take (in the case of a semaphore) operation must not be performed on a member of a queue set unless a call to `xQueueSelectFromSet()` has first returned a handle to that set member.

**Parameters**

- **xQueueSet** – The queue set on which the task will (potentially) block.
- **xTicksToWait** – The maximum time, in ticks, that the calling task will remain in the Blocked state (with other tasks executing) to wait for a member of the queue set to be ready for a successful queue read or semaphore take operation.

**Returns**

`xQueueSelectFromSet()` will return the handle of a queue (cast to a `QueueSetMemberHandle_t` type) contained in the queue set that contains data, or the handle of a semaphore (cast to a `QueueSetMemberHandle_t` type) contained in the queue set that is available, or NULL if no such queue or semaphore exists before before the specified block time expires.

**QueueSetMemberHandle_t** `xQueueSelectFromSetFromISR(QueueHandle_t xQueueSet)`

A version of `xQueueSelectFromSet()` that can be used from an ISR.

**Macros**

`xQueueCreate(uxQueueLength, uxItemSize)`

Creates a new queue instance, and returns a handle by which the new queue can be referenced.

Internally, within the FreeRTOS implementation, queues use two blocks of memory. The first block is used to hold the queue’s data structures. The second block is used to hold items placed into the queue. If a queue is created using `xQueueCreate()` then both blocks of memory are automatically dynamically allocated inside the `xQueueCreate()` function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If a queue is created using `xQueueCreateStatic()` then the application writer must provide the memory that will get used by the queue. `xQueueCreateStatic()` therefore allows a queue to be created without using any dynamic memory allocation.


**Example usage:**

```c
struct AMessage
{
    char ucMessageID;
    char ucData[ 20 ];
};

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ));
    if( xQueue1 == 0 )
    {
        // Queue was not created and must not be used.
    }

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ));
    if( xQueue2 == 0 )
    {
        // Queue was not created and must not be used.
    }

    // ... Rest of task code.
}
```
Parameters

- **uxQueueLength** - The maximum number of items that the queue can contain.
- **uxItemSize** - The number of bytes each item in the queue will require. Items are queued by copy, not by reference, so this is the number of bytes that will be copied for each posted item. Each item on the queue must be the same size.

Returns

- If the queue is successfully created then a handle to the newly created queue is returned.
- If the queue cannot be created then 0 is returned.

**xQueueCreateStatic(uxQueueLength, uxItemSize, pucQueueStorage, pxQueueBuffer)**

Creates a new queue instance, and returns a handle by which the new queue can be referenced.

Internally, within the FreeRTOS implementation, queues use two blocks of memory. The first block is used to hold the queue’s data structures. The second block is used to hold items placed into the queue. If a queue is created using `xQueueCreate()` then both blocks of memory are automatically dynamically allocated inside the `xQueueCreate()` function. (see https://www.FreeRTOS.org/a00111.html). If a queue is created using `xQueueCreateStatic()` then the application writer must provide the memory that will get used by the queue. `xQueueCreateStatic()` therefore allows a queue to be created without using any dynamic memory allocation.


Example usage:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
};

#define QUEUE_LENGTH 10
#define ITEM_SIZE sizeof( uint32_t )

// xQueueBuffer will hold the queue structure.
StaticQueue_t xQueueBuffer;

// ucQueueStorage will hold the items posted to the queue. Must be at least 
// [(queue length) * ( queue item size)] bytes long.
uint8_t ucQueueStorage[QUEUE_LENGTH * ITEM_SIZE];

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( QUEUE_LENGTH, // The number of items the queue can...
                           ITEM_SIZE     // The size of each item in the queue
                           & ucQueueStorage[0]), // The buffer that will...
                           // hold the items in the queue.
                           &xQueueBuffer ); // The buffer that will hold the...
                           // queue structure.

    // The queue is guaranteed to be created successfully as no dynamic memory
    // allocation is used. Therefore xQueue1 is now a handle to a valid queue.
    // ... Rest of task code.
}
```

Parameters

- **uxQueueLength** - The maximum number of items that the queue can contain.
- **uxItemSize** - The number of bytes each item in the queue will require. Items are queued by copy, not by reference, so this is the number of bytes that will be copied for each posted item. Each item on the queue must be the same size.
each posted item. Each item on the queue must be the same size.

- **pucQueueStorage** - If uxItemSize is not zero then pucQueueStorageBuffer must point to a uint8_t array that is at least large enough to hold the maximum number of items that can be in the queue at any one time - which is (uxQueueLength * uxItemsSize) bytes. If uxItemSize is zero then pucQueueStorageBuffer can be NULL.

- **pxQueueBuffer** - Must point to a variable of type StaticQueue_t, which will be used to hold the queue’s data structure.

**Returns** If the queue is created then a handle to the created queue is returned. If pxQueueBuffer is NULL then NULL is returned.

### xQueueGetStaticBuffers

(xQueue, ppucQueueStorage, ppxStaticQueue)

**xQueueSendToFront**

(xQueue, pItemToQueue, xTicksToWait)

Post an item to the front of a queue. The item is queued by copy, not by reference. This function must not be called from an interrupt service routine. See xQueueSendFromISR() for an alternative which may be used in an ISR.

**Example usage:**

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

    // ...

    if( xQueue1 != 0 )
    {
        // Send an uint32_t. Wait for 10 ticks for space to become available if necessary.
        if( xQueueSendToFront( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10 ) != pdPASS )
        {
            // Failed to post the message, even after 10 ticks.
        }
    }

    if( xQueue2 != 0 )
    {
        // Send a pointer to a struct AMessage object. Don't block if the queue is already full.
        pxMessage = & xMessage;
        xQueueSendToFront( xQueue2, ( void * ) &pxMessage, ( TickType_t ) 0 );
    }
```

(continues on next page)
Parameters

- `xQueue` - The handle to the queue on which the item is to be posted.
- `pvItemToQueue` - A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from `pvItemToQueue` into the queue storage area.
- `xTicksToWait` - The maximum amount of time the task should block waiting for space to become available on the queue, should it already be full. The call will return immediately if this is set to 0 and the queue is full. The time is defined in tick periods so the constant portTICK_PERIOD_MS should be used to convert to real time if this is required.

Returns

- `pdTRUE` if the item was successfully posted, otherwise `errQUEUE_FULL`.

### `xQueueSendToBack` (xQueue, pvItemToQueue, xTicksToWait)

This is a macro that calls `xQueueGenericSend()`.

Post an item to the back of a queue. The item is queued by copy, not by reference. This function must not be called from an interrupt service routine. See `xQueueSendFromISR()` for an alternative which may be used in an ISR.

Example usage:

```c
struct AMessage
{
    char ucMessageID;
    char ucData[20];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
    QueueHandle_t xQueue1, xQueue2;
    struct AMessage *pxMessage;

    // Create a queue capable of containing 10 uint32_t values.
    xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

    // Create a queue capable of containing 10 pointers to AMessage structures.
    // These should be passed by pointer as they contain a lot of data.
    xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

    // ...

    if( xQueue1 != 0 )
    {
        // Send an uint32_t. Wait for 10 ticks for space to become available if necessary.
        if( xQueueSendToBack( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10 ) != pdPASS )
        {
            // Failed to post the message, even after 10 ticks.
        }
    }

    if( xQueue2 != 0 )
    {
        // ...
    }

    if( xQueue1 != 0 )
    {
        // ...
    }

    if( xQueue2 != 0 )
    {
        // ...
    }
```
// Send a pointer to a struct AMessage object. Don't block if the queue is already full.
pxMessage = &xMessage;
xQueueSendToBack( xQueue2, ( void * ) &pxMessage, ( TickType_t ) 0 );

// ... Rest of task code.

Parameters

- **xQueue** - The handle to the queue on which the item is to be posted.
- **pvItemToQueue** - A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from pvItemToQueue into the queue storage area.
- **xTicksToWait** - The maximum amount of time the task should block waiting for space to become available on the queue, should it already be full. The call will return immediately if this is set to 0 and the queue is full. The time is defined in tick periods so the constant portTICK_PERIOD_MS should be used to convert to real time if this is required.

Returns

pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

**xQueueSend**(xQueue, pvItemToQueue, xTicksToWait)

This is a macro that calls xQueueGenericSend(). It is included for backward compatibility with versions of FreeRTOS.org that did not include the xQueueSendToFront() and xQueueSendToBack() macros. It is equivalent to xQueueSendToBack().

Post an item on a queue. The item is queued by copy, not by reference. This function must not be called from an interrupt service routine. See xQueueSendFromISR() for an alternative which may be used in an ISR.

Example usage:

```c
struct AMessage
{
  char ucMessageID;
  char ucData[ 20 ];
} xMessage;

uint32_t ulVar = 10UL;

void vATask( void *pvParameters )
{
  QueueHandle_t xQueue1, xQueue2;

  struct AMessage *pxMessage;

  // Create a queue capable of containing 10 uint32_t values.
  xQueue1 = xQueueCreate( 10, sizeof( uint32_t ) );

  // Create a queue capable of containing 10 pointers to AMessage structures.
  // These should be passed by pointer as they contain a lot of data.
  xQueue2 = xQueueCreate( 10, sizeof( struct AMessage * ) );

  // ...

  if( xQueue1 != 0 )
  {
    // Send an uint32_t. Wait for 10 ticks for space to become available if necessary.
    if( xQueueSend( xQueue1, ( void * ) &ulVar, ( TickType_t ) 10 ) != pdPASS_)
```

(continues on next page)
{  // Failed to post the message, even after 10 ticks.
}

if( xQueue2 != 0 )
{
    // Send a pointer to a struct AMessage object. Don't block if the
    // queue is already full.
    pxMessage = & xMessage;
    xQueueSend( xQueue2, ( void * ) pxMessage, ( TickType_t ) 0 );
}
// ... Rest of task code.

Parameters
• xQueue – The handle to the queue on which the item is to be posted.
• pvItemToQueue – A pointer to the item that is to be placed on the queue. The size of
  the items the queue will hold was defined when the queue was created, so this many bytes
  will be copied from pvItemToQueue into the queue storage area.
• xTicksToWait – The maximum amount of time the task should block waiting for space
  to become available on the queue, should it already be full. The call will return immediately
  if this is set to 0 and the queue is full. The time is defined in tick periods so the constant
  portTICK_PERIOD_MS should be used to convert to real time if this is required.

Returns  pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

xQueueOverwrite (xQueue, pvItemToQueue)
Only for use with queues that have a length of one - so the queue is either empty or full.
Post an item on a queue. If the queue is already full then overwrite the value held in the queue. The item is
queued by copy, not by reference.
This function must not be called from an interrupt service routine. See xQueueOverwriteFromISR () for an
alternative which may be used in an ISR.

Example usage:

void vFunction( void *pvParameters )
{
    QueueHandle_t xQueue;
    uint32_t ulVarToSend, ulValReceived;

    // Create a queue to hold one uint32_t value. It is strongly
    // recommended *not* to use xQueueOverwrite() on queues that can
    // contain more than one value, and doing so will trigger an assertion
    // if configASSERT() is defined.
    xQueue = xQueueCreate( 1, sizeof( uint32_t ) );

    // Write the value 10 to the queue using xQueueOverwrite().
    ulVarToSend = 10;
    xQueueOverwrite( xQueue, &ulVarToSend );

    // Peeking the queue should now return 10, but leave the value 10 in
    // the queue. A block time of zero is used as it is known that the
    // queue holds a value.
    ulValReceived = 0;
    xQueuePeek( xQueue, &ulValReceived, 0 );
If `ulValReceived` != 10

{  
  // Error unless the item was removed by a different task.
}

// The queue is still full. Use `xQueueOverwrite()` to overwrite the
// value held in the queue with 100.
ulVarToSend = 100;
xQueueOverwrite( xQueue, &ulVarToSend );

// This time read from the queue, leaving the queue empty once more.
// A block time of 0 is used again.
xQueueReceive( xQueue, &ulValReceived, 0 );

// The value read should be the last value written, even though the
// queue was already full when the value was written.
if( ulValReceived != 100 )
{
  // Error!
}

// ...

Parameters

- **xQueue** - The handle of the queue to which the data is being sent.
- **pvItemToQueue** - A pointer to the item that is to be placed on the queue. The size of
  the items the queue will hold was defined when the queue was created, so this many bytes
  will be copied from `pvItemToQueue` into the queue storage area.

Returns

`xQueueOverwrite()` is a macro that calls `xQueueGenericSend()`, and therefore has the
same return values as `xQueueSendToFront()`. However, `pdPASS` is the only value that can be
returned because `xQueueOverwrite()` will write to the queue even when the queue is already
full.

---

### Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
  char cIn;
  BaseType_t xHigherPriorityTaskWoken;

  // We have not woken a task at the start of the ISR.
  xHigherPriorityTaskWoken = pdFALSE;

  // Loop until the buffer is empty.
  do
  {
    // Obtain a byte from the buffer.
    cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );
  }
  while( cIn != -1 );
```

(continues on next page)
// Post the byte.
xQueueSendToFrontFromISR(xRxQueue, &cIn, &xHigherPriorityTaskWoken );
}
while( portINPUT_BYTE( BUFFER_COUNT ) );

// Now the buffer is empty we can switch context if necessary.
if( xHigherPriorityTaskWoken )
{
    portYIELD_FROM_ISR ();
}

Parameters

- **xQueue** - The handle to the queue on which the item is to be posted.
- **pvItemToQueue** - A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from pvItemToQueue into the queue storage area.
- **pxHigherPriorityTaskWoken** - [out] xQueueSendToFrontFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE if sending to the queue caused a task to un-block, and the unblocked task has a priority higher than the currently running task. If xQueueSendToFromFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

Returns pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

---

**xQueueSendToBackFromISR** (xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)

This is a macro that calls xQueueGenericSendFromISR().

Post an item to the back of a queue. It is safe to use this macro from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWoken;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWoken = pdFALSE;

    // Loop until the buffer is empty.
    do
    {
        // Obtain a byte from the buffer.
        cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );

        // Post the byte.
        xQueueSendToBackFromISR(xRxQueue, &cIn, &xHigherPriorityTaskWoken );
    } while( portINPUT_BYTE( BUFFER_COUNT ) );

    // Now the buffer is empty we can switch context if necessary.
    if( xHigherPriorityTaskWoken )
    {
        portYIELD_FROM_ISR ();
    }
}
```
Parameters

- **xQueue**: The handle to the queue on which the item is to be posted.
- **pvItemToQueue**: A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from pvItemToQueue into the queue storage area.
- **pxHigherPriorityTaskWoken** [out] xQueueSendToBackFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE if sending to the queue caused a task to unblock, and the unblocked task has a priority higher than the currently running task. If xQueueSendToBackFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

**Returns** pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

**xQueueOverwriteFromISR** (xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)

A version of xQueueOverwrite() that can be used in an interrupt service routine (ISR).

Only for use with queues that can hold a single item - so the queue is either empty or full.

Post an item on a queue. If the queue is already full then overwrite the value held in the queue. The item is queued by copy, not by reference.

Example usage:

```c
QueueHandle_t xQueue;

void vFunction( void *pvParameters )
{
    // Create a queue to hold one uint32_t value. It is strongly
    // recommended *not* to use xQueueOverwriteFromISR() on queues that can
    // contain more than one value, and doing so will trigger an assertion
    // if configASSERT() is defined.
    xQueue = xQueueCreate( 1, sizeof( uint32_t ) );
}

void vAnInterruptHandler( void )
{
    // pxHigherPriorityTaskWoken must be set to pdFALSE before it is used.
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;
    uint32_t ulVarToSend, ulValReceived;

    // Write the value 10 to the queue using xQueueOverwriteFromISR().
    ulVarToSend = 10;
    xQueueOverwriteFromISR( xQueue, &ulVarToSend, &xHigherPriorityTaskWoken );

    // The queue is full, but calling xQueueOverwriteFromISR() again will still
    // pass because the value held in the queue will be overwritten with the
    // new value.
    ulVarToSend = 100;
    xQueueOverwriteFromISR( xQueue, &ulVarToSend, &xHigherPriorityTaskWoken );

    // Reading from the queue will now return 100.
    // ...

    if( xHigherPriorityTaskWoken == pdTRUE )
    {
        // Writing to the queue caused a task to unblock and the unblocked task
        // has a priority higher than or equal to the priority of the currently
        // executing task (the task this interrupt interrupted). Perform an-
        // → context
        // switch so this interrupt returns directly to the unblocked task.
    }

    // (continues on next page)
```
portYIELD_FROM_ISR(); // or portEND_SWITCHING_ISR() depending on the port.
}

Parameters

- **xQueue** - The handle to the queue on which the item is to be posted.
- **pvItemToQueue** - A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from pvItemToQueue into the queue storage area.
- **pxHigherPriorityTaskWoken** - [out] xQueueOverwriteFromISR() will set *px-HigherPriorityTaskWoken to pdTRUE if sending to the queue caused a task to un-block, and the unblocked task has a priority higher than the currently running task. If xQueueOverwriteFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

Returns

xQueueOverwriteFromISR() is a macro that calls xQueueGenericSendFromISR(), and therefore has the same return values as xQueueSendToFrontFromISR(). However, pdPASS is the only value that can be returned because xQueueOverwriteFromISR() will write to the queue even when the queue is already full.

xQueueSendFromISR (xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)

This is a macro that calls xQueueGenericSendFromISR(). It is included for backward compatibility with versions of FreeRTOS.org that did not include the xQueueSendToBackFromISR() and xQueueSendToFrontFromISR() macros.

Post an item to the back of a queue. It is safe to use this function from within an interrupt service routine.

Items are queued by copy not reference so it is preferable to only queue small items, especially when called from an ISR. In most cases it would be preferable to store a pointer to the item being queued.

Example usage for buffered IO (where the ISR can obtain more than one value per call):

```c
void vBufferISR( void )
{
    char cIn;
    BaseType_t xHigherPriorityTaskWoken;

    // We have not woken a task at the start of the ISR.
    xHigherPriorityTaskWoken = pdFALSE;

    // Loop until the buffer is empty.
    do
    {
        // Obtain a byte from the buffer.
        cIn = portINPUT_BYTE( RX_REGISTER_ADDRESS );

        // Post the byte.
        xQueueSendFromISR( xRxQueue, &cIn, &xHigherPriorityTaskWoken );
    } while( portINPUT_BYTE( BUFFER_COUNT ) );

    // Now the buffer is empty we can switch context if necessary.
    if( xHigherPriorityTaskWoken )
    {
        // Actual macro used here is port specific.
        portYIELD_FROM_ISR();
    }
}
```
Parameters

• **xQueue** - The handle to the queue on which the item is to be posted.
• **pvItemToQueue** - A pointer to the item that is to be placed on the queue. The size of the items the queue will hold was defined when the queue was created, so this many bytes will be copied from pvItemToQueue into the queue storage area.
• **pxHigherPriorityTaskWoken** - [out] xQueueSendFromISR() will set pxHigherPriorityTaskWoken to pdTRUE if sending to the queue caused a task to unblock, and the unblocked task has a priority higher than the currently running task. If xQueueSendFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

Returns  pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

xQueueReset(xQueue)

Reset a queue back to its original empty state. The return value is now obsolete and is always set to pdPASS.

Type Definitions

typedef struct QueueDefinition *QueueHandle_t

typedef struct QueueDefinition *QueueSetHandle_t

Type by which queue sets are referenced. For example, a call to xQueueCreateSet() returns an xQueueSet variable that can then be used as a parameter to xQueueSelectFromSet(), xQueueAddToSet(), etc.

typedef struct QueueDefinition *QueueSetMemberHandle_t

Queue sets can contain both queues and semaphores, so the QueueSetMemberHandle_t is defined as a type to be used where a parameter or return value can be either a QueueHandle_t or an SemaphoreHandle_t.

Semaphore API

Header File

• components/freertos/FreeRTOS-Kernel/include/freertos/semphr.h

Macros

semBINARY_SEMAPHORE_QUEUE_LENGTH

semSEMAPHORE_QUEUE_ITEM_LENGTH

semGIVE_BLOCK_TIME

vSemaphoreCreateBinary(xSemaphore)

In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a binary semaphore! [https://www.FreeRTOS.org/RTOS-task-notifications.html](https://www.FreeRTOS.org/RTOS-task-notifications.html)

This old vSemaphoreCreateBinary() macro is now deprecated in favour of the xSemaphoreCreateBinary() function. Note that binary semaphores created using the vSemaphoreCreateBinary() macro are created in a state such that the first call to ‘take’ the semaphore would pass, whereas binary semaphores created using xSemaphoreCreateBinary() are created in a state such that the the semaphore must first be ‘given’ before it can be ‘taken’.

Macro that implements a semaphore by using the existing queue mechanism. The queue length is 1 as this is a binary semaphore. The data size is 0 as we don’t want to actually store any data - we just want to know if the queue is empty or full.
This type of semaphore can be used for pure synchronisation between tasks or between an interrupt and a task. The semaphore need not be given back once obtained, so one task/interrupt can continuously ‘give’ the semaphore while another continuously ‘takes’ the semaphore. For this reason this type of semaphore does not use a priority inheritance mechanism. For an alternative that does use priority inheritance see xSemaphoreCreateMutex().

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;

void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to vSemaphoreCreateBinary ().
    // This is a macro so pass the variable in directly.
    vSemaphoreCreateBinary( xSemaphore );

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```

Parameters

- `xSemaphore` - Handle to the created semaphore. Should be of type SemaphoreHandle_t.

`xSemaphoreCreateBinary()`

Creates a new binary semaphore instance, and returns a handle by which the new semaphore can be referenced.

In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a binary semaphore! [https://www.FreeRTOS.org/RTOS-task-notifications.html](https://www.FreeRTOS.org/RTOS-task-notifications.html)

Internally, within the FreeRTOS implementation, binary semaphores use a block of memory, in which the semaphore structure is stored. If a binary semaphore is created using xSemaphoreCreateBinary() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateBinary() function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If a binary semaphore is created using xSemaphoreCreateBinaryStatic() then the application writer must provide the memory. xSemaphoreCreateBinaryStatic() therefore allows a binary semaphore to be created without using any dynamic memory allocation.

The old vSemaphoreCreateBinary() macro is now deprecated in favour of this xSemaphoreCreateBinary() function. Note that binary semaphores created using the vSemaphoreCreateBinary() macro are created in a state such that the first call to ‘take’ the semaphore would pass, whereas binary semaphores created using xSemaphoreCreateBinary() are created in a state such that the the semaphore must first be ‘given’ before it can be ‘taken’.

This type of semaphore can be used for pure synchronisation between tasks or between an interrupt and a task. The semaphore need not be given back once obtained, so one task/interrupt can continuously ‘give’ the semaphore while another continuously ‘takes’ the semaphore. For this reason this type of semaphore does not use a priority inheritance mechanism. For an alternative that does use priority inheritance see xSemaphoreCreateMutex().

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;

void vATask( void * pvParameters )
{
    // (continues on next page)
}
```
// Semaphore cannot be used before a call to xSemaphoreCreateBinary().
// This is a macro so pass the variable in directly.
xSemaphore = xSemaphoreCreateBinary();

if( xSemaphore != NULL )
{
    // The semaphore was created successfully.
    // The semaphore can now be used.
}

Returns Handle to the created semaphore, or NULL if the memory required to hold the
semaphore’s data structures could not be allocated.

xSemaphoreCreateBinaryStatic (pxStaticSemaphore)
Creates a new binary semaphore instance, and returns a handle by which the new semaphore can be referenced.

NOTE: In many usage scenarios it is faster and more memory efficient to use a direct to task notification in
place of a binary semaphore! https://www.FreeRTOS.org/RTOS-task-notifications.html

Internally, within the FreeRTOS implementation, binary semaphores use a block of memory, in which the
semaphore structure is stored. If a binary semaphore is created using xSemaphoreCreateBinary() then the
required memory is automatically dynamically allocated inside the xSemaphoreCreateBinary() function. (see
https://www.FreeRTOS.org/a00111.html). If a binary semaphore is created using xSemaphoreCreateBina-
ryStatic() then the application writer must provide the memory. xSemaphoreCreateBinaryStatic() therefore
allows a binary semaphore to be created without using any dynamic memory allocation.

This type of semaphore can be used for pure synchronisation between tasks or between an interrupt and a
task. The semaphore need not be given back once obtained, so one task/interrupt can continuously ‘give’ the
semaphore while another continuously ‘takes’ the semaphore. For this reason this type of semaphore does not use
a priority inheritance mechanism. For an alternative that does use priority inheritance see xSemaphoreCre-
ateMutex().

Example usage:

SemaphoreHandle_t xSemaphore = NULL;
StaticSemaphore_t xSemaphoreBuffer;

void vATask ( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateBinaryStatic().
    // The semaphore's data structures will be placed in the xSemaphoreBuffer
    // variable, the address of which is passed into the function. The
    // function's parameter is not NULL, so the function will not attempt any
    // dynamic memory allocation, and therefore the function will not return
    // return NULL.
    xSemaphore = xSemaphoreCreateBinaryStatic( &xSemaphoreBuffer );
    // Rest of task code goes here.
}

Parameters
  • pxStaticSemaphore – Must point to a variable of type StaticSemaphore_t, which will
then be used to hold the semaphore’s data structure, removing the need for the memory
to be allocated dynamically.

Returns If the semaphore is created then a handle to the created semaphore is returned. If
pxSemaphoreBuffer is NULL then NULL is returned.

**xSemaphoreTake** (xSemaphore, xBlockTime)

*Macro* to obtain a semaphore. The semaphore must have previously been created with a call to `xSemaphoreCreateBinary()`, `xSemaphoreCreateMutex()` or `xSemaphoreCreateCounting()`.

Example usage:

```c
SemaphoreHandle_t xSemaphore = NULL;

// A task that creates a semaphore.
void vATask( void * pvParameters )
{
    // Create the semaphore to guard a shared resource.
    xSemaphore = xSemaphoreCreateBinary();
}

// A task that uses the semaphore.
void vAnotherTask( void * pvParameters )
{
    // ... Do other things.
    if( xSemaphore != NULL )
    {
        // See if we can obtain the semaphore. If the semaphore is not available
        // wait 10 ticks to see if it becomes free.
        if( xSemaphoreTake( xSemaphore, ( TickType_t ) 10 ) == pdTRUE )
        {
            // We were able to obtain the semaphore and can now access the
            // shared resource.
            // ...
            // We have finished accessing the shared resource. Release the
            // semaphore.
            xSemaphoreGive( xSemaphore );
        }
        else
        {
            // We could not obtain the semaphore and can therefore not access
            // the shared resource safely.
        }
    }
}
```

**Parameters**

- **xSemaphore** - A handle to the semaphore being taken - obtained when the semaphore was created.
- **xBlockTime** - The time in ticks to wait for the semaphore to become available. The macro `portTICK_PERIOD_MS` can be used to convert this to a real time. A block time of zero can be used to poll the semaphore. A block time of `portMAX_DELAY` can be used to block indefinitely (provided `INCLUDE_vTaskSuspend` is set to 1 in FreeRTOSConfig.h).

**Returns** `pdTRUE` if the semaphore was obtained. `pdFALSE` if `xBlockTime` expired without the semaphore becoming available.

**xSemaphoreTakeRecursive** (xMutex, xBlockTime)

*Macro* to recursively obtain, or “take”, a mutex type semaphore. The mutex must have previously been created using a call to `xSemaphoreCreateRecursiveMutex()`;

`configUSE_RECURSIVE_MUTEXES` must be set to 1 in FreeRTOSConfig.h for this macro to be available. This macro must not be used on mutexes created using `xSemaphoreCreateMutex()`.

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A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

Example usage:

```c
SemaphoreHandle_t xMutex = NULL;

// A task that creates a mutex.
void vATask( void * pvParameters )
{
    // Create the mutex to guard a shared resource.
    xMutex = xSemaphoreCreateRecursiveMutex();
}

// A task that uses the mutex.
void vAnotherTask( void * pvParameters )
{
    // ... Do other things.
    if( xMutex != NULL )
    {
        // See if we can obtain the mutex. If the mutex is not available
        // wait 10 ticks to see if it becomes free.
        if( xSemaphoreTakeRecursive( xSemaphore, ( TickType_t ) 10 ) == pdTRUE )
        {
            // We were able to obtain the mutex and can now access the
            // shared resource.
            // ...
            // For some reason due to the nature of the code further calls to
            // xSemaphoreTakeRecursive() are made on the same mutex. In real
            // code these would not be just sequential calls as this would make
            // no sense. Instead the calls are likely to be buried inside
            // a more complex call structure.
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );
            // The mutex has now been 'taken' three times, so will not be
            // available to another task until it has also been given back
            // three times. Again it is unlikely that real code would have
            // these calls sequentially, but instead buried in a more complex
            // call structure. This is just for illustrative purposes.
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );
            // Now the mutex can be taken by other tasks.
        }
        else
        {
            // We could not obtain the mutex and can therefore not access
            // the shared resource safely.
        }
    }
}
```

**Parameters**

- `xMutex` — A handle to the mutex being obtained. This is the handle returned by xSemaphoreCreateRecursiveMutex();
• **xBlockTime** - The time in ticks to wait for the semaphore to become available. The macro portTICK_PERIOD_MS can be used to convert this to a real time. A block time of zero can be used to poll the semaphore. If the task already owns the semaphore then xSemaphoreTakeRecursive() will return immediately no matter what the value of xBlockTime.

**Returns** pdTRUE if the semaphore was obtained. pdFALSE if xBlockTime expired without the semaphore becoming available.

**xSemaphoreGive** *(xSemaphore)*

*Macro* to release a semaphore. The semaphore must have previously been created with a call to xSemaphoreCreateBinary(), xSemaphoreCreateMutex() or xSemaphoreCreateCounting(), and obtained using xSemaphoreTake().

This macro must not be used from an ISR. See xSemaphoreGiveFromISR () for an alternative which can be used from an ISR.

This macro must also not be used on semaphores created using xSemaphoreCreateRecursiveMutex().

**Example usage:**

```c
SemaphoreHandle_t xSemaphore = NULL;

void vATask( void * pvParameters )
{
   // Create the semaphore to guard a shared resource.
   xSemaphore = vSemaphoreCreateBinary();

   if( xSemaphore != NULL )
   {
      if( xSemaphoreGive( xSemaphore ) != pdTRUE )
      {
         // We would expect this call to fail because we cannot give
         // a semaphore without first "taking" it!
      }

      // Obtain the semaphore - don't block if the semaphore is not
      // immediately available.
      if( xSemaphoreTake( xSemaphore, ( TickType_t ) 0 ) )
      {
         // We now have the semaphore and can access the shared resource.
         // ...

         // We have finished accessing the shared resource so can free the
         // semaphore.
         if( xSemaphoreGive( xSemaphore ) != pdTRUE )
         {
            // We would not expect this call to fail because we must have
            // obtained the semaphore to get here.
         }
      }
   }
}
```

**Parameters**

• **xSemaphore** - A handle to the semaphore being released. This is the handle returned when the semaphore was created.

**Returns** pdTRUE if the semaphore was released. pdFALSE if an error occurred. Semaphores are implemented using queues. An error can occur if there is no space on the queue to post a message - indicating that the semaphore was not first obtained correctly.
**xSemaphoreGiveRecursive(xMutex)**

*Macro* to recursively release, or ‘give’, a mutex type semaphore. The mutex must have previously been created using a call to xSemaphoreCreateRecursiveMutex();

`configUSE_RECURSIVE_MUTEXES` must be set to 1 in FreeRTOSConfig.h for this macro to be available.

This macro must not be used on mutexes created using xSemaphoreCreateMutex().

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

Example usage:

```c
SemaphoreHandle_t xMutex = NULL;

// A task that creates a mutex.
void vATask( void * pvParameters )
{
    // Create the mutex to guard a shared resource.
    xMutex = xSemaphoreCreateRecursiveMutex();
}

// A task that uses the mutex.
void vAnotherTask( void * pvParameters )
{
    // ... Do other things.
    if( xMutex != NULL )
    {
        // See if we can obtain the mutex. If the mutex is not available
        // wait 10 ticks to see if it becomes free.
        if( xSemaphoreTakeRecursive( xMutex, (TickType_t)10 ) == pdTRUE )
        {
            // We were able to obtain the mutex and can now access the
            // shared resource.

            // ... For some reason due to the nature of the code further calls to
            // xSemaphoreTakeRecursive() are made on the same mutex. In real
            // code these would not be just sequential calls as this would make
            // no sense. Instead the calls are likely to be buried inside
            // a more complex call structure.
            xSemaphoreTakeRecursive( xMutex, (TickType_t)10 );
            xSemaphoreTakeRecursive( xMutex, (TickType_t)10 );

            // The mutex has now been 'taken' three times, so will not be
            // available to another task until it has also been given back
            // three times. Again it is unlikely that real code would have
            // these calls sequentially, it would be more likely that the calls
            // to xSemaphoreGiveRecursive() would be called as a call stack
            // unwound. This is just for demonstrative purposes.
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );

            // Now the mutex can be taken by other tasks.
        } else
        {
            // We could not obtain the mutex and can therefore not access
```

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Parameters

- **xMutex** - A handle to the mutex being released, or ‘given’. This is the handle returned by xSemaphoreCreateMutex();

Returns  pdTRUE if the semaphore was given.

```c
xSemaphoreGiveFromISR(xSemaphore, pxHigherPriorityTaskWoken)
```

Macro to release a semaphore. The semaphore must have previously been created with a call to xSemaphoreCreateBinary() or xSemaphoreCreateCounting().

Mutex type semaphores (those created using a call to xSemaphoreCreateMutex()) must not be used with this macro.

This macro can be used from an ISR.

Example usage:

```c
#define LONG_TIME 0xffff
#define TICKS_TO_WAIT 10
SemaphoreHandle_t xSemaphore = NULL;

// Repetitive task.
void vATask( void * pvParameters )
{
    for(;;)
    {
        // We want this task to run every 10 ticks of a timer. The semaphore
        // was created before this task was started.

        // Block waiting for the semaphore to become available.
        if( xSemaphoreTake( xSemaphore, LONG_TIME ) == pdTRUE )
        {
            // It is time to execute.
            // ...

            // We have finished our task. Return to the top of the loop where
            // we will block on the semaphore until it is time to execute
            // again. Note when using the semaphore for synchronisation with an
            // ISR in this manner there is no need to 'give' the semaphore back.
        }
    }
}

// Timer ISR
void vTimerISR( void * pvParameters )
{
    static uint8_t ucLocalTickCount = 0;
    static BaseType_t xHigherPriorityTaskWoken;

    // A timer tick has occurred.
    // ...
    // Is it time for vATask () to run?
```
xHigherPriorityTaskWoken = pdFALSE;
ucLocalTickCount++;
if( ucLocalTickCount >= TICKS_TO_WAIT )
{
    // Unblock the task by releasing the semaphore.
xSemaphoreGiveFromISR( xSemaphore, &xHigherPriorityTaskWoken );

    // Reset the count so we release the semaphore again in 10 ticks time.
    ucLocalTickCount = 0;
}

if( xHigherPriorityTaskWoken != pdFALSE )
{
    // We can force a context switch here. Context switching from an
    // ISR uses port specific syntax. Check the demo task for your port
    // to find the syntax required.
}

Parameters

- **xSemaphore** - A handle to the semaphore being released. This is the handle returned when the semaphore was created.
- **pxHigherPriorityTaskWoken** - xSemaphoreGiveFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE if giving the semaphore caused a task to unblock, and the unblocked task has a priority higher than the currently running task. If xSemaphoreGiveFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

Returns pdTRUE if the semaphore was successfully given, otherwise errQUEUE_FULL.

xSemaphoreTakeFromISR( xSemaphore, pxHigherPriorityTaskWoken )

Macro to take a semaphore from an ISR. The semaphore must have previously been created with a call to xSemaphoreCreateBinary() or xSemaphoreCreateCounting().

Mutex type semaphores (those created using a call to xSemaphoreCreateMutex()) must not be used with this macro.

This macro can be used from an ISR, however taking a semaphore from an ISR is not a common operation. It is likely to only be useful when taking a counting semaphore when an interrupt is obtaining an object from a resource pool (when the semaphore count indicates the number of resources available).

Parameters

- **xSemaphore** - A handle to the semaphore being taken. This is the handle returned when the semaphore was created.
- **pxHigherPriorityTaskWoken** - [out] xSemaphoreTakeFromISR() will set *px-HigherPriorityTaskWoken to pdTRUE if taking the semaphore caused a task to unblock, and the unblocked task has a priority higher than the currently running task. If xSemaphoreTakeFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

Returns pdTRUE if the semaphore was successfully taken, otherwise pdFALSE

xSemaphoreCreateMutex()

Creates a new mutex type semaphore instance, and returns a handle by which the new mutex can be referenced.

Internally, within the FreeRTOS implementation, mutex semaphores use a block of memory, in which the mutex structure is stored. If a mutex is created using xSemaphoreCreateMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateMutex() function. (see https://www.FreeRTOS.org/a00111.html). If a mutex is created using xSemaphoreCreateMutexStatic() then the application writer must provided the memory. xSemaphoreCreateMutexStatic() therefore allows a mutex to be created without using any dynamic memory allocation.
Mutexes created using this function can be accessed using the xSemaphoreTake() and xSemaphoreGive() macros. The xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros must not be used.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```

**Returns** If the mutex was successfully created then a handle to the created semaphore is returned.

If there was not enough heap to allocate the mutex data structures then NULL is returned.

**xSemaphoreCreateMutexStatic**(pxMutexBuffer)

Creates a new mutex type semaphore instance, and returns a handle by which the new mutex can be referenced.

Internally, within the FreeRTOS implementation, mutex semaphores use a block of memory, in which the mutex structure is stored. If a mutex is created using xSemaphoreCreateMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateMutex() function. (see https://www.FreeRTOS.org/a00111.html). If a mutex is created using xSemaphoreCreateMutexStatic() then the application writer must provided the memory. xSemaphoreCreateMutexStatic() therefore allows a mutex to be created without using any dynamic memory allocation.

Mutexes created using this function can be accessed using the xSemaphoreTake() and xSemaphoreGive() macros. The xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros must not be used.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;
void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```
A mutex cannot be used before it has been created. xMutexBuffer is into xSemaphoreCreateMutexStatic() so no dynamic memory allocation is attempted.

```c
xSemaphore = xSemaphoreCreateMutexStatic( &xMutexBuffer );
```

As no dynamic memory allocation was performed, xSemaphore cannot be NULL, so there is no need to check it.

### Parameters

- `pxMutexBuffer` – Must point to a variable of type StaticSemaphore_t, which will be used to hold the mutex’s data structure, removing the need for the memory to be allocated dynamically.

### Returns

If the mutex was successfully created then a handle to the created mutex is returned. If pxMutexBuffer was NULL then NULL is returned.

**xSemaphoreCreateCounting** (uxMaxCount, uxInitialCount)

Creates a new recursive mutex type semaphore instance, and returns a handle by which the new recursive mutex can be referenced.

Internally, within the FreeRTOS implementation, recursive mutexes use a block of memory, in which the mutex structure is stored. If a recursive mutex is created using xSemaphoreCreateRecursiveMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateRecursiveMutex() function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If a recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic() then the application writer must provide the memory that will get used by the mutex. xSemaphoreCreateRecursiveMutexStatic() therefore allows a recursive mutex to be created without using any dynamic memory allocation.

Mutexes created using this macro can be accessed using the xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros. The xSemaphoreTake() and xSemaphoreGive() macros must not be used.

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

### Example usage:

```c
SemaphoreHandle_t xSemaphore;

void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This is a macro so pass the variable in directly.
    xSemaphore = xSemaphoreCreateRecursiveMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
    }
```

(continues on next page)
// The semaphore can now be used.
}
}

Creates a new recursive mutex type semaphore instance, and returns a handle by which the new recursive mutex can be referenced.

Internally, within the FreeRTOS implementation, recursive mutexes use a block of memory, in which the mutex structure is stored. If a recursive mutex is created using xSemaphoreCreateRecursiveMutex() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateRecursiveMutex() function. (see https://www.FreeRTOS.org/a00111.html). If a recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic() then the application writer must provide the memory that will get used by the mutex. xSemaphoreCreateRecursiveMutexStatic() therefore allows a recursive mutex to be created without using any dynamic memory allocation.

 Mutexes created using this macro can be accessed using the xSemaphoreTakeRecursive() and xSemaphoreGiveRecursive() macros. The xSemaphoreTake() and xSemaphoreGive() macros must not be used.

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called xSemaphoreGiveRecursive() for each successful ‘take’ request. For example, if a task successfully ‘takes’ the same mutex 5 times then the mutex will not be available to any other task until it has also ‘given’ the mutex back exactly five times.

This type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore MUST ALWAYS ‘give’ the semaphore back once the semaphore it is no longer required.

Mutex type semaphores cannot be used from within interrupt service routines.

See xSemaphoreCreateBinary() for an alternative implementation that can be used for pure synchronisation (where one task or interrupt always ‘gives’ the semaphore and another always ‘takes’ the semaphore) and from within interrupt service routines.

Example usage:

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;

void vATask( void * pvParameters )
{
    // A recursive semaphore cannot be used before it is created. Here a
    // recursive mutex is created using xSemaphoreCreateRecursiveMutexStatic().
    // The address of xMutexBuffer is passed into the function, and will hold
    // the mutexes data structures - so no dynamic memory allocation will be
    // attempted.
    xSemaphore = xSemaphoreCreateRecursiveMutexStatic( &xMutexBuffer );
    // As no dynamic memory allocation was performed, xSemaphore cannot be NULL,
    // so there is no need to check it.
}
```

Creates a new counting semaphore instance, and returns a handle by which the new counting semaphore can be referenced.

In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a counting semaphore! https://www.FreeRTOS.org/RTOS-task-notifications.html

Internally, within the FreeRTOS implementation, counting semaphores use a block of memory, in which the counting semaphore structure is stored. If a counting semaphore is created using xSemaphoreCreateCounting() then the required memory is automatically dynamically allocated inside the xSemaphoreCreateCounting() function. (see https://www.FreeRTOS.org/a00111.html). If a counting semaphore is created using xSemaphoreCreateCountingStatic() then the application writer can instead optionally provide the memory
that will get used by the counting semaphore. `xSemaphoreCreateCountingStatic()` therefore allows a counting semaphore to be created without using any dynamic memory allocation.

Counting semaphores are typically used for two things:

1) Counting events.

In this usage scenario an event handler will ‘give’ a semaphore each time an event occurs (incrementing the semaphore count value), and a handler task will ‘take’ a semaphore each time it processes an event (decrementing the semaphore count value). The count value is therefore the difference between the number of events that have occurred and the number that have been processed. In this case it is desirable for the initial count value to be zero.

2) Resource management.

In this usage scenario the count value indicates the number of resources available. To obtain control of a resource a task must first obtain a semaphore - decrementing the semaphore count value. When the count value reaches zero there are no free resources. When a task finishes with the resource it ‘gives’ the semaphore back - incrementing the semaphore count value. In this case it is desirable for the initial count value to be equal to the maximum count value, indicating that all resources are free.

Example usage:

```c
SemaphoreHandle_t xSemaphore;

void vATask( void * pvParameters )
{
    SemaphoreHandle_t xSemaphore = NULL;

    // Semaphore cannot be used before a call to xSemaphoreCreateCounting().
    // The max value to which the semaphore can count should be 10, and the
    // initial value assigned to the count should be 0.
    xSemaphore = xSemaphoreCreateCounting( 10, 0 );

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
```

Returns `xSemaphore Handle to the created mutex semaphore. Should be of type SemaphoreHandle_t.`

Parameters

- **pxStaticSemaphore** - Must point to a variable of type StaticSemaphore_t, which will then be used to hold the recursive mutex’s data structure, removing the need for the memory to be allocated dynamically.
- **uxMaxCount** - The maximum count value that can be reached. When the semaphore reaches this value it can no longer be ‘given’.
- **uxInitialCount** - The count value assigned to the semaphore when it is created.

Returns If the recursive mutex was successfully created then a handle to the created recursive mutex is returned. If `pxMutexBuffer` was `NULL` then `NULL` is returned.

Returns Handle to the created semaphore. Null if the semaphore could not be created.

`xSemaphoreCreateCountingStatic(uxMaxCount, uxInitialCount, pxSemaphoreBuffer)`

Creates a new counting semaphore instance, and returns a handle by which the new counting semaphore can be referenced.

In many usage scenarios it is faster and more memory efficient to use a direct to task notification in place of a counting semaphore! [https://www.FreeRTOS.org/RTOS-task-notifications.html](https://www.FreeRTOS.org/RTOS-task-notifications.html)
Internally, within the FreeRTOS implementation, counting semaphores use a block of memory, in which the counting semaphore structure is stored. If a counting semaphore is created using `xSemaphoreCreateCounting()` then the required memory is automatically dynamically allocated inside the `xSemaphoreCreateCounting()` function. (see https://www.FreeRTOS.org/a00111.html). If a counting semaphore is created using `xSemaphoreCreateCountingStatic()` then the application writer must provide the memory. `xSemaphoreCreateCountingStatic()` therefore allows a counting semaphore to be created without using any dynamic memory allocation.

Counting semaphores are typically used for two things:

1) Counting events.

In this usage scenario an event handler will ‘give’ a semaphore each time an event occurs (incrementing the semaphore count value), and a handler task will ‘take’ a semaphore each time it processes an event (decrementing the semaphore count value). The count value is therefore the difference between the number of events that have occurred and the number that have been processed. In this case it is desirable for the initial count value to be zero.

2) Resource management.

In this usage scenario the count value indicates the number of resources available. To obtain control of a resource a task must first obtain a semaphore - decrementing the semaphore count value. When the count value reaches zero there are no free resources. When a task finishes with the resource it ‘gives’ the semaphore back - incrementing the semaphore count value. In this case it is desirable for the initial count value to be equal to the maximum count value, indicating that all resources are free.

**Example usage:**

```c
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xSemaphoreBuffer;

void vATask( void * pvParameters )
{
    SemaphoreHandle_t xSemaphore = NULL;

    // Counting semaphore cannot be used before they have been created. Create
    // a counting semaphore using xSemaphoreCreateCountingStatic(). The max
    // value to which the semaphore can count is 10, and the initial value
    // assigned to the count will be 0. The address of xSemaphoreBuffer is
    // passed in and will be used to hold the semaphore structure, so no dynamic
    // memory allocation will be used.
    xSemaphore = xSemaphoreCreateCounting( 10, 0, &xSemaphoreBuffer );

    // No memory allocation was attempted so xSemaphore cannot be NULL, so there
    // is no need to check its value.
}
```

**Parameters**

- `uxMaxCount` - The maximum count value that can be reached. When the semaphore reaches this value it can no longer be ‘given’.
- `uxInitialCount` - The count value assigned to the semaphore when it is created.
- `pxSemaphoreBuffer` - Must point to a variable of type StaticSemaphore_t, which will then be used to hold the semaphore’s data structure, removing the need for the memory to be allocated dynamically.

**Returns**

If the counting semaphore was successfully created then a handle to the created counting semaphore is returned. If `pxSemaphoreBuffer` was NULL then NULL is returned.

**vSemaphoreDelete**(xSemaphore)

Delete a semaphore. This function must be used with care. For example, do not delete a mutex type semaphore if the mutex is held by a task.
Chapter 2. API Reference

Parameters
  • **xSemaphore** — A handle to the semaphore to be deleted.

**xSemaphoreGetMutexHolder (xSemaphore)**
If xMutex is indeed a mutex type semaphore, return the current mutex holder. If xMutex is not a mutex type semaphore, or the mutex is available (not held by a task), return NULL.

Note: This is a good way of determining if the calling task is the mutex holder, but not a good way of determining the identity of the mutex holder as the holder may change between the function exiting and the returned value being tested.

**xSemaphoreGetMutexHolderFromISR (xSemaphore)**
If xMutex is indeed a mutex type semaphore, return the current mutex holder. If xMutex is not a mutex type semaphore, or the mutex is available (not held by a task), return NULL.

**uxSemaphoreGetCount (xSemaphore)**
If the semaphore is a counting semaphore then uxSemaphoreGetCount() returns its current count value. If the semaphore is a binary semaphore then uxSemaphoreGetCount() returns 1 if the semaphore is available, and 0 if the semaphore is not available.

**xSemaphoreGetStaticBuffer (xSemaphore, ppxSemaphoreBuffer)**
Retrieve pointer to a statically created binary semaphore, counting semaphore, or mutex semaphore’s data structure buffer. This is the same buffer that is supplied at the time of creation.

  Parameters
  • **xSemaphore** — The semaphore for which to retrieve the buffer.
  • **ppxSemaphoreBuffer** — Used to return a pointer to the semaphore’s data structure buffer.

  Returns pdTRUE if buffer was retrieved, pdFALSE otherwise.

Type Definitions

typedef QueueHandle_t SemaphoreHandle_t

Timer API

Header File
  • components/freertos/FreeRTOS-Kernel/include/freertos/timers.h

Functions

**TimerHandle_t xTimerCreate (const char *const pcTimerName, const TickType_t xTimerPeriodInTicks, const UBaseType_t uxAutoReload, void *const pvTimerID, TimerCallbackFunction_t pxCallbackFunction)**

TimerHandle_t xTimerCreate( const char * const pcTimerName, TickType_t xTimerPeriodInTicks, UBaseType_t uxAutoReload, void * pvTimerID, TimerCallbackFunction_t pxCallbackFunction );

Creates a new software timer instance, and returns a handle by which the created software timer can be referenced.

Internally, within the FreeRTOS implementation, software timers use a block of memory, in which the timer data structure is stored. If a software timer is created using xTimerCreate() then the required memory is automatically dynamically allocated inside the xTimerCreate() function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If a software timer is created using xTimerCreateStatic() then the application writer must provide the memory that will get used by the software timer. xTimerCreateStatic() therefore allows a software timer to be created without using any dynamic memory allocation.
Timers are created in the dormant state. The `xTimerStart()`, `xTimerReset()`, `xTimerStartFromISR()`, `xTimerResetFromISR()`, `xTimerChangePeriod()` and `xTimerChangePeriodFromISR()` API functions can all be used to transition a timer into the active state.

Example usage:

```c
#define NUM_TIMERS 5

// An array to hold handles to the created timers.
TimerHandle_t xTimers[NUM_TIMERS];

// An array to hold a count of the number of times each timer expires.
int32_t lExpireCounters[NUM_TIMERS] = { 0 };

// Define a callback function that will be used by multiple timer instances.
// The callback function does nothing but count the number of times the
// associated timer expires, and stop the timer once the timer has expired
// 10 times.
void vTimerCallback( TimerHandle_t pxTimer )
{
    int32_t lArrayIndex;
    const int32_t xMaxExpiryCountBeforeStopping = 10;

    // Optionally do something if the pxTimer parameter is NULL.
    configASSERT( pxTimer );

    // Which timer expired?
    lArrayIndex = ( int32_t ) pvTimerGetTimerID( pxTimer );

    // Increment the number of times that pxTimer has expired.
    lExpireCounters[ lArrayIndex ] += 1;

    // If the timer has expired 10 times then stop it from running.
    if( lExpireCounters[ lArrayIndex ] == xMaxExpiryCountBeforeStopping )
    {
        // Do not use a block time if calling a timer API function from a
        // timer callback function, as doing so could cause a deadlock!
        xTimerStop( pxTimer, 0 );
    }
}

void main( void )
{
    int32_t x;

    // Create then start some timers. Starting the timers before the
    // scheduler
    // has been started means the timers will start running immediately that
    // the scheduler starts.
    for( x = 0; x < NUM_TIMERS; x++ )
    {
        xTimers[ x ] = xTimerCreate( "Timer", // Just a text name,
            ( 100 * x ), // The timer period
            pdTRUE, // The timers will
            ( void * ) x, // Assign each timer
            "not used by the kernel.
            vTimerCallback // Each timer calls...
            auto-reload themselves when they expire.
            a unique id equal to its array index.
            the same callback when it expires.
            )
            (continues on next page)
```

(continues on next page)
if( xTimers[ x ] == NULL )
{
    // The timer was not created.
}
else
{
    // Start the timer. No block time is specified, and even if one was
    // it would be ignored because the scheduler has not yet been started.
    if( xTimerStart( xTimers[ x ], 0 ) != pdPASS )
    {
        // The timer could not be set into the Active state.
    }
}

// Create tasks here.

// Starting the scheduler will start the timers running as they have already
// been set into the active state.
vTaskStartScheduler();

// Should not reach here.
for( ;; );

Parameters

- **pcTimerName** – A text name that is assigned to the timer. This is done purely to assist debugging. The kernel itself only ever references a timer by its handle, and never by its name.

- **xTimerPeriodInTicks** – The timer period. The time is defined in tick periods so the constant portTICK_PERIOD_MS can be used to convert a time that has been specified in milliseconds. For example, if the timer must expire after 100 ticks, then xTimerPeriodInTicks should be set to 100. Alternatively, if the timer must expire after 500ms, then xPeriod can be set to (500 / portTICK_PERIOD_MS) provided configTICK_RATE_HZ is less than or equal to 1000. Time timer period must be greater than 0.

- **uxAutoReload** – If uxAutoReload is set to pdTRUE then the timer will expire repeatedly with a frequency set by the xTimerPeriodInTicks parameter. If uxAutoReload is set to pdFALSE then the timer will be a one-shot timer and enter the dormant state after it expires.

- **pvTimerID** – An identifier that is assigned to the timer being created. Typically this would be used in the timer callback function to identify which timer expired when the same callback function is assigned to more than one timer.

- **pxCallbackFunction** – The function to call when the timer expires. Callback functions must have the prototype defined by TimerCallbackFunction_t, which is “void vCallbackFunction( TimerHandle_t xTimer );”.

Returns If the timer is successfully created then a handle to the newly created timer is returned. If the timer cannot be created because there is insufficient FreeRTOS heap remaining to allocate the timer structures then NULL is returned.
`TimerHandle_t xTimerCreateStatic` (const char *const pcTimerName, const TickType_t xTimerPeriodInTicks, const UBaseType_t uxAutoReload, void *const pvTimerID, TimerCallbackFunction_t pxCallbackFunction, StaticTimer_t *pxTimerBuffer)

```c
TimerHandle_t xTimerCreateStatic(const char * pcTimerName, TickType_t xTimerPeriodInTicks, UBaseType_t uxAutoReload, void * pvTimerID, TimerCallbackFunction_t pxCallbackFunction, StaticTimer_t *pxTimerBuffer);
```

Creates a new software timer instance, and returns a handle by which the created software timer can be referenced.

Internally, within the FreeRTOS implementation, software timers use a block of memory, in which the timer data structure is stored. If a software timer is created using `xTimerCreate()` then the required memory is automatically dynamically allocated inside the `xTimerCreate()` function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If a software timer is created using `xTimerCreateStatic()` then the application writer must provide the memory that will get used by the software timer. `xTimerCreateStatic()` therefore allows a software timer to be created without using any dynamic memory allocation.

Timers are created in the dormant state. The `xTimerStart()`, `xTimerReset()`, `xTimerStartFromISR()`, `xTimerResetFromISR()`, `xTimerChangePeriod()` and `xTimerChangePeriodFromISR()` API functions can all be used to transition a timer into the active state.

Example usage:

```c
* // The buffer used to hold the software timer's data structure.
* static StaticTimer_t xTimerBuffer;
* *
* // A variable that will be incremented by the software timer's callback
* // function.
* UBaseType_t uxVariableToIncrement = 0;
* *
* // A software timer callback function that increments a variable passed to
* // it when the software timer was created. After the 5th increment the
* // callback function stops the software timer.
* static void prvTimerCallback( TimerHandle_t xExpiredTimer )
* {
*     UBaseType_t *puxVariableToIncrement;
*     BaseType_t xReturned;
*     *
*     // Obtain the address of the variable to increment from the timer ID.
*     puxVariableToIncrement = ( UBaseType_t * ) pvTimerGetTimerID( _
*                                     xExpiredTimer );
*     *
*     // Increment the variable to show the timer callback has executed.
*     ( *puxVariableToIncrement )++;
*     *
*     // If this callback has executed the required number of times, stop the
*     // timer.
*     if( *puxVariableToIncrement == 5 )
*         {
*             // This is called from a timer callback so must not block.
*             xTimerStop( xExpiredTimer, staticDONT_BLOCK );
*         }
*     }
*     *
*     *
* void main( void )
* {
*     // Create the software time. xTimerCreateStatic() has an extra parameter
*     // than the normal xTimerCreate() API function. The parameter is a...
```

(continues on next page)
to the StaticTimer_t structure that will hold the software timer
structure. If the parameter is passed as NULL then the structure...
allocated dynamically, just as if xTimerCreate() had been called.
Helps debugging only. Not used by FreeRTOS.
Text name for the task.
Not used by FreeRTOS.
The period of the
variable incremented by the software timer’s callback function
The function to
hold the software timer structure.

The scheduler has not started yet so a block time is not used.
xReturned = xTimerStart( xTimer, 0 );

Create tasks here.

Starting the scheduler will start the timers running as they have
been set into the active state.
vTaskStartScheduler();

Should not reach here.

Parameters

• pcTimerName – A text name that is assigned to the timer. This is done purely to assist
  debugging. The kernel itself only ever references a timer by its handle, and never by its
  name.

• xTimerPeriodInTicks – The timer period. The time is defined in tick periods so the
  constant portTICK_PERIOD_MS can be used to convert a time that has been specified
  in milliseconds. For example, if the timer must expire after 100 ticks, then xTimerPeri-
  odInTicks should be set to 100. Alternatively, if the timer must expire after 500ms, then
  xPeriod can be set to (500/portTICK_PERIOD_MS) provided configTICK_RATE_HZ
  is less than or equal to 1000. The timer period must be greater than 0.

• uxAutoReload – If uxAutoReload is set to pdTRUE then the timer will expire repeati-
  edly with a frequency set by the xTimerPeriodInTicks parameter. If uxAutoReload is set
  to pdFALSE then the timer will be a one-shot timer and enter the dormant state after it
  expires.

• pxCallbackFunction – An identifier that is assigned to the timer being created. Typically this
  would be used in the timer callback function to identify which timer expired when the
  same callback function is assigned to more than one timer.

• pxCallbackFunction – The function to call when the timer expires. Callback func-
  tions must have the prototype defined by TimerCallbackFunction_t, which is “void vCall-
  backFunction( TimerHandle_t xTimer );”.

• pxTimerBuffer – Must point to a variable of type StaticTimer_t, which will be then
  be used to hold the software timer’s data structures, removing the need for the memory
  to be allocated dynamically.

Returns If the timer is created then a handle to the created timer is returned. If pxTimerBuffer
was NULL then NULL is returned.
Chapter 2. API Reference

void *pvTimerGetTimerID(const TimerHandle_t xTimer)
void *pvTimerGetTimerID(TimerHandle_t xTimer);

Returns the ID assigned to the timer.

IDs are assigned to timers using the pvTimerID parameter of the call to xTimerCreated() that was used to create the timer, and by calling the vTimerSetTimerID() API function.

If the same callback function is assigned to multiple timers then the timer ID can be used as time specific (timer local) storage.

Example usage:
See the xTimerCreate() API function example usage scenario.

Parameters xTimer - The timer being queried.
Returns The ID assigned to the timer being queried.

void vTimerSetTimerID(TimerHandle_t xTimer, void* pvNewID);
void vTimerSetTimerID( TimerHandle_t xTimer, void* pvNewID );

Sets the ID assigned to the timer.

IDs are assigned to timers using the pvTimerID parameter of the call to xTimerCreated() that was used to create the timer.

If the same callback function is assigned to multiple timers then the timer ID can be used as time specific (timer local) storage.

Example usage:
See the xTimerCreate() API function example usage scenario.

Parameters
• xTimer - The timer being updated.
• pvNewID - The ID to assign to the timer.

BaseType_t xTimerIsTimerActive(TimerHandle_t xTimer)
BaseType_t xTimerIsTimerActive( TimerHandle_t xTimer );

Queries a timer to see if it is active or dormant.

A timer will be dormant if: 1) It has been created but not started, or 2) It is an expired one-shot timer that has not been restarted.

Timers are created in the dormant state. The xTimerStart(), xTimerReset(), xTimerStartFromISR(), xTimerResetFromISR(), xTimerChangePeriod() and xTimerChangePeriodFromISR() API functions can all be used to transition a timer into the active state.

Example usage:

/* // This function assumes xTimer has already been created.
 * void vAFunction( TimerHandle_t xTimer )
 * {
 *   if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply and
 *       equivalently "if( xTimerIsTimerActive( xTimer ) )"
 *   {
 *     // xTimer is active, do something.
 *   }
 *   else
 *   {
 *     // xTimer is not active, do something else.
 */

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### Parameters
- **xTimer** - The timer being queried.

### Returns
- `pdFALSE` will be returned if the timer is dormant. A value other than `pdFALSE` will be returned if the timer is active.

#### TaskHandle_t xTimerGetTimerDaemonTaskHandle (void)
```c
TaskHandle_t xTimerGetTimerDaemonTaskHandle( void );
```
Simply returns the handle of the timer service/daemon task. It is not valid to call `xTimerGetTimerDaemonTaskHandle()` before the scheduler has been started.

#### BaseType_t xTimerPendFunctionCallFromISR (PendedFunction_t xFunctionToPend, void *pvParameter1, uint32_t ulParameter2, BaseType_t *pxHigherPriorityTaskWoken)
```c
BaseType_t xTimerPendFunctionCallFromISR( PendedFunction_t xFunctionToPend, void *pvParameter1, uint32_t ulParameter2, BaseType_t *pxHigherPriorityTaskWoken );
```
Used from application interrupt service routines to defer the execution of a function to the RTOS daemon task (the timer service task, hence this function is implemented in timers.c and is prefixed with ‘Timer’).

Ideally an interrupt service routine (ISR) is kept as short as possible, but sometimes an ISR either has a lot of processing to do, or needs to perform processing that is not deterministic. In these cases `xTimerPendFunctionCallFromISR()` can be used to defer processing of a function to the RTOS daemon task.

A mechanism is provided that allows the interrupt to return directly to the task that will subsequently execute the pended callback function. This allows the callback function to execute contiguously in time with the interrupt - just as if the callback had executed in the interrupt itself.

#### Example usage:
```c
* // The callback function that will execute **in** the context of the daemon...
  * // task.
  * // Note callback functions must **all** use this same prototype.
  * void vProcessInterface( void *pvParameter1, uint32_t ulParameter2 )
  * {
  *   BaseType_t xInterfaceToService;
  *   /*
  *     // The interface that requires servicing **is** passed **in** the second
  *     // parameter. The first parameter **is not** used **in** this case.
  *     xInterfaceToService = ( BaseType_t ) ulParameter2;
  *   */
  *   // ...Perform the processing here...
  * }
  *
  * // An ISR that receives data packets **from multiple** interfaces
  * void vAnISR( void )
  * {
  *   BaseType_t xInterfaceToService, xHigherPriorityTaskWoken;
  *   /*
  *     // Query the hardware to determine which interface needs processing.
  *     xInterfaceToService = prvCheckInterfaces();
  *     /*
  *     // The actual processing **is** to be deferred to a task. Request the
  *     // vProcessInterface() callback function **is** executed, passing **in** the
  *     // number of the interface that needs processing. The interface to
```
Parameters

- **xFunctionToPend** – The function to execute from the timer service/daemon task. The function must conform to the PendedFunction_t prototype.
- **pvParameter1** – The value of the callback function’s first parameter. The parameter has a void * type to allow it to be used to pass any type. For example, unsigned longs can be cast to a void *, or the void * can be used to point to a structure.
- **ulParameter2** – The value of the callback function’s second parameter.
- **pxHigherPriorityTaskWoken** – As mentioned above, calling this function will result in a message being sent to the timer daemon task. If the priority of the timer daemon task (which is set using configTIMER_TASK_PRIORITY in FreeRTOSConfig.h) is higher than the priority of the currently running task (the task the interrupt interrupted) then **pxHigherPriorityTaskWoken** will be set to pdTRUE within xTimerPendFunctionCallFromISR(), indicating that a context switch should be requested before the interrupt exits. For that reason **pxHigherPriorityTaskWoken** must be initialised to pdFALSE. See the example code below.

Returns pdPASS is returned if the message was successfully sent to the timer daemon task, otherwise pdFALSE is returned.

```c
BaseType_t xTimerPendFunctionCall( PendedFunction_t xFunctionToPend, void *pvParameter1, uint32_t ulParameter2, TickType_t xTicksToWait )
```

Used to defer the execution of a function to the RTOS daemon task (the timer service task, hence this function is implemented in timers.c and is prefixed with ‘Timer’).

Parameters

- **xFunctionToPend** – The function to execute from the timer service/daemon task. The function must conform to the PendedFunction_t prototype.
- **pvParameter1** – The value of the callback function’s first parameter. The parameter has a void * type to allow it to be used to pass any type. For example, unsigned longs can be cast to a void *, or the void * can be used to point to a structure.
- **ulParameter2** – The value of the callback function’s second parameter.
- **xTicksToWait** – Calling this function will result in a message being sent to the timer daemon task on a queue. xTicksToWait is the amount of time the calling task should remain in the Blocked state (so not using any processing time) for space to become available on the timer queue if the queue is found to be full.

Returns pdPASS is returned if the message was successfully sent to the timer daemon task, otherwise pdFALSE is returned.

```c
const char *pcTimerGetName(TimerHandle_t xTimer)
```

Returns the name that was assigned to a timer when the timer was created.

```c
const char * const pcTimerGetName( TimerHandle_t xTimer ) ;
```
**Parameters**

- **xTimer** – The handle of the timer being queried.

**Returns**

The name assigned to the timer specified by the xTimer parameter.

void **vTimerSetReloadMode** (TimerHandle_t xTimer, const UBaseType_t uxAutoReload)

void vTimerSetReloadMode( TimerHandle_t xTimer, const UBaseType_t uxAutoReload );

Updates a timer to be either an auto-reload timer, in which case the timer automatically resets itself each time it expires, or a one-shot timer, in which case the timer will only expire once unless it is manually restarted.

**Parameters**

- **xTimer** – The handle of the timer being updated.
- **uxAutoReload** – If uxAutoReload is set to pdTRUE then the timer will expire repeatedly with a frequency set by the timer’s period (see the xTimerPeriodInTicks parameter of the xTimerCreate() API function). If uxAutoReload is set to pdFALSE then the timer will be a one-shot timer and enter the dormant state after it expires.

**Returns**

If the timer is an auto-reload timer then pdTRUE is returned, otherwise pdFALSE is returned.

TickType_t **xTimerGetPeriod** (TimerHandle_t xTimer)

TickType_t xTimerGetPeriod( TimerHandle_t xTimer );

Returns the period of a timer.

**Parameters**

- **xTimer** – The handle of the timer being queried.

**Returns**

The period of the timer in ticks.

TickType_t **xTimerGetExpiryTime** (TimerHandle_t xTimer)

TickType_t xTimerGetExpiryTime( TimerHandle_t xTimer );

Returns the time in ticks at which the timer will expire. If this is less than the current tick count then the expiry time has overflowed from the current time.

**Parameters**

- **xTimer** – The handle of the timer being queried.

**Returns**

If the timer is running then the time in ticks at which the timer will next expire is returned. If the timer is not running then the return value is undefined.

BaseType_t **xTimerGetStaticBuffer** (TimerHandle_t xTimer, StaticTimer_t **ppxTimerBuffer)

BaseType_t xTimerGetStaticBuffer( TimerHandle_t xTimer, StaticTimer_t **ppxTimerBuffer );

Retrieve pointer to a statically created timer’s data structure buffer. This is the same buffer that is supplied at the time of creation.

**Parameters**

- **xTimer** – The timer for which to retrieve the buffer.
- **ppxTimerBuffer** – Used to return a pointer to the timer’s data structure buffer.

**Returns**

pdTRUE if the buffer was retrieved, pdFALSE otherwise.

void **vApplicationGetTimerTaskMemory** (StaticTask_t **pxxTimerTaskTCBBuffer, StackType_t **pxxTimerTaskStackBuffer, uint32_t *pulTimerTaskStackSize)

This function is used to provide a statically allocated block of memory to FreeRTOS to hold the Timer Task TCB. This function is required when configSUPPORT_STATIC_ALLOCATION is set. For more information see this URI: [https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION](https://www.FreeRTOS.org/a00110.html#configSUPPORT_STATIC_ALLOCATION)

**Parameters**

- **pxxTimerTaskTCBBuffer** – A handle to a statically allocated TCB buffer
• **ppxTimerTaskStackBuffer** – A handle to a statically allocated Stack buffer for the idle task
• **pulTimerTaskStackSize** – A pointer to the number of elements that will fit in the allocated stack buffer

**Macros**

- `tmrCOMMAND_EXECUTE_CALLBACK_FROM_ISR`
- `tmrCOMMAND_EXECUTE_CALLBACK`
- `tmrCOMMAND_START_DONT_TRACE`
- `tmrCOMMAND_START`
- `tmrCOMMAND_RESET`
- `tmrCOMMAND_STOP`
- `tmrCOMMAND_CHANGE_PERIOD`
- `tmrCOMMAND_DELETE`
- `tmrFIRST_FROM_ISR_COMMAND`
- `tmrCOMMAND_START_FROM_ISR`
- `tmrCOMMAND_RESET_FROM_ISR`
- `tmrCOMMAND_STOP_FROM_ISR`
- `tmrCOMMAND_CHANGE_PERIOD_FROM_ISR`

**xTimerStart** (xTimer, xTicksToWait)

```c
BaseType_t xTimerStart( TimerHandle_t xTimer, TickType_t xTicksToWait );
```

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API functions send commands to the timer service task through a queue called the timer command queue. The length of the timer command queue is set by the configTIMER_QUEUE_LENGTH configuration constant.

`xTimerStart()` starts a timer that was previously created using the `xTimerCreate()` API function. If the timer had already been started and was already in the active state, then `xTimerStart()` has equivalent functionality to the `xTimerReset()` API function.

Starting a timer ensures the timer is in the active state. If the timer is not stopped, deleted, or reset in the mean time, the callback function associated with the timer will get called ‘n’ ticks after `xTimerStart()` was called, where ‘n’ is the timers defined period.

It is valid to call `xTimerStart()` before the scheduler has been started, but when this is done the timer will not actually start until the scheduler is started, and the timers expiry time will be relative to when the scheduler is started, not relative to when `xTimerStart()` was called.

The configUSE_TIMERS configuration constant must be set to 1 for `xTimerStart()` to be available.
Example usage:

See the \texttt{xTimerCreate()} API function example usage scenario.

**Parameters**

- \texttt{xTimer} - The handle of the timer being started/restarted.
- \texttt{xTicksToWait} - Specifies the time, in ticks, that the calling task should be held in the Blocked state to wait for the start command to be successfully sent to the timer command queue, should the queue already be full when \texttt{xTimerStart()} was called. \texttt{xTicksToWait} is ignored if \texttt{xTimerStart()} is called before the scheduler is started.

**Returns**

\texttt{pdFAIL} will be returned if the start command could not be sent to the timer command queue even after \texttt{xTicksToWait} ticks had passed. \texttt{pdPASS} will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system, although the timers expiry time is relative to when \texttt{xTimerStart()} is actually called. The timer service/daemon task priority is set by the \texttt{configTIMER_TASK_PRIORITY} configuration constant.

\textbf{\texttt{xTimerStop} (xTimer, xTicksToWait)}

BaseType\_t \texttt{xTimerStop (TimerHandle\_t xTimer, TickType\_t xTicksToWait );}

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API functions send commands to the timer service task through a queue called the timer command queue. The timer command queue is private to the kernel itself and is not directly accessible to application code. The length of the timer command queue is set by the \texttt{configTIMER\_QUEUE\_LENGTH} configuration constant.

\texttt{xTimerStop()} stops a timer that was previously started using either of the The \texttt{xTimerStart()}, \texttt{xTimerReset()}, \texttt{xTimerStartFromISR()}, \texttt{xTimerResetFromISR()}, \texttt{xTimerChangePeriod()} or \texttt{xTimerChangePeriodFromISR()} API functions.

Stopping a timer ensures the timer is not in the active state.

The \texttt{configUSE\_TIMERS} configuration constant must be set to 1 for \texttt{xTimerStop()} to be available.

Example usage:

See the \texttt{xTimerCreate()} API function example usage scenario.

**Parameters**

- \texttt{xTimer} - The handle of the timer being stopped.
- \texttt{xTicksToWait} - Specifies the time, in ticks, that the calling task should be held in the Blocked state to wait for the stop command to be successfully sent to the timer command queue, should the queue already be full when \texttt{xTimerStop()} was called. \texttt{xTicksToWait} is ignored if \texttt{xTimerStop()} is called before the scheduler is started.

**Returns**

\texttt{pdFAIL} will be returned if the stop command could not be sent to the timer command queue even after \texttt{xTicksToWait} ticks had passed. \texttt{pdPASS} will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system. The timer service/daemon task priority is set by the \texttt{configTIMER_TASK_PRIORITY} configuration constant.

\textbf{\texttt{xTimerChangePeriod} (xTimer, xNewPeriod, xTicksToWait)}

BaseType\_t \texttt{xTimerChangePeriod (TimerHandle\_t xTimer, TickType\_t xNewPeriod, TickType\_t xTicksToWait );}

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API functions send commands to the timer service task through a queue called the timer command queue. The timer command queue is private to the kernel itself and is not directly accessible to application code. The length of the timer command queue is set by the \texttt{configTIMER\_QUEUE\_LENGTH} configuration constant.
xTimerChangePeriod() changes the period of a timer that was previously created using the xTimerCreate() API function.

xTimerChangePeriod() can be called to change the period of an active or dormant state timer.

The configUSE_TIMERS configuration constant must be set to 1 for xTimerChangePeriod() to be available.

Example usage:

```c
void vAFunction( TimerHandle_t xTimer ) {
  // This function assumes xTimer has already been created. If the timer
  // referenced by xTimer is already active when it is called, then the timer
  // is deleted. If the timer referenced by xTimer is not active when it is
  // called, then the period of the timer is set to 500ms and the timer is
  // started.
  if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply and equivalently "if( xTimerIsTimerActive( xTimer ) )"
  {
    // xTimer is already active - delete it.
    xTimerDelete( xTimer );
  }
  else
  {
    // xTimer is not active, change its period to 500ms. This will also
    // cause the timer to start. Block for a maximum of 100 ticks if the
    // change period command cannot immediately be sent to the timer
    // command queue.
    if( xTimerChangePeriod( xTimer, 500 / portTICK_PERIOD_MS, 100 ) == pdPASS )
    {
      // The command was successfully sent.
    }
    else
    {
      // The command could not be sent, even after waiting for 100 ticks
      // to pass. Take appropriate action here.
    }
  }
}
```

Parameters

- **xTimer** - The handle of the timer that is having its period changed.
- **xNewPeriod** - The new period for xTimer. Timer periods are specified in tick periods, so the constant portTICK_PERIOD_MS can be used to convert a time that has been specified in milliseconds. For example, if the timer must expire after 100 ticks, then xNewPeriod should be set to 100. Alternatively, if the timer must expire after 500ms, then xNewPeriod can be set to (500 / portTICK_PERIOD_MS) provided configTICK_RATE_HZ is less than or equal to 1000.
- **xTicksToWait** - Specifies the time, in ticks, that the calling task should be held in the Blocked state to wait for the change period command to be successfully sent to the timer command queue, should the queue already be full when xTimerChangePeriod() was called. xTicksToWait is ignored if xTimerChangePeriod() is called before the scheduler is started.

Returns pdFAIL will be returned if the change period command could not be sent to the timer command queue even after xTicksToWait ticks had passed. pdPASS will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative
to other tasks in the system. The timer service/daemon task priority is set by the config-
TIMER_TASK_PRIORITY configuration constant.

\textbf{xTimerDelete} (xTimer, xTicksToWait)
BaseType\_t xTimerDelete( TimerHandle\_t xTimer, TickType\_t xTicksToWait );

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API
functions send commands to the timer service task through a queue called the timer command queue. The
timer command queue is private to the kernel itself and is not directly accessible to application code. The
length of the timer command queue is set by the configTIMER\_QUEUE\_LENGTH configuration constant.

xTimerDelete() deletes a timer that was previously created using the xTimerCreate() API function.
The configUSE\_TIMERS configuration constant must be set to 1 for xTimerDelete() to be available.

Example usage:
See the xTimerChangePeriod() API function example usage scenario.

**Parameters**
- \textbf{xTimer} - The handle of the timer being deleted.
- \textbf{xTicksToWait} - Specifies the time, in ticks, that the calling task should be held in the
  Blocked state to wait for the delete command to be successfully sent to the timer command queue,
  should the queue already be full when xTimerDelete() was called. xTicksToWait
  is ignored if xTimerDelete() is called before the scheduler is started.

**Returns**
pdFAIL will be returned if the delete command could not be sent to the timer command
queue even after xTicksToWait ticks had passed. pdPASS will be returned if the command
was successfully sent to the timer command queue. When the command is actually processed
will depend on the priority of the timer service/daemon task relative to other tasks in the sys-
tem. The timer service/daemon task priority is set by the configTIMER\_TASK\_PRIORITY
configuration constant.

\textbf{xTimerReset} (xTimer, xTicksToWait)
BaseType\_t xTimerReset( TimerHandle\_t xTimer, TickType\_t xTicksToWait );

Timer functionality is provided by a timer service/daemon task. Many of the public FreeRTOS timer API
functions send commands to the timer service task through a queue called the timer command queue. The
timer command queue is private to the kernel itself and is not directly accessible to application code. The
length of the timer command queue is set by the configTIMER\_QUEUE\_LENGTH configuration constant.

xTimerReset() re-starts a timer that was previously created using the xTimerCreate() API function. If the
timer had already been started and was already in the active state, then xTimerReset() will cause the timer
to re-evaluate its expiry time so that it is relative to when xTimerReset() was called. If the timer was in the
dormant state then xTimerReset() has equivalent functionality to the xTimerStart() API function.

Resetting a timer ensures the timer is in the active state. If the timer is not stopped, deleted, or reset in the
mean time, the callback function associated with the timer will get called ‘n’ ticks after xTimerReset() was
called, where ‘n’ is the timers defined period.

It is valid to call xTimerReset() before the scheduler has been started, but when this is done the timer will not
actually start until the scheduler is started, and the timers expiry time will be relative to when the scheduler is
started, not relative to when xTimerReset() was called.

The configUSE\_TIMERS configuration constant must be set to 1 for xTimerReset() to be available.

Example usage:

```c
* // When a key \textbf{is} pressed, an LCD back-light \textbf{is} switched on. If 5 seconds...
  → \textbf{pass}
* // without a key being pressed, then the LCD back-light \textbf{is} switched off. In
* // this case, the timer \textbf{is} a one-shot timer.
```

(continues on next page)
TimerHandle_t xBacklightTimer = NULL;

// The callback function assigned to the one-shot timer. In this case the
// parameter is not used.
void vBacklightTimerCallback( TimerHandle_t pxTimer )
{
    // The timer expired, therefore 5 seconds must have passed since a key
    // was pressed. Switch off the LCD back-light.
    vSetBacklightState( BACKLIGHT_OFF );
}

// The key press event handler.
void vKeyPressEventHandler( char cKey )
{
    // Ensure the LCD back-light is on, then reset the timer that is
    // responsible for turning the back-light off after 5 seconds of
    // key inactivity. Wait 10 ticks for the command to be successfully sent
    // if it cannot be sent immediately.
    vSetBacklightState( BACKLIGHT_ON );
    if( xTimerReset( xBacklightTimer, 100 ) != pdPASS )
        // The reset command was not executed successfully. Take appropriate
        // action here.
    
    // Perform the rest of the key processing here.
}

void main( void )
{
    int32_t x;

    // Create then start the one-shot timer that is responsible for turning
    // the back-light off if no keys are pressed within a 5 second period.
    xBacklightTimer = xTimerCreate( "BacklightTimer",  // Just a_
        ( 5000 / portTICK_PERIOD_MS), // The_
        pdFALSE, // The timer_
        0, // The id is_
        vBacklightTimerCallback // The_
        //callback function that switches the LCD back-light off.
    );

    if( xBacklightTimer == NULL )
    {
        // The timer was not created.
    } else
    {
        // Start the timer. No block time is specified, and even if one was
        // it would be ignored because the scheduler has not yet been
        // started.
        if( xTimerStart( xBacklightTimer, 0 ) != pdPASS )
        {
            // The timer could not be set into the Active state.
        }
    }
}
Create tasks here.

Starting the scheduler will start the timer running as it has already been set into the active state.

vTaskStartScheduler();

Should not reach here.

for(;;);

Parameters

- **xTimer** - The handle of the timer being reset/started/restarted.
- **xTicksToWait** - Specifies the time, in ticks, that the calling task should be held in the Blocked state to wait for the reset command to be successfully sent to the timer command queue, should the queue already be full when `xTimerReset()` was called. `xTicksToWait` is ignored if `xTimerReset()` is called before the scheduler is started.

Returns `pdFAIL` will be returned if the reset command could not be sent to the timer command queue even after `xTicksToWait` ticks had passed. `pdPASS` will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system, although the timers expiry time is relative to when `xTimerStart()` is actually called. The timer service/daemon task priority is set by the `CONFIG_TIMER_TASK_PRIORITY` configuration constant.

**xTimerStartFromISR**(xTimer, pxHigherPriorityTaskWoken)

BaseType_t xTimerStartFromISR( TimerHandle_t xTimer, BaseType_t *pxHigherPriorityTaskWoken );

A version of `xTimerStart()` that can be called from an interrupt service routine.

Example usage:

```c
void vBacklightTimerCallback( TimerHandle_t pxTimer )
{
    // The timer expired, therefore 5 seconds must have passed since a key was pressed. Switch off the LCD backlight.
    vSetBacklightState( BACKLIGHT_OFF );
}

void vKeyPressEventInterruptHandler( void )
{
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;
    
    // Ensure the LCD backlight is on, then restart the timer that is responsible for turning the backlight off after 5 seconds of
```

(continues on next page)
/* key inactivity. This is an interrupt service routine so can only */
/* call FreeRTOS API functions that end in "FromISR". */
vSetBacklightState( BACKLIGHT_ON );

/* xTimerStartFromISR() or xTimerResetFromISR() could be called here */
/* as both cause the timer to re-calculate its expiry time. */
/* xHigherPriorityTaskWoken was initialised to pdFALSE when it was */
/* declared (in this function). */
if( xTimerStartFromISR( xBacklightTimer, &xHigherPriorityTaskWoken ) != pdPASS )
{
    // The start command was not executed successfully. Take appropriate
    // action here.
}

/* Perform the rest of the key processing here. */

/* If xHigherPriorityTaskWoken equals pdTRUE, then a context switch */
/* should be performed. The syntax required to perform a context switch */
/* from inside an ISR varies from port to port, and from compiler to */
/* compiler. Inspect the demos for the port you are using to find the */
/* actual syntax required. */
if( xHigherPriorityTaskWoken != pdFALSE )
{
    // Call the interrupt safe yield function here (actual function
    // depends on the FreeRTOS port being used).
}

Parameters

- **xTimer** - The handle of the timer being started/restarted.
- **pxHigherPriorityTaskWoken** - The timer service/daemon task spends most of its
  time in the Blocked state, waiting for messages to arrive on the timer command queue.
  Calling xTimerStartFromISR() writes a message to the timer command queue, so has the
  potential to transition the timer service/daemon task out of the Blocked state.
  If calling xTimerStartFromISR() causes the timer service/daemon task to leave the Blocked state,
  and the timer service/ daemon task has a priority equal to or greater than the currently
  executing task (the task that was interrupted), then *pxHigherPriorityTaskWoken will get
  set to pdTRUE internally within the xTimerStartFromISR() function. If xTimerStart-
  FromISR() sets this value to pdTRUE then a context switch should be performed before
  the interrupt exits.

Returns pdFAIL will be returned if the start command could not be sent to the timer command
queue. pdPASS will be returned if the command was successfully sent to the timer command
queue. When the command is actually processed will depend on the priority of the timer
service/daemon task relative to other tasks in the system, although the timers expiry time is relative
to when xTimerStartFromISR() is actually called. The timer service/daemon task priority is
set by the configTIMER_TASK_PRIORITY configuration constant.

xTimerStopFromISR(xTimer, pxHigherPriorityTaskWoken)

BaseType_t xTimerStopFromISR( TimerHandle_t xTimer, BaseType_t *pxHigherPriorityTaskWoken );

A version of xTimerStop() that can be called from an interrupt service routine.

Example usage:

/* This scenario assumes xTimer has already been created and started. When */
/* an interrupt occurs, the timer should be simply stopped. */

(continues on next page)
The interrupt service routine that stops the timer.

```c
void vAnExampleInterruptServiceRoutine( void ) {
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;

    // The interrupt has occurred - simply stop the timer.
    // xHigherPriorityTaskWoken was set to pdFALSE where it was defined
    // (within this function). As this is an interrupt service routine, only
    // FreeRTOS API functions that end in "FromISR" can be used.
    if( xTimerStopFromISR( xTimer, &xHigherPriorityTaskWoken ) != pdPASS ) {
        // The stop command was not executed successfully. Take appropriate
        // action here.
    }

    // If xHigherPriorityTaskWoken equals pdTRUE, then a context switch
    // should be performed. The syntax required to perform a context switch
    // from inside an ISR varies from port to port, and from compiler to
    // compiler. Inspect the demos for the port you are using to find the
    // actual syntax required.
    if( xHigherPriorityTaskWoken != pdFALSE ) {
        // Call the interrupt safe yield function here (actual function
        // depends on the FreeRTOS port being used).
    }
}
```

### Parameters
- `xTimer` - The handle of the timer being stopped.
- `pxHigherPriorityTaskWoken` - The timer service/daemon task spends most of its time in the Blocked state, waiting for messages to arrive on the timer command queue. Calling `xTimerStopFromISR()` writes a message to the timer command queue, so has the potential to transition the timer service/daemon task out of the Blocked state. If calling `xTimerStopFromISR()` causes the timer service/daemon task to leave the Blocked state, and the timer service/daemon task has a priority equal to or greater than the currently executing task (the task that was interrupted), then `*pxHigherPriorityTaskWoken` will get set to `pdTRUE` internally within the `xTimerStopFromISR()` function. If `xTimerStopFromISR()` sets this value to `pdTRUE` then a context switch should be performed before the interrupt exits.

### Returns
- `pdFAIL` will be returned if the stop command could not be sent to the timer command queue. `pdPASS` will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system. The timer service/daemon task priority is set by the `configTIMER_TASK_PRIORITY` configuration constant.

```c
xTimerChangePeriodFromISR( xTimer, xNewPeriod, pxHigherPriorityTaskWoken )
```

A version of `xTimerChangePeriod()` that can be called from an interrupt service routine.

### Example usage:
```c
/* // This scenario assumes xTimer has already been created and started. When
 /* // an interrupt occurs, the period of xTimer should be changed to 500ms.
 */
```
The interrupt service routine that changes the period of `xTimer`.

```c
void vAnExampleInterruptServiceRoutine( void )
{
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;

    // The interrupt has occurred - change the period of xTimer to 500ms.
    // xHigherPriorityTaskWoken was set to pdFALSE where it was defined
    // (within this function). As this is an interrupt service routine, only
    // FreeRTOS API functions that end in "FromISR" can be used.
    if( xTimerChangePeriodFromISR( xTimer, &xHigherPriorityTaskWoken ) != pdPASS )
    {
        // The command to change the timers period was not executed
        // successfully. Take appropriate action here.
    }

    // If xHigherPriorityTaskWoken equals pdTRUE, then a context switch
    // should be performed. The syntax required to perform a context switch
    // from inside an ISR varies from port to port, and from compiler to
    // compiler. Inspect the demos for the port you are using to find the
    // actual syntax required.
    if( xHigherPriorityTaskWoken != pdFALSE )
    {
        // Call the interrupt safe yield function here (actual function
        // depends on the FreeRTOS port being used).
    }
}
```

### Parameters
- `xTimer` - The handle of the timer that is having its period changed.
- `xNewPeriod` - The new period for `xTimer`. Timer periods are specified in tick periods, so the constant `portTICK_PERIOD_MS` can be used to convert a time that has been specified in milliseconds. For example, if the timer must expire after 100 ticks, then `xNewPeriod` should be set to 100. Alternatively, if the timer must expire after 500ms, then `xNewPeriod` can be set to `(500 / portTICK_PERIOD_MS)` provided `configTICK_RATE_HZ` is less than or equal to 1000.
- `pxHigherPriorityTaskWoken` - The timer service/daemon task spends most of its time in the Blocked state, waiting for messages to arrive on the timer command queue. Calling `xTimerChangePeriodFromISR()` writes a message to the timer command queue, so has the potential to transition the timer service/daemon task out of the Blocked state. If calling `xTimerChangePeriodFromISR()` causes the timer service/daemon task to leave the Blocked state, and the timer service/daemon task has a priority equal to or greater than the currently executing task (the task that was interrupted), then `pxHigherPriorityTaskWoken` will get set to `pdTRUE` internally within the `xTimerChangePeriodFromISR()` function. If `xTimerChangePeriodFromISR()` sets this value to `pdTRUE` then a context switch should be performed before the interrupt exits.

### Returns
- `pdFAIL` will be returned if the command to change the timers period could not be sent to the timer command queue. `pdPASS` will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system. The timer service/daemon task priority is set by the `configTIMER_TASK_PRIORITY` configuration constant.

```c
xTimerResetFromISR( xTimer, pxHigherPriorityTaskWoken )
```

A version of `xTimerReset()` that can be called from an interrupt service routine.

---

**Parameters**
- `xTimer` - The handle of the timer that is having its period changed.
- `xNewPeriod` - The new period for `xTimer`. Timer periods are specified in tick periods, so the constant `portTICK_PERIOD_MS` can be used to convert a time that has been specified in milliseconds. For example, if the timer must expire after 100 ticks, then `xNewPeriod` should be set to 100. Alternatively, if the timer must expire after 500ms, then `xNewPeriod` can be set to `(500 / portTICK_PERIOD_MS)` provided `configTICK_RATE_HZ` is less than or equal to 1000.
- `pxHigherPriorityTaskWoken` - The timer service/daemon task spends most of its time in the Blocked state, waiting for messages to arrive on the timer command queue. Calling `xTimerChangePeriodFromISR()` writes a message to the timer command queue, so has the potential to transition the timer service/daemon task out of the Blocked state. If calling `xTimerChangePeriodFromISR()` causes the timer service/daemon task to leave the Blocked state, and the timer service/daemon task has a priority equal to or greater than the currently executing task (the task that was interrupted), then `pxHigherPriorityTaskWoken` will get set to `pdTRUE` internally within the `xTimerChangePeriodFromISR()` function. If `xTimerChangePeriodFromISR()` sets this value to `pdTRUE` then a context switch should be performed before the interrupt exits.

**Returns** `pdFAIL` will be returned if the command to change the timers period could not be sent to the timer command queue. `pdPASS` will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system. The timer service/daemon task priority is set by the `configTIMER_TASK_PRIORITY` configuration constant.

```c
xTimerResetFromISR( xTimer, pxHigherPriorityTaskWoken )
```

A version of `xTimerReset()` that can be called from an interrupt service routine.
Example usage:

```c
/* // This scenario assumes xBacklightTimer has already been created. When a
  // key is pressed, an LCD back-light is switched on. If 5 seconds pass
  // without a key being pressed, then the LCD back-light is switched off. In
  // this case, the timer is a one-shot timer, and unlike the example given for
  // the xTimerReset() function, the key press event handler is an interrupt
  // service routine.

  // The callback function assigned to the one-shot timer. In this case the
  // parameter is not used.
  void vBacklightTimerCallback( TimerHandle_t pxTimer )
  {
    // The timer expired, therefore 5 seconds must have passed since a key
    // was pressed. Switch off the LCD back-light.
    vSetBacklightState( BACKLIGHT_OFF );
  }

  // The key press interrupt service routine.
  void vKeyPressEventInterruptHandler( void )
  {
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;

    // Ensure the LCD back-light is on, then reset the timer that is
    // responsible for turning the back-light off after 5 seconds of
    // key inactivity. This is an interrupt service routine so can only
    // call FreeRTOS API functions that end in "FromISR".
    vSetBacklightState( BACKLIGHT_ON );

    // xTimerStartFromISR() or xTimerResetFromISR() could be called here
    // as both cause the timer to re-calculate its expiry time.
    // xHigherPriorityTaskWoken was initialised to pdFALSE when it was
    // declared (in this function).
    if( xTimerResetFromISR( xBacklightTimer, &xHigherPriorityTaskWoken ) != pdPASS )
    {
      // The reset command was not executed successfully. Take appropriate
      // action here.
    }

    // Perform the rest of the key processing here.

    // If xHigherPriorityTaskWoken equals pdTRUE, then a context switch
    // should be performed. The syntax required to perform a context switch
    // from inside an ISR varies from port to port, and from compiler to
    // compiler. Inspect the demos for the port you are using to find the
    // actual syntax required.
    if( xHigherPriorityTaskWoken != pdFALSE )
    {
      // Call the interrupt safe yield function here (actual function
      // depends on the FreeRTOS port being used).
    }
  }
```

**Parameters**

- **xTimer** - The handle of the timer that is to be started, reset, or restarted.
- **pxHigherPriorityTaskWoken** - The timer service/daemon task spends most of its time in the Blocked state, waiting for messages to arrive on the timer command queue. Calling xTimerResetFromISR() writes a message to the timer command queue, so has the potential to transition the timer service/daemon task out of the Blocked state. If calling
xTimerResetFromISR() causes the timer service/daemon task to leave the Blocked state, and the timer service/daemon task has a priority equal to or greater than the currently executing task (the task that was interrupted), then *pxHigherPriorityTaskWoken will get set to pdTRUE internally within the xTimerResetFromISR() function. If xTimerResetFromISR() sets this value to pdTRUE then a context switch should be performed before the interrupt exits.

**Returns** pdFAIL will be returned if the reset command could not be sent to the timer command queue. pdPASS will be returned if the command was successfully sent to the timer command queue. When the command is actually processed will depend on the priority of the timer service/daemon task relative to other tasks in the system, although the timers expiry time is relative to when xTimerResetFromISR() is actually called. The timer service/daemon task priority is set by the configTIMER_TASK_PRIORITY configuration constant.

**Type Definitions**

typedef struct tmrTimerControl *TimerHandle_t

typedef void (*TimerCallbackFunction_t)(TimerHandle_t xTimer)

typedef void (*PendedFunction_t)(void*, uint32_t)

**Event Group API**

**Header File**

- components/freertos/FreeRTOS-Kernel/include/freertos/event_groups.h

**Functions**

EventGroupHandle_t **xEventGroupCreate**(void)

Create a new event group.

Internally, within the FreeRTOS implementation, event groups use a [small] block of memory, in which the event group’s structure is stored. If an event groups is created using xEventGroupCreate() then the required memory is automatically dynamically allocated inside the xEventGroupCreate() function. (see [https://www.FreeRTOS.org/a00111.html](https://www.FreeRTOS.org/a00111.html)). If an event group is created using xEventGroupCreateStatic() then the application writer must instead provide the memory that will get used by the event group. xEventGroupCreateStatic() therefore allows an event group to be created without using any dynamic memory allocation.

Although event groups are not related to ticks, for internal implementation reasons the number of bits available for use in an event group is dependent on the configUSE_16_BIT_TICKS setting in FreeRTOSConfig.h. If configUSE_16_BIT_TICKS is 1 then each event group contains 8 usable bits (bit 0 to bit 7). If configUSE_16_BIT_TICKS is set to 0 then each event group has 24 usable bits (bit 0 to bit 23). The EventBits_t type is used to store event bits within an event group.

**Example usage:**

```c
// Declare a variable to hold the created event group.
EventGroupHandle_t xCreatedEventGroup;

// Attempt to create the event group.
xCreatedEventGroup = xEventGroupCreate();

// Was the event group created successfully?
if( xCreatedEventGroup == NULL ) {
```

(continues on next page)
// The event group was not created because there was insufficient FreeRTOS heap available.

}  

else
{
    // The event group was created.
}

Returns If the event group was created then a handle to the event group is returned. If there was insufficient FreeRTOS heap available to create the event group then NULL is returned. See https://www.FreeRTOS.org/a00111.html

EventGroupHandle_t xEventGroupCreateStatic(StaticEventGroup_t *pxEventGroupBuffer)

Create a new event group.

Internally, within the FreeRTOS implementation, event groups use a [small] block of memory, in which the event group’s structure is stored. If an event groups is created using xEventGroupCreate() then the required memory is automatically dynamically allocated inside the xEventGroupCreate() function. (see https://www.FreeRTOS.org/a00111.html). If an event group is created using xEventGroupCreateStatic() then the application writer must instead provide the memory that will be used by the event group. xEventGroupCreateStatic() therefore allows an event group to be created without using any dynamic memory allocation.

Although event groups are not related to ticks, for internal implementation reasons the number of bits available for use in an event group is dependent on the configUSE_16_BIT_TICKS setting in FreeRTOSConfig.h. If configUSE_16_BIT_TICKS is 1 then each event group contains 8 usable bits (bit 0 to bit 7). If configUSE_16_BIT_TICKS is set to 0 then each event group has 24 usable bits (bit 0 to bit 23). The EventBits_t type is used to store event bits within an event group.

Example usage:

// StaticEventGroup_t is a publicly accessible structure that has the same size and alignment requirements as the real event group structure. It is provided as a mechanism for applications to know the size of the event group (which is dependent on the architecture and configuration file settings) without breaking the strict data hiding policy by exposing the // real event group internals. This StaticEventGroup_t variable is passed // into the xSemaphoreCreateEventGroupStatic() function and is used to store // the event group's data structures StaticEventGroup_t xEventGroupBuffer;

// Create the event group without dynamically allocating any memory.
xEventGroup = xEventGroupCreateStatic( &xEventGroupBuffer );

Parameters pxEventGroupBuffer – pxEventGroupBuffer must point to a variable of type StaticEventGroup_t, which will be then be used to hold the event group’s data structures, removing the need for the memory to be allocated dynamically.

Returns If the event group was created then a handle to the event group is returned. If pxEventGroupBuffer was NULL then NULL is returned.

EventBits_t xEventGroupWaitBits( EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToWaitFor, const BaseType_t xClearOnExit, const BaseType_t xWaitForAllBits, TickType_t xTicksToWait)

[Potentially] block to wait for one or more bits to be set within a previously created event group.

This function cannot be called from an interrupt.

Example usage:
#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

void aFunction( EventGroupHandle_t xEventGroup )
{
    EventBits_t uxBits;
    const TickType_t xTicksToWait = 100 / portTICK_PERIOD_MS;
    // Wait a maximum of 100ms for either bit 0 or bit 4 to be set within
    // the event group. Clear the bits before exiting.
    uxBits = xEventGroupWaitBits( xEventGroup,  // The event group being tested.
        BIT_0 | BIT_4,  // The bits within the event group to wait...
        ~for. pdTRUE,  // BIT_0 and BIT_4 should be cleared before...
        ~returning. pdFALSE,  // Don't wait for both bits, either bit will...
        ~do. xTicksToWait );  // Wait a maximum of 100ms for either bit to...
    ~be set.

    if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
    {
        // xEventGroupWaitBits() returned because both bits were set.
    }
    else if( ( uxBits & BIT_0 ) != 0 )
    {
        // xEventGroupWaitBits() returned because just BIT_0 was set.
    }
    else if( ( uxBits & BIT_4 ) != 0 )
    {
        // xEventGroupWaitBits() returned because just BIT_4 was set.
    }
    else
    {
        // xEventGroupWaitBits() returned because xTicksToWait ticks passed
        // without either BIT_0 or BIT_4 becoming set.
    }
}

Parameters

- **xEventGroup** - The event group in which the bits are being tested. The event group must have previously been created using a call to xEventGroupCreate().
- **uxBitsToWaitFor** - A bitwise value that indicates the bit or bits to test inside the event group. For example, to wait for bit 0 and/or bit 2 set uxBitsToWaitFor to 0x05. To wait for bits 0 and/or bit 1 and/or bit 2 set uxBitsToWaitFor to 0x07. Etc.
- **xClearOnExit** - If xClearOnExit is set to pdTRUE then any bits within uxBitsToWaitFor that are set within the event group will be cleared before xEventGroupWaitBits() returns if the wait condition was met (if the function returns for a reason other than a timeout). If xClearOnExit is set to pdFALSE then the bits set in the event group are not altered when the call to xEventGroupWaitBits() returns.
- **xWaitForAllBits** - If xWaitForAllBits is set to pdTRUE then xEventGroupWaitBits() will return when either all the bits in uxBitsToWaitFor are set or the specified block time expires. If xWaitForAllBits is set to pdFALSE then xEventGroupWaitBits() will return when any one of the bits set in uxBitsToWaitFor is set or the specified block time expires. The block time is specified by the xTicksToWait parameter.
- **xTicksToWait** - The maximum amount of time (specified in ‘ticks’) to wait for one/all (depending on the xWaitForAllBits value) of the bits specified by uxBitsToWaitFor to become set.

Returns

The value of the event group at the time either the bits being waited for became set, or
the block time expired. Test the return value to know which bits were set. If xEventGroupWaitBits() returned because its timeout expired, then not all the bits being waited for will be set. If xEventGroupWaitBits() returned because the bits it was waiting for were set, then the returned value is the event group value before any bits were automatically cleared in the case that xClearOnExit parameter was set to pdTRUE.

The EventBits_t xEventGroupClearBits(EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToClear)

Clear bits within an event group. This function cannot be called from an interrupt.

Example usage:

```c
#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

void aFunction( EventGroupHandle_t xEventGroup )
{
    EventBits_t uxBits;

    // Clear bit 0 and bit 4 in xEventGroup.
    uxBits = xEventGroupClearBits(
        xEventGroup,       // The event group being updated.
        BIT_0 | BIT_4 );   // The bits being cleared.

    if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
    {
        // Both bit 0 and bit 4 were set before xEventGroupClearBits() was called. Both will now be clear (not set).
    }
    else if( ( uxBits & BIT_0 ) != 0 )
    {
        // Bit 0 was set before xEventGroupClearBits() was called. It will now be clear.
    }
    else if( ( uxBits & BIT_4 ) != 0 )
    {
        // Bit 4 was set before xEventGroupClearBits() was called. It will now be clear.
    }
    else
    {
        // Neither bit 0 nor bit 4 were set in the first place.
    }
}
```

**Parameters**

- **xEventGroup** – The event group in which the bits are to be cleared.
- **xBitsToClear** – A bitwise value that indicates the bit or bits to clear in the event group. For example, to clear bit 3 only, set xBitsToClear to 0x08. To clear bit 3 and bit 0 set xBitsToClear to 0x09.

**Returns** The value of the event group before the specified bits were cleared.

The EventBits_t xEventGroupSetBits(EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToSet)

Set bits within an event group. This function cannot be called from an interrupt. xEventGroupSetBits-FromISR() is a version that can be called from an interrupt.

Setting bits in an event group will automatically unblock tasks that are blocked waiting for the bits.

Example usage:
Chapter 2. API Reference

```c
#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

void aFunction( EventGroupHandle_t xEventGroup )
{
    EventBits_t uxBits;

    // Set bit 0 and bit 4 in xEventGroup.
    uxBits = xEventGroupSetBits( xEventGroup, BIT_0 | BIT_4 );  // The bits being set.

    if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
    {
        // Both bit 0 and bit 4 remained set when the function returned.
    }
    else if( ( uxBits & BIT_0 ) != 0 )
    {
        // Bit 0 remained set when the function returned, but bit 4 was cleared. It might be that bit 4 was cleared automatically as a task that was waiting for bit 4 was removed from the Blocked state.
    }
    else if( ( uxBits & BIT_4 ) != 0 )
    {
        // Bit 4 remained set when the function returned, but bit 0 was cleared. It might be that bit 0 was cleared automatically as a task that was waiting for bit 0 was removed from the Blocked state.
    }
    else
    {
        // Neither bit 0 nor bit 4 remained set. It might be that a task was waiting for both of the bits to be set, and the bits were cleared as the task left the Blocked state.
    }
}
```

Parameters
- **xEventGroup** – The event group in which the bits are to be set.
- **uxBitsToSet** – A bitwise value that indicates the bit or bits to set. For example, to set bit 3 only, set uxBitsToSet to 0x08. To set bit 3 and bit 0 set uxBitsToSet to 0x09.

Returns The value of the event group at the time the call to xEventGroupSetBits() returns. There are two reasons why the returned value might have the bits specified by the uxBitsToSet parameter cleared. First, if setting a bit results in a task that was waiting for the bit leaving the blocked state then it is possible the bit will be cleared automatically (see the xClearBitOnExit parameter of xEventGroupWaitBits()). Second, any unblocked (or otherwise Ready state) task that has a priority above that of the task that called xEventGroupSetBits() will execute and may change the event group value before the call to xEventGroupSetBits() returns.

```c
EventBits_t xEventGroupSync( EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToSet, const EventBits_t uxBitsToWaitFor, TickType_t xTicksToWait )
```

Atomically set bits within an event group, then wait for a combination of bits to be set within the same event group. This functionality is typically used to synchronise multiple tasks, where each task has to wait for the other tasks to reach a synchronisation point before proceeding.

This function cannot be used from an interrupt.

The function will return before its block time expires if the bits specified by the uxBitsToWait parameter are set, or become set within that time. In this case all the bits specified by uxBitsToWait will be automatically cleared before the function returns.
Example usage:

```c
// Bits used by the three tasks.
#define TASK_0_BIT  ( 1 << 0 )
#define TASK_1_BIT  ( 1 << 1 )
#define TASK_2_BIT  ( 1 << 2 )

#define ALL_SYNC_BITS ( TASK_0_BIT | TASK_1_BIT | TASK_2_BIT )

// Use an event group to synchronise three tasks. It is assumed this event
// group has already been created elsewhere.
EventGroupHandle_t xEventBits;

void vTask0( void *pvParameters )
{
    EventBits_t uxReturn;
    TickType_t xTicksToWait = 100 / portTICK_PERIOD_MS;

    for( ;; )
    {
        // Perform task functionality here.

        // Set bit 0 in the event flag to note this task has reached the
        // sync point. The other two tasks will set the other two bits defined
        // by ALL_SYNC_BITS. All three tasks have reached the synchronisation
        // point when all the ALL_SYNC_BITS are set. Wait a maximum of 100ms
        // for this to happen.
        uxReturn = xEventGroupSync( xEventBits, TASK_0_BIT, ALL_SYNC_BITS,
                                    xTicksToWait );

        if( ( uxReturn & ALL_SYNC_BITS ) == ALL_SYNC_BITS )
        {
            // All three tasks reached the synchronisation point before the call
            // to xEventGroupSync() timed out.
        }
    }
}

void vTask1( void *pvParameters )
{
    for( ;; )
    {
        // Perform task functionality here.

        // Set bit 1 in the event flag to note this task has reached the
        // synchronisation point. The other two tasks will set the other two
        // bits defined by ALL_SYNC_BITS. All three tasks have reached the
        // synchronisation point when all the ALL_SYNC_BITS are set. Wait
        // indefinitely for this to happen.
        xEventGroupSync( xEventBits, TASK_1_BIT, ALL_SYNC_BITS, portMAX_DELAY );

        // xEventGroupSync() was called with an indefinite block time, so
        // this task will only reach here if the synchronisation was made by all
        // three tasks, so there is no need to test the return value.
    }
}

void vTask2( void *pvParameters )
{
    for( ;; )
    {
    }
}(continues on next page)```
// Perform task functionality here.

// Set bit 2 in the event flag to note this task has reached the // synchronisation point. The other two tasks will set the other two // bits defined by ALL_SYNC_BITS. All three tasks have reached the // synchronisation point when all the ALL_SYNC_BITS are set. Wait // indefinitely for this to happen.
xEventGroupSync( xEventBits, TASK_2_BIT, ALL_SYNC_BITS, portMAX_DELAY );

// xEventGroupSync() was called with an indefinite block time, so // this task will only reach here if the synchronisation was made by all // three tasks, so there is no need to test the return value.
}
}

Parameters

- **xEventGroup** – The event group in which the bits are being tested. The event group must have previously been created using a call to xEventGroupCreate().
- **uxBitsToSet** – The bits to set in the event group before determining if, and possibly waiting for, all the bits specified by the uxBitsToWait parameter are set.
- **uxBitsToWaitFor** – A bitwise value that indicates the bit or bits to test inside the event group. For example, to wait for bit 0 and bit 2 set uxBitsToWaitFor to 0x05. To wait for bits 0 and bit 1 and bit 2 set uxBitsToWaitFor to 0x07. Etc.
- **xTicksToWait** – The maximum amount of time (specified in ‘ticks’) to wait for all of the bits specified by uxBitsToWaitFor to become set.

Returns

The value of the event group at the time either the bits being waited for became set, or the block time expired. Test the return value to know which bits were set. If xEventGroupSync() returned because its timeout expired then not all the bits being waited for will be set. If xEventGroupSync() returned because all the bits it was waiting for were set then the returned value is the event group value before any bits were automatically cleared.

EventBits_t xEventGroupGetBitsFromISR(EventGroupHandle_t xEventGroup)

A version of xEventGroupGetBits() that can be called from an ISR.

Parameters

- **xEventGroup** – The event group being queried.

Returns

The event group bits at the time xEventGroupGetBitsFromISR() was called.

void vEventGroupDelete(EventGroupHandle_t xEventGroup)

Delete an event group that was previously created by a call to xEventGroupCreate(). Tasks that are blocked on the event group will be unblocked and obtain 0 as the event group’s value.

Parameters

- **xEventGroup** – The event group being deleted.

BaseType_t xEventGroupGetStaticBuffer(EventGroupHandle_t xEventGroup, StaticEventGroup_t **ppxEventGroupBuffer)

Retrieve a pointer to a statically created event groups’ s data structure buffer. It is the same buffer that is supplied at the time of creation.

Parameters

- **xEventGroup** – The event group for which to retrieve the buffer.
- **ppxEventGroupBuffer** – Used to return a pointer to the event groups’s data structure buffer.

Returns

pdTRUE if the buffer was retrieved, pdFALSE otherwise.

Macros

xEventGroupClearBitsFromISR(xEventGroup, uxBitsToClear)

A version of xEventGroupClearBits() that can be called from an interrupt.
Setting bits in an event group is not a deterministic operation because there are an unknown number of tasks that may be waiting for the bit or bits being set. FreeRTOS does not allow nondeterministic operations to be performed while interrupts are disabled, so protects event groups that are accessed from tasks by suspending the scheduler rather than disabling interrupts. As a result event groups cannot be accessed directly from an interrupt service routine. Therefore `xEventGroupClearBitsFromISR()` sends a message to the timer task to have the clear operation performed in the context of the timer task.

Example usage:

```c
#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

// An event group which it is assumed has already been created by a call to
// xEventGroupCreate().
EventGroupHandle_t xEventGroup;

void anInterruptHandler( void )
{
    // Clear bit 0 and bit 4 in xEventGroup.
    xResult = xEventGroupClearBitsFromISR(
        xEventGroup, // The event group being updated.
        BIT_0 | BIT_4 ); // The bits being set.

    if( xResult == pdPASS )
    {
        // The message was posted successfully.
    }
}
```

Parameters

- `xEventGroup` – The event group in which the bits are to be cleared.
- `uxBitsToClear` – A bitwise value that indicates the bit or bits to clear. For example, to clear bit 3 only, set `uxBitsToClear` to 0x08. To clear bit 3 and bit 0 set `uxBitsToClear` to 0x09.

Returns

If the request to execute the function was posted successfully then `pdPASS` is returned, otherwise `pdFALSE` is returned. `pdFALSE` will be returned if the timer service queue was full.

`xEventGroupSetBitsFromISR (xEventGroup, uxBitsToSet, pxHigherPriorityTaskWoken)`

A version of `xEventGroupSetBits()` that can be called from an interrupt.

Setting bits in an event group is not a deterministic operation because there are an unknown number of tasks that may be waiting for the bit or bits being set. FreeRTOS does not allow nondeterministic operations to be performed in interrupts or from critical sections. Therefore `xEventGroupSetBitsFromISR()` sends a message to the timer task to have the set operation performed in the context of the timer task - where a scheduler lock is used in place of a critical section.
BaseType_t xHigherPriorityTaskWoken, xResult;

// xHigherPriorityTaskWoken must be initialised to pdFALSE.
// Set bit 0 and bit 4 in xEventGroup.
xResult = xEventGroupSetBitsFromISR(
    xEventGroup,  // The event group being updated.
    BIT_0 | BIT_4  // The bits being set.
    &xHigherPriorityTaskWoken );

// Was the message posted successfully?
if( xResult == pdPASS )
{
    // If xHigherPriorityTaskWoken is now set to pdTRUE then a context
    // switch should be requested. The macro used is port specific and
    // will be either portYIELD_FROM_ISR() or portEND_SWITCHING_ISR() -
    // refer to the documentation page for the port being used.
    portYIELD_FROM_ISR( xHigherPriorityTaskWoken );
}

Parameters
• xEventGroup – The event group in which the bits are to be set.
• uxBitsToSet – A bitwise value that indicates the bit or bits to set. For example, to set
  bit 3 only, set uxBitsToSet to 0x08. To set bit 3 and bit 0 set uxBitsToSet to 0x09.
• pxHigherPriorityTaskWoken – As mentioned above, calling this function will re-
  sult in a message being sent to the timer daemon task. If the priority of the timer daemon
  task is higher than the priority of the currently running task (the task the interrupt inter-
  rupted) then *pxHigherPriorityTaskWoken will be set to pdTRUE by xEventGroupSet-
  BitsFromISR(), indicating that a context switch should be requested before the interrupt
  exits. For that reason *pxHigherPriorityTaskWoken must be initialised to pdFALSE. See
  the example code below.

Returns If the request to execute the function was posted successfully then pdPASS is returned,
otherwise pdFALSE is returned. pdFALSE will be returned if the timer service queue was
full.

xEventGroupGetBits (xEventGroup)
Returns the current value of the bits in an event group. This function cannot be used from an interrupt.

Parameters
• xEventGroup – The event group being queried.

Returns The event group bits at the time xEventGroupGetBits() was called.

Type Definitions
typedef struct EventGroupDef_t *EventGroupHandle_t

typedef TickType_t EventBits_t

Stream Buffer API

Header File
• components/freertos/FreeRTOS-Kernel/include/freertos/stream_buffer.h
Chapter 2. API Reference

Functions

**BaseType_t xStreamBufferGetStaticBuffers**

(StreamBufferHandle_t xStreamBuffer, uint8_t **ppucStreamBufferStorageArea, StaticStreamBuffer_t **ppxStaticStreamBuffer)

**size_t xStreamBufferSend**

(StreamBufferHandle_t xStreamBuffer, const void *pvTxData, size_t xDataLengthBytes, TickType_t xTicksToWait)

Sends bytes to a stream buffer. The bytes are copied into the stream buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xStreamBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xStreamBufferReceive()) inside a critical section and set the receive block time to 0.

Use xStreamBufferSend() to write to a stream buffer from a task. Use xStreamBufferSendFromISR() to write to a stream buffer from an interrupt service routine (ISR).

Example use:

```c
void vAFunction( StreamBufferHandle_t xStreamBuffer )
{
    size_t xBytesSent;
    uint8_t ucArrayToSend[] = { 0, 1, 2, 3 };
    char *pcStringToSend = "String to send";
    const TickType_t x100ms = pdMS_TO_TICKS( 100 );

    // Send an array to the stream buffer, blocking for a maximum of 100ms to
    // wait for enough space to be available in the stream buffer.
    xBytesSent = xStreamBufferSend( xStreamBuffer, ( void * ) ucArrayToSend, sizeof( ucArrayToSend ), x100ms );

    if( xBytesSent != sizeof( ucArrayToSend ) )
    {
        // The call to xStreamBufferSend() times out before there was enough
        // space in the buffer for the data to be written, but it did
        // successfully write xBytesSent bytes.
    }

    // Send the string to the stream buffer. Return immediately if there is not
    // enough space in the buffer.
    xBytesSent = xStreamBufferSend( xStreamBuffer, ( void * ) pcStringToSend, strlen( pcStringToSend ), 0 );

    if( xBytesSent != strlen( pcStringToSend ) )
    {
        // The entire string could not be added to the stream buffer because
        // there was not enough free space in the buffer, but xBytesSent bytes
        // were sent. Could try again to send the remaining bytes.
    }
}
```

Parameters

- **xStreamBuffer** – The handle of the stream buffer to which a stream is being sent.
- **pvTxData** – A pointer to the buffer that holds the bytes to be copied into the stream buffer.
• **xDataLengthBytes** - The maximum number of bytes to copy from pvTxData into the stream buffer.
• **xTicksToWait** - The maximum amount of time the task should remain in the Blocked state to wait for enough space to become available in the stream buffer, should the stream buffer contain too little space to hold the other xDataLengthBytes bytes. The block time is specified in tick periods, so the absolute time it represents is dependent on the tick frequency. The macro pdMS_TO_TICKS() can be used to convert a time specified in milliseconds into a time specified in ticks. Setting xTicksToWait to portMAX_DELAY will cause the task to wait indefinitely (without timing out), provided INCLUDE_vTaskSuspend is set to 1 in FreeRTOSConfig.h. If a task times out before it can write all xDataLengthBytes into the buffer it will still write as many bytes as possible. A task does not use any CPU time when it is in the blocked state.

**Returns** The number of bytes written to the stream buffer. If a task times out before it can write all xDataLengthBytes into the buffer it will still write as many bytes as possible.

```c
size_t xStreamBufferSendFromISR (StreamBufferHandle_t xStreamBuffer, const void *pvTxData, size_t xDataLengthBytes, BaseType_t *const pxHigherPriorityTaskWoken)
```

Interrupt safe version of the API function that sends a stream of bytes to the stream buffer.

**Example use:**

```c
// A stream buffer that has already been created.
StreamBufferHandle_t xStreamBuffer;

void vAnInterruptServiceRoutine( void )
{
    size_t xBytesSent;
    char *pcStringToSend = "String to send";
    BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

    // Attempt to send the string to the stream buffer.
    xBytesSent = xStreamBufferSendFromISR( xStreamBuffer,
        (void *) pcStringToSend,
        strlen( pcStringToSend ),
        &xHigherPriorityTaskWoken );

    if( xBytesSent != strlen( pcStringToSend ) )
    {
        // There was not enough free space in the stream buffer for the entire
        // string to be written, ut xBytesSent bytes were written.
    }

    // If xHigherPriorityTaskWoken was set to pdTRUE inside
    // xStreamBufferSendFromISR() then a task that has a priority above the
    // priority of the currently executing task was unblocked and a context
    // switch should be performed to ensure the ISR returns to the unblocked
```

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In most FreeRTOS ports this is done by simply passing
xHigherPriorityTaskWoken into taskYIELD_FROM_ISR(), which will test the
variables value, and perform the context switch if necessary. Check the
documentation for the port in use for port specific instructions.
taskYIELD_FROM_ISR( xHigherPriorityTaskWoken );

Parameters

- **xStreamBuffer** - The handle of the stream buffer to which a stream is being sent.
- **pvTxData** - A pointer to the data that is to be copied into the stream buffer.
- **xDataLengthBytes** - The maximum number of bytes to copy from pvTxData into the
  stream buffer.
- **pxHigherPriorityTaskWoken** - It is possible that a stream buffer will have a task
  blocked on it waiting for data. Calling xStreamBufferSendFromISR() can make data
  available, and so cause a task that was waiting for data to leave the Blocked state. If calling
  xStreamBufferSendFromISR() causes a task to leave the Blocked state, and the unblocked
  task has a priority higher than the currently executing task (the task that was interrupted),
  then, internally, xStreamBufferSendFromISR() will set *pxHigherPriorityTaskWoken to
  pdTRUE. If xStreamBufferSendFromISR() sets this value to pdTRUE, then normally a
  context switch should be performed before the interrupt is exited. This will ensure that
  the interrupt returns directly to the highest priority Ready state task. *pxHigherPriori-
  tyTaskWoken should be set to pdFALSE before it is passed into the function. See the
  example code below for an example.

Returns

The number of bytes actually written to the stream buffer, which will be less than xDataL-
engthBytes if the stream buffer didn’t have enough free space for all the bytes to be written.

```c
size_t xStreamBufferReceive( StreamBufferHandle_t xStreamBuffer, void *pvRxData, size_t xBufferLengthBytes, TickType_t xTicksToWait)
```

Receives bytes from a stream buffer.

- : Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementa-
  tion, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that
  will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader).
  It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not
  safe to have multiple different writers or multiple different readers. If there are to be multiple different writers
  then the application writer must place each call to a writing API function (such as xStreamBufferSend()) inside
  a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then
  the application writer must place each call to a reading API function (such as xStreamBufferReceive()) inside
  a critical section and set the receive block time to 0.

Use xStreamBufferReceive() to read from a stream buffer from a task. Use xStreamBufferReceiveFromISR() to
read from a stream buffer from an interrupt service routine (ISR).

Example use:

```c
void vAFunction( StreamBuffer_t xStreamBuffer )
{
    uint8_t ucRxData[ 20 ];
    size_t xReceivedBytes;
    const TickType_t xBlockTime = pdMS_TO_TICKS( 20 );

    // Receive up to another sizeof( ucRxData ) bytes from the stream buffer.
    // Wait in the Blocked state (so not using any CPU processing time) for a
    // maximum of 100ms for the full sizeof( ucRxData ) number of bytes to be
    // available.
    xReceivedBytes = xStreamBufferReceive( xStreamBuffer,
        ( void * ) ucRxData,
```
size_t xStreamBufferReceiveFromISR(StreamBufferHandle_t xStreamBuffer, void *pvRxData, size_t xBufferLengthBytes, BaseType_t *const pxHigherPriorityTaskWoken)

An interrupt safe version of the API function that receives bytes from a stream buffer.

Use xStreamBufferReceive() to read bytes from a stream buffer from a task. Use xStreamBufferReceiveFromISR() to read bytes from a stream buffer from an interrupt service routine (ISR).

Example use:

```c
void vAnInterruptServiceRoutine( void )
{
    uint8_t ucRxData[ 20 ];
    size_t xReceivedBytes;
    BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

    // Receive the next stream from the stream buffer.
    xReceivedBytes = xStreamBufferReceiveFromISR( xStreamBuffer,
    { void * ) ucRxData,
        sizeof( ucRxData ),
        &xHigherPriorityTaskWoken );

    if( xReceivedBytes > 0 )
    {
        // ucRxData contains xReceivedBytes read from the stream buffer.
        // Process the stream here....
    }
}
```
// If xHigherPriorityTaskWoken was set to pdTRUE inside
// xStreamBufferReceiveFromISR() then a task that has a priority above the
// priority of the currently executing task was unblocked and a context
// switch should be performed to ensure the ISR returns to the unblocked
// task. In most FreeRTOS ports this is done by simply passing
// xHigherPriorityTaskWoken into taskYIELD_FROM_ISR(), which will test the
// variables value, and perform the context switch if necessary. Check the
// documentation for the port in use for port specific instructions.

taskYIELD_FROM_ISR( xHigherPriorityTaskWoken );
}  

Parameters

- **xStreamBuffer** – The handle of the stream buffer from which a stream is being received.
- **pvRxData** – A pointer to the buffer into which the received bytes are copied.
- **xBUFFERLengthBytes** – The length of the buffer pointed to by the pvRxData parameter. This sets the maximum number of bytes to receive in one call. xStreamBufferReceive will return as many bytes as possible up to a maximum set by xBUFFERLengthBytes.
- **pxHigherPriorityTaskWoken** – It is possible that a stream buffer will have a task blocked on it waiting for space to become available. Calling xStreamBufferReceiveFromISR() can make space available, and so cause a task that is waiting for space to leave the Blocked state. If calling xStreamBufferReceiveFromISR() causes a task to leave the Blocked state, and the unblocked task has a priority higher than the currently executing task (the task that was interrupted), then, internally, xStreamBufferReceiveFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE. If xStreamBufferReceiveFromISR() sets this value to pdTRUE, then normally a context switch should be performed before the interrupt is exited. That will ensure the interrupt returns directly to the highest priority Ready state task. *pxHigherPriorityTaskWoken should be set to pdFALSE before it is passed into the function. See the code example below for an example.

Returns The number of bytes read from the stream buffer, if any.

```c
void vStreamBufferDelete (StreamBufferHandle_t xStreamBuffer)

Deletes a stream buffer that was previously created using a call to xStreamBufferCreate() or xStreamBufferCreateStatic(). If the stream buffer was created using dynamic memory (that is, by xStreamBufferCreate()), then the allocated memory is freed.

A stream buffer handle must not be used after the stream buffer has been deleted.

Parameters xStreamBuffer – The handle of the stream buffer to be deleted.
```

```c
BaseType_t xStreamBufferIsFull (StreamBufferHandle_t xStreamBuffer)

Queries a stream buffer to see if it is full. A stream buffer is full if it does not have any free space, and therefore cannot accept any more data.

Parameters xStreamBuffer – The handle of the stream buffer being queried.

Returns If the stream buffer is full then pdTRUE is returned. Otherwise pdFALSE is returned.
```

```c
BaseType_t xStreamBufferIsEmpty (StreamBufferHandle_t xStreamBuffer)

Queries a stream buffer to see if it is empty. A stream buffer is empty if it does not contain any data.

Parameters xStreamBuffer – The handle of the stream buffer being queried.

Returns If the stream buffer is empty then pdTRUE is returned. Otherwise pdFALSE is returned.
```

```c
BaseType_t xStreamBufferReset (StreamBufferHandle_t xStreamBuffer)

Resets a stream buffer to its initial, empty, state. Any data that was in the stream buffer is discarded. A stream buffer can only be reset if there are no tasks blocked waiting to either send to or receive from the stream buffer.

Parameters xStreamBuffer – The handle of the stream buffer being reset.
```
Chapter 2. API Reference

Returns. If the stream buffer is reset then pdPASS is returned. If there was a task blocked waiting to send to or read from the stream buffer then the stream buffer is not reset and pdFAIL is returned.

size_t xStreamBufferSpacesAvailable (StreamBufferHandle_t xStreamBuffer)

Queries a stream buffer to see how much free space it contains, which is equal to the amount of data that can be sent to the stream buffer before it is full.

Parameters xStreamBuffer – The handle of the stream buffer being queried.

Returns. The number of bytes that can be written to the stream buffer before the stream buffer would be full.

size_t xStreamBufferBytesAvailable (StreamBufferHandle_t xStreamBuffer)

Queries a stream buffer to see how much data it contains, which is equal to the number of bytes that can be read from the stream buffer before the stream buffer would be empty.

Parameters xStreamBuffer – The handle of the stream buffer being queried.

Returns. The number of bytes that can be read from the stream buffer before the stream buffer would be empty.

BaseType_t xStreamBufferSetTriggerLevel (StreamBufferHandle_t xStreamBuffer, size_t xTriggerLevel)

A stream buffer’s trigger level is the number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task’s block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 then the task will not be unblocked until the stream buffer contains at least 10 bytes or the task’s block time expires. If a reading task’s block time expires before the trigger level is reached then the task will still receive however many bytes are actually available. Setting a trigger level of 0 will result in a trigger level of 1 being used. It is not valid to specify a trigger level that is greater than the buffer size.

A trigger level is set when the stream buffer is created, and can be modified using xStreamBufferSetTriggerLevel().

Parameters

* xStreamBuffer – The handle of the stream buffer being updated.

xTriggerLevel – The new trigger level for the stream buffer.

Returns. If xTriggerLevel was less than or equal to the stream buffer’s length then the trigger level will be updated and pdTRUE is returned. Otherwise pdFALSE is returned.

BaseType_t xStreamBufferSendCompletedFromISR (StreamBufferHandle_t xStreamBuffer, BaseType_t *pxHigherPriorityTaskWoken)

For advanced users only.

The sbSEND_COMPLETED() macro is called from within the FreeRTOS APIs when data is sent to a message buffer or stream buffer. If there was a task that was blocked on the message or stream buffer waiting for data to arrive then the sbSEND_COMPLETED() macro sends a notification to the task to remove it from the Blocked state. xStreamBufferSendCompletedFromISR() does the same thing. It is provided to enable application writers to implement their own version of sbSEND_COMPLETED(), and MUST NOT BE USED AT ANY OTHER TIME.

See the example implemented in FreeRTOS/Demo/Minimal/MessageBufferAMP.c for additional information.

Parameters

* xStreamBuffer – The handle of the stream buffer to which data was written.

* pxHigherPriorityTaskWoken – *pxHigherPriorityTaskWoken should be initialised to pdFALSE before it is passed into xStreamBufferSendCompletedFromISR(). If calling xStreamBufferSendCompletedFromISR() removes a task from the Blocked state, and the task has a priority above the priority of the currently running task, then *pxHigherPriorityTaskWoken will get set to pdTRUE indicating that a context switch should be performed before exiting the ISR.
Returns If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

BaseType_t xStreamBufferReceiveCompletedFromISR(StreamBufferHandle_t xStreamBuffer, BaseType_t *pxHigherPriorityTaskWoken)

For advanced users only.

The sbRECEIVE_COMPLETED() macro is called from within the FreeRTOS APIs when data is read out of a message buffer or stream buffer. If there was a task that was blocked on the message or stream buffer waiting for data to arrive then the sbRECEIVE_COMPLETED() macro sends a notification to the task to remove it from the Blocked state. xStreamBufferReceiveCompletedFromISR() does the same thing. It is provided to enable application writers to implement their own version of sbRECEIVE_COMPLETED(), and MUST NOT BE USED AT ANY OTHER TIME.

See the example implemented in FreeRTOS/Demo/Minimal/MessageBufferAMP.c for additional information.

Parameters

- **xStreamBuffer** – The handle of the stream buffer from which data was read.
- **pxHigherPriorityTaskWoken** – pxHigherPriorityTaskWoken should be initialised to pdFALSE before it is passed into xStreamBufferReceiveCompletedFromISR(). If calling xStreamBufferReceiveCompletedFromISR() removes a task from the Blocked state, and the task has a priority above the priority of the currently running task, then *pxHigherPriorityTaskWoken will get set to pdTRUE indicating that a context switch should be performed before exiting the ISR.

Returns If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

Macros

**xStreamBufferCreate** (xBufferSizeBytes, xTriggerLevelBytes)

Creates a new stream buffer using dynamically allocated memory. See xStreamBufferCreateStatic() for a version that uses statically allocated memory (memory that is allocated at compile time).

configSUPPORT_DYNAMIC_ALLOCATION must be set to 1 or left undefined in FreeRTOSConfig.h for xStreamBufferCreate() to be available.

Example use:

```c
void vAFunction( void )
{
    StreamBufferHandle_t xStreamBuffer;
    const size_t xStreamBufferSizeBytes = 100, xTriggerLevel = 10;

    // Create a stream buffer that can hold 100 bytes. The memory used to hold
    // both the stream buffer structure and the data in the stream buffer is
    // allocated dynamically.
    xStreamBuffer = xStreamBufferCreate( xStreamBufferSizeBytes, xTriggerLevel );

    if( xStreamBuffer == NULL )
    { // There was not enough heap memory space available to create the
        // stream buffer. 
    }
    else
    { // The stream buffer was created successfully and can now be used. 
    }
}
```

Parameters
• **xBufferSizeBytes** – The total number of bytes the stream buffer will be able to hold at any one time.

• **xTriggerLevelBytes** – The number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task’s block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 then the task will not be unblocked until the stream buffer contains at least 10 bytes or the task’s block time expires. If a reading task’s block time expires before the trigger level is reached then the task will still receive however many bytes are actually available. Setting a trigger level of 0 will result in a trigger level of 1 being used. It is not valid to specify a trigger level that is greater than the buffer size.

**Returns** If NULL is returned, then the stream buffer cannot be created because there is insufficient heap memory available for FreeRTOS to allocate the stream buffer data structures and storage area. A non-NULL value being returned indicates that the stream buffer has been created successfully - the returned value should be stored as the handle to the created stream buffer.

**xStreamBufferCreateStatic** (xBufferSizeBytes, xTriggerLevelBytes, pucStreamBufferStorageArea, pxStaticStreamBuffer)

Creates a new stream buffer using statically allocated memory. See **xStreamBufferCreate()** for a version that uses dynamically allocated memory.

**configSUPPORT_STATIC_ALLOCATION** must be set to 1 in FreeRTOSConfig.h for **xStreamBufferCreateStatic()** to be available.

**Example use:**

```c
#define STORAGE_SIZE_BYTES 1000

// Defines the memory that will actually hold the streams within the stream buffer.
static uint8_t ucStorageBuffer[ STORAGE_SIZE_BYTES ];

// The variable used to hold the stream buffer structure.
StaticStreamBuffer_t xStreamBufferStruct;

void MyFunction( void )
{
    StreamBufferHandle_t xStreamBuffer;
    const size_t xTriggerLevel = 1;

    xStreamBuffer = xStreamBufferCreateStatic( sizeof( ucBufferStorage ),
                                           xTriggerLevel,
                                           ucBufferStorage,
                                           &xStreamBufferStruct );

    // As neither the pucStreamBufferStorageArea or pxStaticStreamBuffer
    // parameters were NULL, xStreamBuffer will not be NULL, and can be used to
    // reference the created stream buffer in other stream buffer API calls.

    // Other code that uses the stream buffer can go here.
}
```

**Parameters**

• **xBufferSizeBytes** – The size, in bytes, of the buffer pointed to by the pucStreamBufferStorageArea parameter.
- **xTriggerLevelBytes** - The number of bytes that must be in the stream buffer before a task that is blocked on the stream buffer to wait for data is moved out of the blocked state. For example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 1 then the task will be unblocked when a single byte is written to the buffer or the task’s block time expires. As another example, if a task is blocked on a read of an empty stream buffer that has a trigger level of 10 then the task will not be unblocked until the stream buffer contains at least 10 bytes or the task’s block time expires. If a reading task’s block time expires before the trigger level is reached then the task will still receive however many bytes are actually available. Setting a trigger level of 0 will result in a trigger level of 1 being used. It is not valid to specify a trigger level that is greater than the buffer size.

- **pucStreamBufferStorageArea** - Must point to a uint8_t array that is at least xBufferSizeBytes + 1 big. This is the array to which streams are copied when they are written to the stream buffer.

- **pxStaticStreamBuffer** - Must point to a variable of type StaticStreamBuffer_t, which will be used to hold the stream buffer’s data structure.

**Returns** If the stream buffer is created successfully then a handle to the created stream buffer is returned. If either pucStreamBufferStorageArea or pxStaticstreamBuffer are NULL then NULL is returned.

**Type Definitions**

```c
typedef struct StreamBufferDef_t *StreamBufferHandle_t
```

**Message Buffer API**

**Header File**

- components/freertos/FreeRTOS-Kernel/include/freertos/message_buffer.h

**Macros**

- **xMessageBufferCreate** (xBufferSizeBytes)

  Creates a new message buffer using dynamically allocated memory. See xMessageBufferCreateStatic() for a version that uses statically allocated memory (memory that is allocated at compile time).

  `configSUPPORT_DYNAMIC_ALLOCATION` must be set to 1 or left undefined in FreeRTOSConfig.h for xMessageBufferCreate() to be available.

  Example use:

```c
void vAFunction( void )
{
    MessageBufferHandle_t xMessageBuffer;
    const size_t xMessageBufferSizeBytes = 100;

    // Create a message buffer that can hold 100 bytes. The memory used to hold
    // both the message buffer structure and the messages themselves is allocated
    // dynamically. Each message added to the buffer consumes an additional 4
    // bytes which are used to hold the length of the message.
    xMessageBuffer = xMessageBufferCreate( xMessageBufferSizeBytes );

    if( xMessageBuffer == NULL )
    {
        // There was not enough heap memory space available to create the
        // message buffer.
    }
```

(continues on next page)
else
{
    // The message buffer was created successfully and can now be used.
}

Parameters

• xBufferSizeBytes – The total number of bytes (not messages) the message buffer will be able to hold at any one time. When a message is written to the message buffer an additional sizeof(size_t) bytes are also written to store the message’s length. sizeof(size_t) is typically 4 bytes on a 32-bit architecture, so on most 32-bit architectures a 10 byte message will take up 14 bytes of message buffer space.

Returns If NULL is returned, then the message buffer cannot be created because there is insufficient heap memory available for FreeRTOS to allocate the message buffer data structures and storage area. A non-NULL value being returned indicates that the message buffer has been created successfully - the returned value should be stored as the handle to the created message buffer.

xMessageBufferCreateStatic(xBufferSizeBytes, pucMessageBufferStorageArea, pxStaticMessageBuffer)

Creates a new message buffer using statically allocated memory. See xMessageBufferCreate() for a version that uses dynamically allocated memory.

Example use:

```c
// Used to dimension the array used to hold the messages. The available space // will actually be one less than this, so 999.
#define STORAGE_SIZE_BYTES 1000

// Defines the memory that will actually hold the messages within the message // buffer.
static uint8_t ucStorageBuffer[ STORAGE_SIZE_BYTES ];

// The variable used to hold the message buffer structure.
StaticMessageBuffer_t xMessageBufferStruct;

void MyFunction( void )
{
    MessageBufferHandle_t xMessageBuffer;

    xMessageBuffer = xMessageBufferCreateStatic( sizeof( ucBufferStorage ),
                                                 ucBufferStorage,
                                                 &xMessageBufferStruct );

    // As neither the pucMessageBufferStorageArea or pxStaticMessageBuffer // parameters were NULL, xMessageBuffer will not be NULL, and can be used to // reference the created message buffer in other message buffer API calls.

    // Other code that uses the message buffer can go here.
}
```

Parameters

• xBufferSizeBytes – The size, in bytes, of the buffer pointed to by the pucMessageBufferStorageArea parameter. When a message is written to the message buffer an additional sizeof(size_t) bytes are also written to store the message’s length. sizeof(size_t) is typically 4 bytes on a 32-bit architecture, so on most 32-bit architectures a 10 byte message will take up 14 bytes of message buffer space. The maximum number of bytes that can be stored in the message buffer is actually (xBufferSizeBytes - 1).
Chapter 2. API Reference

- **pucMessageBufferStorageArea** - Must point to a uint8_t array that is at least xBufferSizeBytes + 1 big. This is the array to which messages are copied when they are written to the message buffer.

- **pxStaticMessageBuffer** - Must point to a variable of type StaticMessageBuffer_t, which will be used to hold the message buffer’s data structure.

**Returns** If the message buffer is created successfully then a handle to the created message buffer is returned. If either pucMessageBufferStorageArea or pxStaticMessageBuffer are NULL then NULL is returned.

```c
void vAPFunction( MessageBufferHandle_t xMessageBuffer )
{
    size_t xBytesSent;
    uint8_t ucArrayToSend[] = { 0, 1, 2, 3 };
    char *pcStringToSend = "String to send";
    const TickType_t x100ms = pdMS_TO_TICKS( 100 );

    // Send an array to the message buffer, blocking for a maximum of 100ms to
    // wait for enough space to be available in the message buffer.
    xBytesSent = xMessageBufferSend( xMessageBuffer, ( void * ) ucArrayToSend, _
        sizeof( ucArrayToSend ), x100ms );

    if( xBytesSent != sizeof( ucArrayToSend ) )
    {
        // The call to xMessageBufferSend() times out before there was enough
        // space in the buffer for the data to be written.
    }

    // Send the string to the message buffer. Return immediately if there is
    // not enough space in the buffer.
    xBytesSent = xMessageBufferSend( xMessageBuffer, ( void * ) pcStringToSend, _
        strlen( pcStringToSend ), 0 );

    if( xBytesSent != strlen( pcStringToSend ) )
    {
        // The string could not be added to the message buffer because there was
        // not enough free space in the buffer.
    }
}
```

Use xMessageBufferSend() to write to a message buffer from a task. Use xMessageBufferSendFromISR() to write to a message buffer from an interrupt service routine (ISR).
Chapter 2. API Reference

Parameters

- **xMessageBuffer** - The handle of the message buffer to which a message is being sent.
- **pvTxData** - A pointer to the message that is to be copied into the message buffer.
- **xDATALengthBytes** - The length of the message. That is, the number of bytes to copy from pvTxData into the message buffer. When a message is written to the message buffer an additional sizeof(size_t) bytes are also written to store the message’s length. sizeof(size_t) is typically 4 bytes on a 32-bit architecture, so on most 32-bit architecture setting xDataLengthBytes to 20 will reduce the free space in the message buffer by 24 bytes (20 bytes of message data and 4 bytes to hold the message length).
- **xTicksToWait** - The maximum amount of time the calling task should remain in the Blocked state to wait for enough space to become available in the message buffer, should the message buffer have insufficient space when xMessageBufferSend() is called. The calling task will never block if xTicksToWait is zero. The block time is specified in tick periods, so the absolute time it represents is dependent on the tick frequency. The macro pdMS_TO_TICKS() can be used to convert a time specified in milliseconds into a time specified in ticks. Setting xTicksToWait to portMAX_DELAY will cause the task to wait indefinitely (without timing out), provided INCLUDE_vTaskSuspend is set to 1 in FreeRTOSConfig.h. Tasks do not use any CPU time when they are in the Blocked state.

**Returns**

The number of bytes written to the message buffer. If the call to xMessageBufferSend() times out before there was enough space to write the message into the message buffer then zero is returned. If the call did not time out then xDataLengthBytes is returned.

### xMessageBufferSendFromISR(xMessageBuffer, pvTxData, xDataLengthBytes, pxHigherPriorityTaskWoken)

Interrupt safe version of the API function that sends a discrete message to the message buffer. The message can be any length that fits within the buffer’s free space, and is copied into the buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xMessageBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xMessageBufferRead()) inside a critical section and set the receive block time to 0.

Use xMessageBufferSend() to write to a message buffer from a task. Use xMessageBufferSendFromISR() to write to a message buffer from an interrupt service routine (ISR).

Example use:

```c
// A message buffer that has already been created.
MessageBufferHandle_t xMessageBuffer;

void vAnInterruptServiceRoutine( void )
{
    size_t xBytesSent;
    char *pcStringToSend = "String to send";
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;  // Initialised to pdFALSE.

    // Attempt to send the string to the message buffer.
    xBytesSent = xMessageBufferSendFromISR( xMessageBuffer,
                                             ( void * ) pcStringToSend,
                                             strlen( pcStringToSend ),
                                             &xHigherPriorityTaskWoken );

    if( xBytesSent != strlen( pcStringToSend ) )
    {
        // Handle the error non-deterministically.
    }
}
```
The string could not be added to the message buffer because there was not enough free space in the buffer.

If xHigherPriorityTaskWoken was set to pdTRUE inside xMessageBufferSendFromISR(), then a task that has a priority above the priority of the currently executing task was unblocked and a context switch should be performed to ensure the ISR returns to the unblocked task. In most FreeRTOS ports this is done by simply passing xHigherPriorityTaskWoken into portYIELD_FROM_ISR(), which will test the variables value, and perform the context switch if necessary. Check the documentation for the port in use for port specific instructions.

```
portYIELD_FROM_ISR(xHigherPriorityTaskWoken);
```

### Parameters

- **xMessageBuffer** - The handle of the message buffer to which a message is being sent.
- **pvTxData** - A pointer to the message that is to be copied into the message buffer.
- **xDataLengthBytes** - The length of the message. That is, the number of bytes to copy from pvTxData into the message buffer. When a message is written to the message buffer an additional sizeof(size_t) bytes are also written to store the message’s length. sizeof(size_t) is typically 4 bytes on a 32-bit architecture, so on most 32-bit architectures setting xDataLengthBytes to 20 will reduce the free space in the message buffer by 24 bytes (20 bytes of message data and 4 bytes to hold the message length).
- **pxHigherPriorityTaskWoken** - It is possible that a message buffer will have a task blocked on it waiting for data. Calling xMessageBufferSendFromISR() can make data available, and so cause a task that was waiting for data to leave the Blocked state. If calling xMessageBufferSendFromISR() causes a task to leave the Blocked state, and the unblocked task has a priority higher than the currently executing task (the task that was interrupted), then, internally, xMessageBufferSendFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE. If xMessageBufferSendFromISR() sets this value to pdTRUE, then normally a context switch should be performed before the interrupt is exited. This will ensure that the interrupt returns directly to the highest priority Ready state task. *pxHigherPriorityTaskWoken should be set to pdFALSE before it is passed into the function. See the code example below for an example.

### Returns

The number of bytes actually written to the message buffer. If the message buffer didn’t have enough free space for the message to be stored then 0 is returned, otherwise xDataLengthBytes is returned.

### xMessageBufferReceive(xMessageBuffer, pvRxData, xBufferLengthBytes, xTicksToWait)

Receives a discrete message from a message buffer. Messages can be of variable length and are copied out of the buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xMessageBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xMessageBufferRead()) inside a critical section and set the receive block time to 0.

Use xMessageBufferReceive() to read from a message buffer from a task. Use xMessageBufferReceiveFromISR() to read from a message buffer from an interrupt service routine (ISR).

Example use:
```c
void vAFunction( MessageBuffer_t xMessageBuffer )
{
  uint8_t ucRxData[ 20 ];
  size_t xReceivedBytes;
  const TickType_t xBlockTime = pdMS_TO_TICKS( 20 );

  // Receive the next message from the message buffer. Wait in the Blocked
  // state (so not using any CPU processing time) for a maximum of 100ms for
  // a message to become available.
  xReceivedBytes = xMessageBufferReceive( xMessageBuffer,
                                          ( void * ) ucRxData,
                                          sizeof( ucRxData ),
                                          xBlockTime );

  if( xReceivedBytes > 0 )
  {
    // A ucRxData contains a message that is xReceivedBytes long. Process
    // the message here....
  }
}
```

### Parameters

- **xMessageBuffer** – The handle of the message buffer from which a message is being received.
- **pvRxData** – A pointer to the buffer into which the received message is to be copied.
- **xBUFFER_LENGTH_BYTES** – The length of the buffer pointed to by the pvRxData parameter. This sets the maximum length of the message that can be received. If xBUFFER_LENGTH_BYTES is too small to hold the next message then the message will be left in the message buffer and 0 will be returned.
- **xTicksToWait** – The maximum amount of time the task should remain in the Blocked state to wait for a message, should the message buffer be empty. xMessageBufferReceive() will return immediately if xTicksToWait is zero and the message buffer is empty. The block time is specified in tick periods, so the absolute time it represents is dependent on the tick frequency. The macro pdMS_TO_TICKS() can be used to convert a time specified in milliseconds into a time specified in ticks. Setting xTicksToWait to portMAX_DELAY will cause the task to wait indefinitely (without timing out), provided INCLUDE_vTaskSuspend is set to 1 in FreeRTOSConfig.h. Tasks do not use any CPU time when they are in the Blocked state.

### Returns

- The length, in bytes, of the message read from the message buffer, if any. If xMessageBufferReceive() times out before a message became available then zero is returned. If the length of the message is greater than xBUFFER_LENGTH_BYTES then the message will be left in the message buffer and zero is returned.

---

**xMessageBufferReceiveFromISR** (xMessageBuffer, pvRxData, xBUFFER_LENGTH_BYTES, pxHigherPriorityTaskWoken)

An interrupt safe version of the API function that receives a discrete message from a message buffer. Messages can be of variable length and are copied out of the buffer.

: Uniquely among FreeRTOS objects, the stream buffer implementation (so also the message buffer implementation, as message buffers are built on top of stream buffers) assumes there is only one task or interrupt that will write to the buffer (the writer), and only one task or interrupt that will read from the buffer (the reader). It is safe for the writer and reader to be different tasks or interrupts, but, unlike other FreeRTOS objects, it is not safe to have multiple different writers or multiple different readers. If there are to be multiple different writers then the application writer must place each call to a writing API function (such as xMessageBufferSend()) inside a critical section and set the send block time to 0. Likewise, if there are to be multiple different readers then the application writer must place each call to a reading API function (such as xMessageBufferRead()) inside a critical section and set the receive block time to 0.

Use xMessageBufferReceive() to read from a message buffer from a task. Use xMessageBufferReceive-
FromISR() to read from a message buffer from an interrupt service routine (ISR).

Example use:

```c
// A message buffer that has already been created.
MessageBuffer_t xMessageBuffer;

void vAnInterruptServiceRoutine( void )
{
  uint8_t ucRxData[ 20 ];
  size_t xReceivedBytes;
  BaseType_t xHigherPriorityTaskWoken = pdFALSE; // Initialised to pdFALSE.

  // Receive the next message from the message buffer.
  xReceivedBytes = xMessageBufferReceiveFromISR( xMessageBuffer,
      { void * } ucRxData,
      sizeof( ucRxData ),
      &xHigherPriorityTaskWoken );

  if( xReceivedBytes > 0 )
  {
    // A ucRxData contains a message that is xReceivedBytes long. Process
    // the message here....
  }

  // If xHigherPriorityTaskWoken was set to pdTRUE inside
  // xMessageBufferReceiveFromISR() then a task that has a priority above the
  // priority of the currently executing task was unblocked and a context
  // switch should be performed to ensure the ISR returns to the unblocked
  // task. In most FreeRTOS ports this is done by simply passing
  // xHigherPriorityTaskWoken into portYIELD_FROM_ISR(), which will test the
  // variables value, and perform the context switch if necessary. Check the
  // documentation for the port in use for port specific instructions.
  portYIELD_FROM_ISR( xHigherPriorityTaskWoken );
}
```

**Parameters**

- **xMessageBuffer** – The handle of the message buffer from which a message is being received.
- **pvRxData** – A pointer to the buffer into which the received message is to be copied.
- **xBufferLengthBytes** – The length of the buffer pointed to by the pvRxData parameter. This sets the maximum length of the message that can be received. If xBufferLengthBytes is too small to hold the next message then the message will be left in the message buffer and 0 will be returned.
- **pxHigherPriorityTaskWoken** – It is possible that a message buffer will have a task blocked on it waiting for space to become available. Calling xMessageBufferReceiveFromISR() can make space available, and so cause a task that is waiting for space to leave the Blocked state. If calling xMessageBufferReceiveFromISR() causes a task to leave the Blocked state, and the unblocked task has a priority higher than the currently executing task (the task that was interrupted), then, internally, xMessageBufferReceiveFromISR() will set *pxHigherPriorityTaskWoken to pdTRUE. If xMessageBufferReceiveFromISR() sets this value to pdTRUE, then normally a context switch should be performed before the interrupt is exited. That will ensure the interrupt returns directly to the highest priority Ready state task. *pxHigherPriorityTaskWoken should be set to pdFALSE before it is passed into the function. See the code example below for an example.

**Returns** The length, in bytes, of the message read from the message buffer, if any.

**vMessageBufferDelete(xMessageBuffer)**

Deletes a message buffer that was previously created using a call to xMessageBufferCreate() or xMessage-
BufferCreateStatic(). If the message buffer was created using dynamic memory (that is, by xMessageBufferCreate()), then the allocated memory is freed.

A message buffer handle must not be used after the message buffer has been deleted.

**Parameters**
- **xMessageBuffer** – The handle of the message buffer to be deleted.

**xMessageBufferIsFull (xMessageBuffer)**
Tests to see if a message buffer is full. A message buffer is full if it cannot accept any more messages, of any size, until space is made available by a message being removed from the message buffer.

**Parameters**
- **xMessageBuffer** – The handle of the message buffer being queried.

**Returns**
- If the message buffer referenced by xMessageBuffer is full then pdTRUE is returned.
- Otherwise pdFALSE is returned.

**xMessageBufferIsEmpty (xMessageBuffer)**
Tests to see if a message buffer is empty (does not contain any messages).

**Parameters**
- **xMessageBuffer** – The handle of the message buffer being queried.

**Returns**
- If the message buffer referenced by xMessageBuffer is empty then pdTRUE is returned.
- Otherwise pdFALSE is returned.

**xMessageBufferReset (xMessageBuffer)**
Resets a message buffer to its initial empty state, discarding any message it contained.

A message buffer can only be reset if there are no tasks blocked on it.

**Parameters**
- **xMessageBuffer** – The handle of the message buffer being reset.

**Returns**
- If the message buffer was reset then pdPASS is returned.
- If the message buffer could not be reset because either there was a task blocked on the message queue to wait for space to become available, or to wait for a message to be available, then pdFAIL is returned.

**xMessageBufferSpacesAvailable (xMessageBuffer)**
Returns the number of bytes of free space in the message buffer.

**Parameters**
- **xMessageBuffer** – The handle of the message buffer being queried.

**Returns**
- The number of bytes that can be written to the message buffer before the message buffer would be full. When a message is written to the message buffer an additional sizeof( size_t ) bytes are also written to store the message’s length. sizeof( size_t ) is typically 4 bytes on a 32-bit architecture, so if xMessageBufferSpacesAvailable() returns 10, then the size of the largest message that can be written to the message buffer is 6 bytes.

**xMessageBufferNextLengthBytes (xMessageBuffer)**
Returns the length (in bytes) of the next message in a message buffer. Useful if xMessageBufferReceive() returned 0 because the size of the buffer passed into xMessageBufferReceive() was too small to hold the next message.

**Parameters**
- **xMessageBuffer** – The handle of the message buffer being queried.

**Returns**
- The length (in bytes) of the next message in the message buffer, or 0 if the message buffer is empty.

**xMessageBufferSendCompletedFromISR (xMessageBuffer, pxHigherPriorityTaskWoken)**
For advanced users only.

The sbSEND_COMPLETED() macro is called from within the FreeRTOS APIs when data is sent to a message buffer or stream buffer. If there was a task that was blocked on the message or stream buffer waiting for data to
arrive then the sbSEND_COMPLETED() macro sends a notification to the task to remove it from the Blocked state. xMessageBufferSendCompletedFromISR() does the same thing. It is provided to enable application writers to implement their own version of sbSEND_COMPLETED(), and MUST NOT BE USED AT ANY OTHER TIME.

See the example implemented in FreeRTOS/Demo/Minimal/MessageBufferAMP.c for additional information.

**Parameters**

- **xMessageBuffer** – The handle of the stream buffer to which data was written.
- **pxHigherPriorityTaskWoken** – pxHigherPriorityTaskWoken should be initialised to pdFALSE before it is passed into xMessageBufferSendCompletedFromISR(). If calling xMessageBufferSendCompletedFromISR() removes a task from the Blocked state, and the task has a priority above the priority of the currently running task, then pxHigherPriorityTaskWoken will get set to pdTRUE indicating that a context switch should be performed before exiting the ISR.

**Returns** If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

```c
xMessageBufferSendCompletedFromISR(xMessageBuffer, pxHigherPriorityTaskWoken)
```

For advanced users only.

The sbRECEIVE_COMPLETED() macro is called from within the FreeRTOS APIs when data is read out of a message buffer or stream buffer. If there was a task that was blocked on the message or stream buffer waiting for data to arrive then the sbRECEIVE_COMPLETED() macro sends a notification to the task to remove it from the Blocked state. xMessageBufferReceiveCompletedFromISR() does the same thing. It is provided to enable application writers to implement their own version of sbRECEIVE_COMPLETED(), and MUST NOT BE USED AT ANY OTHER TIME.

See the example implemented in FreeRTOS/Demo/Minimal/MessageBufferAMP.c for additional information.

**Parameters**

- **xMessageBuffer** – The handle of the stream buffer from which data was read.
- **pxHigherPriorityTaskWoken** – pxHigherPriorityTaskWoken should be initialised to pdFALSE before it is passed into xMessageBufferReceiveCompletedFromISR(). If calling xMessageBufferReceiveCompletedFromISR() removes a task from the Blocked state, and the task has a priority above the priority of the currently running task, then pxHigherPriorityTaskWoken will get set to pdTRUE indicating that a context switch should be performed before exiting the ISR.

**Returns** If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

```c
xMessageBufferReceiveCompletedFromISR(xMessageBuffer, pxHigherPriorityTaskWoken)
```

**Type Definitions**

typedef void *MessageBufferHandle_t

Type by which message buffers are referenced. For example, a call to xMessageBufferCreate() returns an MessageBufferHandle_t variable that can then be used as a parameter to xMessageBufferSend(), xMessageBufferReceive(), etc.

### 2.10.12 FreeRTOS (Supplemental Features)

ESP-IDF provides multiple features to supplement the features offered by FreeRTOS. These supplemental features are available on all FreeRTOS implementations supported by ESP-IDF (i.e., ESP-IDF FreeRTOS and Amazon SMP FreeRTOS). This document describes these supplemental features and is split into the following sections:

**Contents**

- FreeRTOS (Supplemental Features)
  - Overview
Overview

ESP-IDF adds various new features to supplement the capabilities of FreeRTOS as follows:

- **Ring Buffers**: Ring buffers provide a FIFO buffer that can accept entries of arbitrary lengths.
- **ESP-IDF Tick and Idle Hooks**: ESP-IDF provides multiple custom tick interrupt hooks and idle task hooks that are more numerous and more flexible when compared to FreeRTOS tick and idle hooks.
- **Thread Local Storage Pointer (TLSP) Deletion Callbacks**: TLSP Deletion callbacks are run automatically when a task is deleted, thus allowing users to clean up their TLSPs automatically.
- **Component Specific Properties**: Currently added only one component specific property ORIG_INCLUDE_PATH.

Ring Buffers

FreeRTOS provides stream buffers and message buffers as the primary mechanisms to send arbitrarily sized data between tasks and ISRs. However, FreeRTOS stream buffers and message buffers have the following limitations:

- Strictly single sender and single receiver
- Data is passed by copy
- Unable to reserve buffer space for a deferred send (i.e., send acquire)

Therefore, ESP-IDF provides a separate ring buffer implementation to address the issues above. ESP-IDF ring buffers are strictly FIFO buffers that supports arbitrarily sized items. Ring buffers are a more memory efficient alternative to FreeRTOS queues in situations where the size of items is variable. The capacity of a ring buffer is not measured by the number of items it can store, but rather by the amount of memory used for storing items. The ring buffer provides APIs to send an item, or to allocate space for an item in the ring buffer to be filled manually by the user. For efficiency reasons, items are always retrieved from the ring buffer by reference. As a result, all retrieved items must also be returned to the ring buffer by using vRingbufferReturnItem() or vRingbufferReturnItemFromISR(), in order for them to be removed from the ring buffer completely. The ring buffers are split into the three following types:

- **No-Split buffers** will guarantee that an item is stored in contiguous memory and will not attempt to split an item under any circumstances. Use No-Split buffers when items must occupy contiguous memory. Only this buffer type allows you to get the data item address and write to the item by yourself. Refer the documentation of the functions xRingbufferSendAcquire() and xRingbufferSendComplete() for more details.

- **Allow-Split buffers** will allow an item to be split in two parts when wrapping around the end of the buffer if there is enough space at the tail and the head of the buffer combined to store the item. Allow-Split buffers are more memory efficient than No-Split buffers but can return an item in two parts when retrieving.

- **Byte buffers** do not store data as separate items. All data is stored as a sequence of bytes, and any number of bytes can be sent or retrieved each time. Use byte buffers when separate items do not need to be maintained (e.g. a byte stream).

**Note**: No-Split buffers and Allow-Split buffers will always store items at 32-bit aligned addresses. Therefore, when retrieving an item, the item pointer is guaranteed to be 32-bit aligned. This is useful especially when you need to send some data to the DMA.

**Note**: Each item stored in No-Split or Allow-Split buffers will require an additional 8 bytes for a header. Item
sizes will also be rounded up to a 32-bit aligned size (multiple of 4 bytes), however the true item size is recorded within the header. The sizes of No-Split and Allow-Split buffers will also be rounded up when created.

**Usage** The following example demonstrates the usage of `xRingbufferCreate()` and `xRingbufferSend()` to create a ring buffer and then send an item to it.

```c
#include "freertos/ringbuf.h"
static char tx_item[] = "test_item";
...

//Create ring buffer
RingbufHandle_t buf_handle;
buf_handle = xRingbufferCreate(1028, RINGBUF_TYPE_NOSPLIT);
if (buf_handle == NULL) {
    printf("Failed to create ring buffer\n");
}

//Send an item
UBaseType_t res = xRingbufferSend(buf_handle, tx_item, sizeof(tx_item), pdMS_TO_TICKS(1000));
if (res != pdTRUE) {
    printf("Failed to send item\n");
}
```

The following example demonstrates the usage of `xRingbufferSendAcquire()` and `xRingbufferSendComplete()` instead of `xRingbufferSend()` to acquire memory on the ring buffer (of type `RINGBUF_TYPE_NOSPLIT`) and then send an item to it. This adds one more step, but allows getting the address of the memory to write to, and writing to the memory yourself.

```c
#include "freertos/ringbuf.h"
#include "soc/lldesc.h"

typedef struct {
    lldesc_t dma_desc;
    uint8_t buf[1];
} dma_item_t;

#define DMA_ITEM_SIZE(N) (sizeof(lldesc_t)+(((N)+3)&(~3))
...

//Retrieve space for DMA descriptor and corresponding data buffer
//This has to be done with SendAcquire, or the address may be different when...

//we copy
dma_item_t item;
UBaseType_t res = xRingbufferSendAcquire(buf_handle, &item, DMA_ITEM_SIZE(buffer_size), pdMS_TO_TICKS(1000));
if (res != pdTRUE) {
    printf("Failed to acquire memory for item\n");
}
item->dma_desc = (lldesc_t) {
    .size = buffer_size,
    .length = buffer_size,
    .eof = 0,
    .owner = 1,
    .buf = &item->buf,
};
//Actually send to the ring buffer for consumer to use
res = xRingbufferSendComplete(buf_handle, &item);
```
if (res != pdTRUE) {
    printf("Failed to send item\n");
}

The following example demonstrates retrieving and returning an item from a No-Split ring buffer using xRingbufferReceive() and vRingbufferReturnItem()

...  
//Receive an item from no-split ring buffer
size_t item_size;
char *item = (char *)xRingbufferReceive(buf_handle, &item_size, pdMS_TO_TICKS(1000));

//Check received item
if (item != NULL) {
    //Print item
    for (int i = 0; i < item_size; i++) {
        printf("%c", item[i]);
    }
    printf("\n");
    //Return Item
    vRingbufferReturnItem(buf_handle, (void *)item);
} else {
    //Failed to receive item
    printf("Failed to receive item\n");
}

The following example demonstrates retrieving and returning an item from an Allow-Split ring buffer using xRingbufferReceiveSplit() and vRingbufferReturnItem()

...  
//Receive an item from allow-split ring buffer
size_t item_size1, item_size2;
char *item1, *item2;
BaseType_t ret = xRingbufferReceiveSplit(buf_handle, (void **)item1, (void **)item2, &item_size1, &item_size2, pdMS_TO_TICKS(1000));

//Check received item
if (ret == pdTRUE && item1 != NULL) {
    for (int i = 0; i < item_size1; i++) {
        printf("%c", item1[i]);
    }
    vRingbufferReturnItem(buf_handle, (void *)item1);
    //Check if item was split
    if (item2 != NULL) {
        for (int i = 0; i < item_size2; i++) {
            printf("%c", item2[i]);
        }
        vRingbufferReturnItem(buf_handle, (void *)item2);
    }
    printf("\n");
} else {
    //Failed to receive item
    printf("Failed to receive item\n");
}

The following example demonstrates retrieving and returning an item from a byte buffer using xRingbufferReceiveUpTo() and vRingbufferReturnItem()
//Receive data from byte buffer
size_t item_size;
char *item = (char*)xRingbufferReceiveUpTo(buf_handle, &item_size, pdMS_TO_TICKS(1000), sizeof(tx_item));

//Check received data
if (item != NULL) {
    //Print item
    for (int i = 0; i < item_size; i++) {
        printf("%c", item[i]);
    }
    printf("\n");
    //Return Item
    vRingbufferReturnItem(buf_handle, (void*)item);
} else {
    //Failed to receive item
    printf("Failed to receive item\n");
}

For ISR safe versions of the functions used above, call xRingbufferSendFromISR(), xRingbufferReceiveFromISR(), xRingbufferReceiveSplitFromISR(), xRingbufferReceiveUpToFromISR(), and vRingbufferReturnItemFromISR()

Note: Two calls to RingbufferReceive[UpTo][FromISR]() are required if the bytes wraps around the end of the ring buffer.

Sending to Ring Buffer  The following diagrams illustrate the differences between No-Split and Allow-Split buffers as compared to byte buffers with regard to sending items/data. The diagrams assume that three items of sizes 18, 3, and 27 bytes are sent respectively to a buffer of 128 bytes.

Fig. 33: Sending items to No-Split or Allow-Split ring buffers

For No-Split and Allow-Split buffers, a header of 8 bytes precedes every data item. Furthermore, the space occupied by each item is rounded up to the nearest 32-bit aligned size in order to maintain overall 32-bit alignment. However, the true size of the item is recorded inside the header which will be returned when the item is retrieved.

Referring to the diagram above, the 18, 3, and 27 byte items are rounded up to 20, 4, and 28 bytes respectively. An 8 byte header is then added in front of each item.

Byte buffers treat data as a sequence of bytes and does not incur any overhead (no headers). As a result, all data sent to a byte buffer is merged into a single item.

Referring to the diagram above, the 18, 3, and 27 byte items are sequentially written to the byte buffer and merged into a single item of 48 bytes.

Using SendAcquire and SendComplete  Items in No-Split buffers are acquired (by SendAcquire) in strict FIFO order and must be sent to the buffer by SendComplete for the data to be accessible by the consumer.
Multiple items can be sent or acquired without calling `SendComplete`, and the items do not necessarily need to be completed in the order they were acquired. However, the receiving of data items must occur in FIFO order, therefore not calling `SendComplete` for the earliest acquired item will prevent the subsequent items from being received.

The following diagrams illustrate what will happen when `SendAcquire` and `SendComplete` don’t happen in the same order. At the beginning, there is already a data item of 16 bytes sent to the ring buffer. Then `SendAcquire` is called to acquire space of 20, 8, 24 bytes on the ring buffer.

After that, we fill (use) the buffers, and send them to the ring buffer by `SendComplete` in the order of 8, 24, 20. When 8 bytes and 24 bytes data are sent, the consumer still can only get the 16 bytes data item. Hence, if `SendComplete` is not called for the 20 bytes, it will not be available, nor will the data items following the 20 bytes item.

When the 20 bytes item is finally completed, all the 3 data items can be received now, in the order of 20, 8, 24 bytes, right after the 16 bytes item existing in the buffer at the beginning.

Allow-Split buffers and byte buffers do not allow using `SendAcquire` or `SendComplete` since acquired buffers are required to be complete (not wrapped).

**Wrap around** The following diagrams illustrate the differences between No-Split, Allow-Split, and byte buffers when a sent item requires a wrap around. The diagrams assume a buffer of **128 bytes** with **56 bytes of free space that wraps around** and a sent item of **28 bytes**.
Chapter 2. API Reference

No-Split buffers will only store an item in continuous free space and will not split an item under any circumstances. When the free space at the tail of the buffer is insufficient to completely store the item and its header, the free space at the tail will be marked as dummy data. The buffer will then wrap around and store the item in the free space at the head of the buffer.

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to store the 28 byte item. Therefore, the 16 bytes is marked as dummy data and the item is written to the free space at the head of the buffer instead.

![Fig. 37: Wrap around in Allow-Split buffers](image)

Allow-Split buffers will attempt to split the item into two parts when the free space at the tail of the buffer is insufficient to store the item data and its header. Both parts of the split item will have their own headers (therefore incurring an extra 8 bytes of overhead).

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to store the 28 byte item. Therefore, the item is split into two parts (8 and 20 bytes) and written as two parts to the buffer.

**Note:** Allow-Split buffers treat both parts of the split item as two separate items, therefore call `xRingbufferReceiveSplit()` instead of `xRingbufferReceive()` to receive both parts of a split item in a thread safe manner.

![Fig. 38: Wrap around in byte buffers](image)

Byte buffers will store as much data as possible into the free space at the tail of buffer. The remaining data will then be stored in the free space at the head of the buffer. No overhead is incurred when wrapping around in byte buffers.

Referring to the diagram above, the 16 bytes of free space at the tail of the buffer is insufficient to completely store the 28 bytes of data. Therefore, the 16 bytes of free space is filled with data, and the remaining 12 bytes are written to the free space at the head of the buffer. The buffer now contains data in two separate continuous parts, and each continuous part will be treated as a separate item by the byte buffer.

**Retrieving/Returning** The following diagrams illustrate the differences between No-Split and Allow-Split buffers as compared to byte buffers in retrieving and returning data.

Items in No-Split buffers and Allow-Split buffers are retrieved in strict FIFO order and must be returned for the occupied space to be freed. Multiple items can be retrieved before returning, and the items do not necessarily need to be returned in the order they were retrieved. However, the freeing of space must occur in FIFO order, therefore not returning the earliest retrieved item will prevent the space of subsequent items from being freed.
Referring to the diagram above, the 16, 20, and 8 byte items are retrieved in FIFO order. However, the items are not returned in the order they were retrieved. First, the 20 byte item is returned followed by the 8 byte and the 16 byte items. The space is not freed until the first item, i.e., the 16 byte item is returned.

Byte buffers do not allow multiple retrievals before returning (every retrieval must be followed by a return before another retrieval is permitted). When using \texttt{xRingbufferReceive()} or \texttt{xRingbufferReceiveFromISR()}, all continuous stored data will be retrieved. \texttt{xRingbufferReceiveUpTo()} or \texttt{xRingbufferReceiveUpToFromISR()} can be used to restrict the maximum number of bytes retrieved. Since every retrieval must be followed by a return, the space will be freed as soon as the data is returned.

Referring to the diagram above, the 38 bytes of continuous stored data at the tail of the buffer is retrieved, returned, and freed. The next call to \texttt{xRingbufferReceive()} or \texttt{xRingbufferReceiveFromISR()} then wraps around and does the same to the 30 bytes of continuous stored data at the head of the buffer.

\textbf{Ring Buffers with Queue Sets} \hspace{1em} Ring buffers can be added to FreeRTOS queue sets using \texttt{xRingbufferAddToQueueSetRead()} such that every time a ring buffer receives an item or data, the queue set is notified. Once added to a queue set, every attempt to retrieve an item from a ring buffer should be preceded by a call to \texttt{xQueueSelectFromSet()} or \texttt{xQueueSelectFromSetNoReset()}. To check whether the selected queue set member is the ring buffer, call \texttt{xRingbufferCanRead()}.

The following example demonstrates queue set usage with ring buffers.

```c
#include "freertos/queue.h"
#include "freertos/ringbuf.h"
...

//Create ring buffer and queue set
RingbufHandle_t buf_handle = xRingbufferCreate(1028, RINGBUF_TYPE_NOSPLIT);
```

(continues on next page)
Chapter 2. API Reference

QueueSetHandle_t queue_set = xQueueCreateSet(3);

//Add ring buffer to queue set
if (xRingbufferAddToQueueSetRead(buf_handle, queue_set) != pdTRUE) {
    printf("Failed to add to queue set\n");
}
...

//Block on queue set
QueueSetMemberHandle_t member = xQueueSelectFromSet(queue_set, pdMS_TO_TICKS(1000));

//Check if member is ring buffer
if (member != NULL && xRingbufferCanRead(buf_handle, member) == pdTRUE) {
    //Member is ring buffer, receive item from ring buffer
    size_t item_size;
    char *item = (char *)xRingbufferReceive(buf_handle, &item_size, 0);
    //Handle item
    ...
} else {
    ...
}

Ring Buffers with Static Allocation  The xRingbufferCreateStatic() can be used to create ring buffers with specific memory requirements (such as a ring buffer being allocated in external RAM). All blocks of memory used by a ring buffer must be manually allocated beforehand then passed to the xRingbufferCreateStatic() to be initialized as a ring buffer. These blocks include the following:

- The ring buffer’s data structure of type StaticRingbuffer_t
- The ring buffer’s storage area of size xBufferSize. Note that xBufferSize must be 32-bit aligned for No-Split and Allow-Split buffers.

The manner in which these blocks are allocated will depend on the users requirements (e.g. all blocks being statically declared, or dynamically allocated with specific capabilities such as external RAM).

Note:  When deleting a ring buffer created via xRingbufferCreateStatic(), the function vRingbufferDelete() will not free any of the memory blocks. This must be done manually by the user after vRingbufferDelete() is called.

The code snippet below demonstrates a ring buffer being allocated entirely in external RAM.

```c
#include "freertos/ringbuf.h"
#include "freertos/semphr.h"
#include "esp_heap_caps.h"
#define BUFFER_SIZE 400 //32-bit aligned size
#define BUFFER_TYPE RINGBUF_TYPE_NOSPLIT
...

//Allocate ring buffer data structure and storage area into external RAM
StaticRingbuffer_t *buffer_struct = (StaticRingbuffer_t *)heap_caps_malloc(sizeof(StaticRingbuffer_t), MALLOC_CAP_SPIRAM);
uint8_t *buffer_storage = (uint8_t *)heap_caps_malloc(sizeof(uint8_t)*BUFFER_SIZE,...
                         MALLOC_CAP_SPIRAM);
```

(continues on next page)
Create a ring buffer with manually allocated memory

```c
RingbufHandle_t handle = xRingbufferCreateStatic(BUFFER_SIZE, BUFFER_TYPE, buffer_storage, buffer_struct);
...

//Delete the ring buffer after used
vRingbufferDelete(handle);

//Manually free all blocks of memory
free(buffer_struct);
free(buffer_storage);
```

ESP-IDF Tick and Idle Hooks

FreeRTOS allows applications to provide a tick hook and an idle hook at compile time:

- FreeRTOS tick hook can be enabled via the `CONFIG_FREERTOS_USE_TICK_HOOK` option. The application must provide the `void vApplicationTickHook( void )` callback.
- FreeRTOS idle hook can be enabled via the `CONFIG_FREERTOS_USE_IDLE_HOOK` option. The application must provide the `void vApplicationIdleHook( void )` callback.

However, the FreeRTOS tick hook and idle hook have the following drawbacks:

- The FreeRTOS hooks are registered at compile time
- Only one of each hook can be registered
- On multi-core targets, the FreeRTOS hooks are symmetric, meaning each CPU’s tick interrupt and idle tasks end up calling the same hook.

Therefore, ESP-IDF tick and idle hooks are provided to supplement the features of FreeRTOS tick and idle hooks. The ESP-IDF hooks have the following features:

- The hooks can be registered and deregistered at run-time
- Multiple hooks can be registered (with a maximum of 8 hooks of each type per CPU)
- On multi-core targets, the hooks can be asymmetric, meaning different hooks can be registered to each CPU

ESP-IDF hooks can be registered and deregistered using the following APIs:

- For tick hooks:
  - Register using `esp_register_freertos_tick_hook()` or `esp_register_freertos_tick_hook_for_cpu()`
  - Deregister using `esp_deregister_freertos_tick_hook()` or `esp_deregister_freertos_tick_hook_for_cpu()`

- For idle hooks:
  - Register using `esp_register_freertos_idle_hook()` or `esp_register_freertos_idle_hook_for_cpu()`
  - Deregister using `esp_deregister_freertos_idle_hook()` or `esp_deregister_freertos_idle_hook_for_cpu()`

**Note:** The tick interrupt stays active while the cache is disabled, therefore any tick hook (FreeRTOS or ESP-IDF) functions must be placed in internal RAM. Please refer to the *SPI flash API documentation* for more details.

TLSP Deletion Callbacks

Vanilla FreeRTOS provides a Thread Local Storage Pointers (TLSP) feature. These are pointers stored directly in the Task Control Block (TCB) of a particular task. TLSPs allow each task to have its own unique set of pointers to data structures. Vanilla FreeRTOS expects users to…
Chapter 2. API Reference

- set a task’s TLSPs by calling `vTaskSetThreadLocalStoragePointer()` after the task has been created.
- get a task’s TLSPs by calling `pvTaskGetThreadLocalStoragePointer()` during the task’s lifetime.
- free the memory pointed to by the TLSPs before the task is deleted.

However, there can be instances where users may want the freeing of TLSP memory to be automatic. Therefore, ESP-IDF provides the additional feature of TLSP deletion callbacks. These user provided deletion callbacks are called automatically when a task is deleted, thus allowing the TLSP memory to be cleaned up without needing to add the cleanup logic explicitly to the code of every task.

The TLSP deletion callbacks are set in a similar fashion to the TLSPs themselves.

- `vTaskSetThreadLocalStoragePointerAndDelCallback()` sets both a particular TLSP and its associated callback.
- Calling the Vanilla FreeRTOS function `vTaskSetThreadLocalStoragePointer()` will simply set the TLSP’s associated Deletion Callback to `NULL` meaning that no callback will be called for that TLSP during task deletion.

When implementing TLSP callbacks, users should note the following:

- The callback must never attempt to block or yield and critical sections should be kept as short as possible
- The callback is called shortly before a deleted task’s memory is freed. Thus, the callback can either be called from `vTaskDelete()` itself, or from the idle task.

IDF Additional API

The `freertos/esp_additions/include/freertos/idf_additions.h` header contains FreeRTOS related helper functions added by ESP-IDF. Users can include this header via `#include "freertos/idf_additions.h"`.

Component Specific Properties

Besides standard component variables that are available with basic cmake build properties, FreeRTOS component also provides arguments (only one so far) for simpler integration with other modules:

- `ORIG_INCLUDE_PATH` - contains an absolute path to freertos root include folder. Thus instead of `#include "freertos/FreeRTOS.h"` you can refer to headers directly: `#include "FreeRTOS.h"`.

API Reference

Ring Buffer API

Header File

- `components/esp_ringbuf/include/freertos/ringbuf.h`

Functions

`RingbufHandle_t xRingbufferCreate(size_t xBufferSize, RingbufferType_t xBufferType)`

Create a ring buffer.

**Note:** `xBufferSize` of no-split/allow-split buffers will be rounded up to the nearest 32-bit aligned size.

Parameters

- `xBufferSize` `[in]` Size of the buffer in bytes. Note that items require space for a header in no-split/allow-split buffers
- `xBufferType` `[in]` Type of ring buffer, see documentation.
**Returns**  A handle to the created ring buffer, or NULL in case of error.

```c
RingbufHandle_t xRingbufferCreateNoSplit (size_t xItemSize, size_t xItemNum)
```

Create a ring buffer of type RINGBUF_TYPE_NOSPLIT for a fixed item size.

This API is similar to `xRingbufferCreate()`, but it will internally allocate additional space for the headers.

**Parameters**
- `xItemSize` - [in] Size of each item to be put into the ring buffer
- `xItemNum` - [in] Maximum number of items the buffer needs to hold simultaneously

**Returns**  A RingbufHandle_t handle to the created ring buffer, or NULL in case of error.

```c
RingbufHandle_t xRingbufferCreateStatic (size_t xBufferSize, RingbufferType_t xBufferType, uint8_t *pucRingbufferStorage, StaticRingbuffer_t *pxStaticRingbuffer)
```

Create a ring buffer but manually provide the required memory.

**Note:** `xBufferSize` of no-split/allow-split buffers MUST be 32-bit aligned.

**Parameters**
- `xBufferSize` - [in] Size of the buffer in bytes.
- `xBufferType` - [in] Type of ring buffer, see documentation
- `pucRingbufferStorage` - [in] Pointer to the ring buffer’s storage area. Storage area must have the same size as specified by `xBufferSize`
- `pxStaticRingbuffer` - [in] Pointed to a struct of type StaticRingbuffer_t which will be used to hold the ring buffer’s data structure

**Returns**  A handle to the created ring buffer

```c
BaseType_t xRingbufferSend (RingbufHandle_t xRingbuffer, const void *pvItem, size_t xItemSize, TickType_t xTicksToWait)
```

Insert an item into the ring buffer.

Attempt to insert an item into the ring buffer. This function will block until enough free space is available or until it times out.

**Note:** For no-split/allow-split ring buffers, the actual size of memory that the item will occupy will be rounded up to the nearest 32-bit aligned size. This is done to ensure all items are always stored in 32-bit aligned fashion.

**Note:** For no-split/allow-split buffers, an `xItemSize` of 0 will result in an item with no data being set (i.e., item only contains the header). For byte buffers, an `xItemSize` of 0 will simply return `pdTRUE` without copying any data.

**Parameters**
- `xRingbuffer` - [in] Ring buffer to insert the item into
- `pvItem` - [in] Pointer to data to insert. NULL is allowed if `xItemSize` is 0.
- `xItemSize` - [in] Size of data to insert.
- `xTicksToWait` - [in] Ticks to wait for room in the ring buffer.

**Returns**
- `pdTRUE` if succeeded
- `pdFALSE` on time-out or when the data is larger than the maximum permissible size of the buffer

```c
BaseType_t xRingbufferSendFromISR (RingbufHandle_t xRingbuffer, const void *pvItem, size_t xItemSize, BaseType_t *pxHigherPriorityTaskWoken)
```
Insert an item into the ring buffer in an ISR.

Attempt to insert an item into the ring buffer from an ISR. This function will return immediately if there is insufficient free space in the buffer.

**Note:** For no-split/allow-split ring buffers, the actual size of memory that the item will occupy will be rounded up to the nearest 32-bit aligned size. This is done to ensure all items are always stored in 32-bit aligned fashion.

**Note:** For no-split/allow-split buffers, an xItemSize of 0 will result in an item with no data being set (i.e., item only contains the header). For byte buffers, an xItemSize of 0 will simply return pdTRUE without copying any data.

### Parameters
- **xRingbuffer** - [in] Ring buffer to insert the item into
- **pvItem** - [in] Pointer to data to insert. NULL is allowed if xItemSize is 0.
- **xItemSize** - [in] Size of data to insert.
- **pxHigherPriorityTaskWoken** - [out] Value pointed to will be set to pdTRUE if the function woke up a higher priority task.

### Returns
- pdTRUE if succeeded
- pdFALSE when the ring buffer does not have space.

```c
BaseType_t xRingbufferSendAcquire(RingbufHandle_t xRingbuffer, void **ppvItem, size_t xItemSize, TickType_t xTicksToWait)
```

Acquire memory from the ring buffer to be written to by an external source and to be sent later.

Attempt to allocate buffer for an item to be sent into the ring buffer. This function will block until enough free space is available or until it times out.

The item, as well as the following items SendAcquire or Send after it, will not be able to be read from the ring buffer until this item is actually sent into the ring buffer.

**Note:** Only applicable for no-split ring buffers now, the actual size of memory that the item will occupy will be rounded up to the nearest 32-bit aligned size. This is done to ensure all items are always stored in 32-bit aligned fashion.

**Note:** An xItemSize of 0 will result in a buffer being acquired, but the buffer will have a size of 0.

### Parameters
- **xRingbuffer** - [in] Ring buffer to allocate the memory
- **ppvItem** - [out] Double pointer to memory acquired (set to NULL if no memory were retrieved)
- **xItemSize** - [in] Size of item to acquire.
- **xTicksToWait** - [in] Ticks to wait for room in the ring buffer.

### Returns
- pdTRUE if succeeded
- pdFALSE on time-out or when the data is larger than the maximum permissible size of the buffer

```c
BaseType_t xRingbufferSendComplete(RingbufHandle_t xRingbuffer, void *pvItem)
```

Actually send an item into the ring buffer allocated before by xRingbufferSendAcquire.
Note: Only applicable for no-split ring buffers. Only call for items allocated by `xRingbufferSendAcquire`.

Parameters
- `xRingbuffer` [in] Ring buffer to insert the item into
- `pvItem` [in] Pointer to item in allocated memory to insert.

Returns
- `pdTRUE` if succeeded
- `pdFALSE` if fail for some reason.

void *`xRingbufferReceive(RingbufHandle_t xRingbuffer, size_t *pxItemSize, TickType_t xTicksToWait)`
Retrieve an item from the ring buffer.

Attempt to retrieve an item from the ring buffer. This function will block until an item is available or until it times out.

Note: A call to `vRingbufferReturnItem()` is required after this to free the item retrieved.

Note: It is possible to receive items with a pxItemSize of 0 on no-split/allow split buffers.

Parameters
- `xRingbuffer` [in] Ring buffer to retrieve the item from
- `pxItemSize` [out] Pointer to a variable to which the size of the retrieved item will be written.
- `xTicksToWait` [in] Ticks to wait for items in the ring buffer.

Returns
- Pointer to the retrieved item on success; *pxItemSize filled with the length of the item.
- NULL on timeout, *pxItemSize is untouched in that case.

void *`xRingbufferReceiveFromISR(RingbufHandle_t xRingbuffer, size_t *pxItemSize)`
Retrieve an item from the ring buffer in an ISR.

Attempt to retrieve an item from the ring buffer. This function returns immediately if there are no items available for retrieval.

Note: A call to `vRingbufferReturnItemFromISR()` is required after this to free the item retrieved.

Note: Byte buffers do not allow multiple retrievals before returning an item.

Note: Two calls to `RingbufferReceiveFromISR()` are required if the bytes wrap around the end of the ring buffer.

Note: It is possible to receive items with a pxItemSize of 0 on no-split/allow split buffers.

Parameters
- `xRingbuffer` [in] Ring buffer to retrieve the item from
- `pxItemSize` [out] Pointer to a variable to which the size of the retrieved item will be written.
Returns

- Pointer to the retrieved item on success; *pxItemSize filled with the length of the item.
- NULL when the ring buffer is empty, *pxItemSize is untouched in that case.

BaseType_t xRingbufferReceiveSplit (RingbufHandle_t xRingbuffer, void **ppvHeadItem, void **ppvTailItem, size_t *pxHeadItemSize, size_t *pxTailItemSize, TickType_t xTicksToWait)

Retrieve a split item from an allow-split ring buffer.

Attempt to retrieve a split item from an allow-split ring buffer. If the item is not split, only a single item is retrieved. If the item is split, both parts will be retrieved. This function will block until an item is available or until it times out.

Note: Call(s) to vRingbufferReturnItem() is required after this to free up the item(s) retrieved.

Parameters

- xRingbuffer -[in] Ring buffer to retrieve the item from
- ppvHeadItem -[out] Double pointer to first part (set to NULL if no items were retrieved)
- ppvTailItem -[out] Double pointer to second part (set to NULL if item is not split)
- pxHeadItemSize -[out] Pointer to size of first part (unmodified if no items were retrieved)
- pxTailItemSize -[out] Pointer to size of second part (unmodified if item is not split)
- xTicksToWait -[in] Ticks to wait for items in the ring buffer.

Returns

- pdTRUE if an item (split or unsplit) was retrieved
- pdFALSE when no item was retrieved

BaseType_t xRingbufferReceiveSplitFromISR (RingbufHandle_t xRingbuffer, void **ppvHeadItem, void **ppvTailItem, size_t *pxHeadItemSize, size_t *pxTailItemSize)

Retrieve a split item from an allow-split ring buffer in an ISR.

Attempt to retrieve a split item from an allow-split ring buffer. If the item is not split, only a single item is retrieved. If the item is split, both parts will be retrieved. This function returns immediately if there are no items available for retrieval.

Note: Calls to vRingbufferReturnItemFromISR() is required after this to free up the item(s) retrieved.

Parameters

- xRingbuffer -[in] Ring buffer to retrieve the item from
• **ppvHeadItem** – [out] Double pointer to first part (set to NULL if no items were retrieved)
• **ppvTailItem** – [out] Double pointer to second part (set to NULL if item is not split)
• **pxHeadItemSize** – [out] Pointer to size of first part (unmodified if no items were retrieved)
• **pxTailItemSize** – [out] Pointer to size of second part (unmodified if item is not split)

**Returns**
• pdTRUE if an item (split or unsplit) was retrieved
• pdFALSE when no item was retrieved

```c
void *xRingbufferReceiveUpTo(RingbufHandle_t xRingbuffer, size_t *pxItemSize, TickType_t xTicksToWait, size_t xMaxSize)
```

Retrieve bytes from a byte buffer, specifying the maximum amount of bytes to retrieve. Attempt to retrieve data from a byte buffer whilst specifying a maximum number of bytes to retrieve. This function will block until there is data available for retrieval or until it times out.

**Note:** A call to vRingbufferReturnItem() is required after this to free up the data retrieved.

**Note:** This function should only be called on byte buffers

**Note:** Byte buffers do not allow multiple retrievals before returning an item

**Note:** Two calls to RingbufferReceiveUpTo() are required if the bytes wrap around the end of the ring buffer.

**Parameters**
• **xRingbuffer** – [in] Ring buffer to retrieve the item from
• **pxItemSize** – [out] Pointer to a variable to which the size of the retrieved item will be written.
• **xTicksToWait** – [in] Ticks to wait for items in the ring buffer.
• **xMaxSize** – [in] Maximum number of bytes to return.

**Returns**
• Pointer to the retrieved item on success; *pxItemSize filled with the length of the item.
• NULL on timeout, *pxItemSize is untouched in that case.

```c
void *xRingbufferReceiveUpToFromISR(RingbufHandle_t xRingbuffer, size_t *pxItemSize, size_t xMaxSize)
```

Retrieve bytes from a byte buffer, specifying the maximum amount of bytes to retrieve. Call this from an ISR. Attempt to retrieve bytes from a byte buffer whilst specifying a maximum number of bytes to retrieve. This function will return immediately if there is no data available for retrieval.

**Note:** A call to vRingbufferReturnItemFromISR() is required after this to free up the data received.

**Note:** This function should only be called on byte buffers

**Note:** Byte buffers do not allow multiple retrievals before returning an item
Parameters
• `xRingbuffer` [in] Ring buffer to retrieve the item from
• `pxItemSize` [out] Pointer to a variable to which the size of the retrieved item will be written.
• `xMaxSize` [in] Maximum number of bytes to return. Size of 0 simply returns NULL.

Returns
• Pointer to the retrieved item on success; *pxItemSize filled with the length of the item.
• NULL when the ring buffer is empty, *pxItemSize is untouched in that case.

void `vRingbufferReturnItem` (RingbufHandle_t xRingbuffer, void *pvItem)
Return a previously-retrieved item to the ring buffer.

Note: If a split item is retrieved, both parts should be returned by calling this function twice

Parameters
• `xRingbuffer` [in] Ring buffer the item was retrieved from
• `pvItem` [in] Item that was received earlier

void `vRingbufferReturnItemFromISR` (RingbufHandle_t xRingbuffer, void *pvItem, BaseType_t *pxHigherPriorityTaskWoken)
Return a previously-retrieved item to the ring buffer from an ISR.

Note: If a split item is retrieved, both parts should be returned by calling this function twice

Parameters
• `xRingbuffer` [in] Ring buffer the item was retrieved from
• `pvItem` [in] Item that was received earlier
• `pxHigherPriorityTaskWoken` [out] Value pointed to will be set to pdTRUE if the function woke up a higher priority task.

void `vRingbufferDelete` (RingbufHandle_t xRingbuffer)
Delete a ring buffer.

Note: This function will not deallocate any memory if the ring buffer was created using `xRingbufferCreateStatic()`. Deallocation must be done manually by the user.

Parameters `xRingbuffer` [in] Ring buffer to delete

size_t `xRingbufferGetMaxItemSize` (RingbufHandle_t xRingbuffer)
Get maximum size of an item that can be placed in the ring buffer.

This function returns the maximum size an item can have if it was placed in an empty ring buffer.

Note: The max item size for a no-split buffer is limited to (((buffer_size/2)-header_size). This limit is imposed so that an item of max item size can always be sent to an empty no-split buffer regardless of the internal positions of the buffer’s read/write/free pointers.

Parameters `xRingbuffer` [in] Ring buffer to query
Returns Maximum size, in bytes, of an item that can be placed in a ring buffer.
size_t xRingbufferGetCurFreeSize(RingbufHandle_t xRingbuffer)
Get current free size available for an item/data in the buffer.
This gives the real time free space available for an item/data in the ring buffer. This represents the maximum size an item/data can have if it was currently sent to the ring buffer.

**Note:** An empty no-split buffer has a max current free size for an item that is limited to ((buffer_size/2)-header_size). See API reference for xRingbufferGetMaxItemSize().

**Warning:** This API is not thread safe. So, if multiple threads are accessing the same ring buffer, it is the application’s responsibility to ensure atomic access to this API and the subsequent Send

**Parameters**
- **xRingbuffer** – [in] Ring buffer to query

**Returns**
- Current free size, in bytes, available for an entry

BaseType_t xRingbufferAddToQueueSetRead(RingbufHandle_t xRingbuffer, QueueSetHandle_t xQueueSet)
Add the ring buffer to a queue set. Notified when data has been written to the ring buffer.
This function adds the ring buffer to a queue set, thus allowing a task to block on multiple queues/ring buffers. The queue set is notified when the new data becomes available to read on the ring buffer.

**Parameters**
- **xRingbuffer** – [in] Ring buffer to add to the queue set
- **xQueueSet** – [in] Queue set to add the ring buffer to

**Returns**
- pdTRUE on success, pdFALSE otherwise

static inline BaseType_t xRingbufferCanRead(RingbufHandle_t xRingbuffer, QueueSetMemberHandle_t xMember)
Check if the selected queue set member is a particular ring buffer.
This API checks if queue set member returned from xQueueSelectFromSet() is a particular ring buffer. If so, this indicates the ring buffer has items waiting to be retrieved.

**Parameters**
- **xRingbuffer** – [in] Ring buffer to check
- **xMember** – [in] Member returned from xQueueSelectFromSet

**Returns**
- pdTRUE when selected queue set member is the ring buffer
- pdFALSE otherwise.

BaseType_t xRingbufferRemoveFromQueueSetRead(RingbufHandle_t xRingbuffer, QueueSetHandle_t xQueueSet)
Remove the ring buffer from a queue set.
This function removes a ring buffer from a queue set. The ring buffer must have been previously added to the queue set using xRingbufferAddToQueueSetRead().

**Parameters**
- **xRingbuffer** – [in] Ring buffer to remove from the queue set
- **xQueueSet** – [in] Queue set to remove the ring buffer from

**Returns**
- pdTRUE on success
- pdFALSE otherwise

void vRingbufferGetInfo(RingbufHandle_t xRingbuffer, UBaseType_t *uxFree, UBaseType_t *uxRead, UBaseType_t *uxWrite, UBaseType_t *uxAcquire, UBaseType_t *uxItemsWaiting)
Get information about ring buffer status.

Get information of a ring buffer’s current status such as free/read/write/acquire pointer positions, and number of items waiting to be retrieved. Arguments can be set to NULL if they are not required.

**Parameters**

- `xRingbuffer` – [in] Ring buffer to remove from the queue set
- `uxFree` – [out] Pointer use to store free pointer position
- `uxRead` – [out] Pointer use to store read pointer position
- `uxWrite` – [out] Pointer use to store write pointer position
- `uxAcquire` – [out] Pointer use to store acquire pointer position
- `uxItemsWaiting` – [out] Pointer use to store number of items (bytes for byte buffer) waiting to be retrieved

```c
void xRingbufferPrintInfo (RingbufHandle_t xRingbuffer)
```

Debugging function to print the internal pointers in the ring buffer.

**Parameters** `xRingbuffer` – Ring buffer to show

**Structures**

```c
struct xSTATIC_RINGBUFFER
```

Struct that is equivalent in size to the ring buffer’s data structure.

The contents of this struct are not meant to be used directly. This structure is meant to be used when creating a statically allocated ring buffer where this struct is of the exact size required to store a ring buffer’s control data structure.

**Type Definitions**

```c
typedef void *RingbufHandle_t
```

Type by which ring buffers are referenced. For example, a call to `xRingbufferCreate()` returns a `RingbufHandle_t` variable that can then be used as a parameter to `xRingbufferSend()`, `xRingbufferReceive()`, etc.

```c
typedef struct xSTATIC_RINGBUFFER StaticRingbuffer_t
```

Struct that is equivalent in size to the ring buffer’s data structure.

The contents of this struct are not meant to be used directly. This structure is meant to be used when creating a statically allocated ring buffer where this struct is of the exact size required to store a ring buffer’s control data structure.

**Enumerations**

```c
enum RingbufferType_t
```

Values:

- `RINGBUF_TYPE_NOSPLIT` No-split buffers will only store an item in contiguous memory and will never split an item. Each item requires an 8 byte overhead for a header and will always internally occupy a 32-bit aligned size of space.

- `RINGBUF_TYPE_ALLOW_SPLIT` Allow-split buffers will split an item into two parts if necessary in order to store it. Each item requires an 8 byte overhead for a header, splitting incurs an extra header. Each item will always internally occupy a 32-bit aligned size of space.
enumerator **RINGBUF_TYPE_BYTEBUF**

Byte buffers store data as a sequence of bytes and do not maintain separate items, therefore byte buffers have no overhead. All data is stored as a sequence of byte and any number of bytes can be sent or retrieved each time.

enumerator **RINGBUF_TYPE_MAX**

## Hooks API

### Header File

- components/esp_system/include/esp_freertos_hooks.h

### Functions

**esp_err_t esp_register_freertos_idle_hook_for_cpu** *(esp_freertos_idle_cb_t new_idle_cb, UBaseType_t cpuid)*

Register a callback to be called from the specified core’s idle hook. The callback should return true if it should be called by the idle hook once per interrupt (or FreeRTOS tick), and return false if it should be called repeatedly as fast as possible by the idle hook.

**Warning:** Idle callbacks MUST NOT, UNDER ANY CIRCUMSTANCES, CALL A FUNCTION THAT MIGHT BLOCK.

**Parameters**

- **new_idle_cb** – [in] Callback to be called
- **cpuid** – [in] id of the core

**Returns**

- ESP_OK: Callback registered to the specified core’s idle hook
- ESP_ERR_NO_MEM: No more space on the specified core’s idle hook to register callback
- ESP_ERR_INVALID_ARG: cpuid is invalid

**esp_err_t esp_register_freertos_idle_hook** *(esp_freertos_idle_cb_t new_idle_cb)*

Register a callback to the idle hook of the core that calls this function. The callback should return true if it should be called by the idle hook once per interrupt (or FreeRTOS tick), and return false if it should be called repeatedly as fast as possible by the idle hook.

**Warning:** Idle callbacks MUST NOT, UNDER ANY CIRCUMSTANCES, CALL A FUNCTION THAT MIGHT BLOCK.

**Parameters**

- **new_idle_cb** – [in] Callback to be called

**Returns**

- ESP_OK: Callback registered to the calling core’s idle hook
- ESP_ERR_NO_MEM: No more space on the calling core’s idle hook to register callback

**esp_err_t esp_register_freertos_tick_hook_for_cpu** *(esp_freertos_tick_cb_t new_tick_cb, UBaseType_t cpuid)*

Register a callback to be called from the specified core’s tick hook.

**Parameters**

- **new_tick_cb** – [in] Callback to be called
- **cpuid** – [in] id of the core
Returns

- ESP_OK: Callback registered to specified core’s tick hook
- ESP_ERR_NO_MEM: No more space on the specified core’s tick hook to register the callback
- ESP_ERR_INVALID_ARG: cpuid is invalid

```
esp_err_t esp_register_freertos_tick_hook(esp_freertos_tick_cb_t new_tick_cb)
```

Register a callback to be called from the calling core’s tick hook.

**Parameters**

- `new_tick_cb` - [in] Callback to be called

**Returns**

- ESP_OK: Callback registered to the calling core’s tick hook
- ESP_ERR_NO_MEM: No more space on the calling core’s tick hook to register the callback

```
void esp_unregister_freertos_idle_hook_for_cpu (esp_freertos_idle_cb_t old_idle_cb, UBaseType_t cpuid)
```

Unregister an idle callback from the idle hook of the specified core.

**Parameters**

- `old_idle_cb` - [in] Callback to be unregistered
- `cpuid` - [in] id of the core

```
void esp_unregister_freertos_idle_hook (esp_freertos_idle_cb_t old_idle_cb)
```

Unregister an idle callback. If the idle callback is registered to the idle hooks of both cores, the idle hook will be unregistered from both cores.

**Parameters**

- `old_idle_cb` - [in] Callback to be unregistered

```
void esp_unregister_freertos_tick_hook_for_cpu (esp_freertos_tick_cb_t old_tick_cb, UBaseType_t cpuid)
```

Unregister a tick callback from the tick hook of the specified core.

**Parameters**

- `old_tick_cb` - [in] Callback to be unregistered
- `cpuid` - [in] id of the core

```
void esp_unregister_freertos_tick_hook (esp_freertos_tick_cb_t old_tick_cb)
```

Unregister a tick callback. If the tick callback is registered to the tick hooks of both cores, the tick hook will be unregistered from both cores.

**Parameters**

- `old_tick_cb` - [in] Callback to be unregistered

**Type Definitions**

- typedef bool (*esp_freertos_idle_cb_t)(void)
- typedef void (*esp_freertos_tick_cb_t)(void)

**Additional API**

**Header File**

- components/freertos/esp_additions/include/freertos/idf_additions.h

**Functions**
BaseType_t xTaskCreatePinnedToCoreWithCaps(TaskFunction_t pvTaskCode, const char *const pcName, const configSTACK_DEPTH_TYPE usStackDepth, void *const pvParameters, UBaseType_t uxPriority, TaskHandle_t *const pvCreatedTask, const BaseType_t xCoreID, UBaseType_t uxMemoryCaps)

Creates a pinned task where its stack has specific memory capabilities.

This function is similar to xTaskCreatePinnedToCore(), except that it allows the memory allocated for the task’s stack to have specific capabilities (e.g., MALLOC_CAP_SPIRAM).

However, the specified capabilities will NOT apply to the task’s TCB as a TCB must always be in internal RAM.

**Parameters**

- **pvTaskCode** - Pointer to the task entry function
- **pcName** - A descriptive name for the task
- **usStackDepth** - The size of the task stack specified as the number of bytes
- **pvParameters** - Pointer that will be used as the parameter for the task being created.
- **uxPriority** - The priority at which the task should run.
- **pvCreatedTask** - Used to pass back a handle by which the created task can be referenced.
- **xCOREID** - Core to which the task is pinned to, or tskNO_AFFINITY if unpinned.
- **uxMemoryCaps** - Memory capabilities of the task stack’s memory (see esp_heap_caps.h)

**Returns**

pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

static inline BaseType_t xTaskCreateWithCaps(TaskFunction_t pvTaskCode, const char *const pcName, configSTACK_DEPTH_TYPE usStackDepth, void *const pvParameters, UBaseType_t uxPriority, TaskHandle_t *pvCreatedTask, UBaseType_t uxMemoryCaps)

Creates a task where its stack has specific memory capabilities.

This function is similar to xTaskCreate(), except that it allows the memory allocated for the task’s stack to have specific capabilities (e.g., MALLOC_CAP_SPIRAM).

However, the specified capabilities will NOT apply to the task’s TCB as a TCB must always be in internal RAM.

**Note:** A task created using this function must only be deleted using vTaskDeleteWithCaps()

**Parameters**

- **pvTaskCode** - Pointer to the task entry function
- **pcName** - A descriptive name for the task
- **usStackDepth** - The size of the task stack specified as the number of bytes
- **pvParameters** - Pointer that will be used as the parameter for the task being created.
- **uxPriority** - The priority at which the task should run.
- **pvCreatedTask** - Used to pass back a handle by which the created task can be referenced.
- **uxMemoryCaps** - Memory capabilities of the task stack’s memory (see esp_heap_caps.h)

**Returns**

pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

void vTaskDeleteWithCaps(TaskHandle_t xTaskToDelete)

Deletes a task previously created using xTaskCreateWithCaps() or xTaskCreatePinnedToCoreWithCaps()

**Parameters**

- **xTaskToDelete** - A handle to the task to be deleted
QueueHandle_t ** QueueHandle_t xQueueCreateWithCaps (UBaseType_t uxQueueLength, UBaseType_t uxItemSize, UBaseType_t uxMemoryCaps)

Creates a queue with specific memory capabilities.

This function is similar to xQueueCreate(), except that it allows the memory allocated for the queue to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A queue created using this function must only be deleted using vQueueDeleteWithCaps()

Parameters

- **uxQueueLength** – The maximum number of items that the queue can contain.
- **uxItemSize** – The number of bytes each item in the queue will require.
- **uxMemoryCaps** – Memory capabilities of the queue’s memory (see esp_heap_caps.h)

Returns Handle to the created queue or NULL on failure.

void vQueueDeleteWithCaps (QueueHandle_t xQueue)

Deletes a queue previously created using xQueueCreateWithCaps()

Parameters xQueue – A handle to the queue to be deleted.

static inline SemaphoreHandle_t ** SemaphoreHandle_t xSemaphoreCreateBinaryWithCaps (UBaseType_t uxMemoryCaps)

Creates a binary semaphore with specific memory capabilities.

This function is similar to vSemaphoreCreateBinary(), except that it allows the memory allocated for the binary semaphore to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A binary semaphore created using this function must only be deleted using vSemaphoreDeleteWithCaps()

Parameters uxMemoryCaps – Memory capabilities of the binary semaphore’s memory (see esp_heap_caps.h)

Returns Handle to the created binary semaphore or NULL on failure.

static inline SemaphoreHandle_t ** SemaphoreHandle_t xSemaphoreCreateCountingWithCaps (UBaseType_t uxMaxCount, UBaseType_t uxInitialCount, UBaseType_t uxMemoryCaps)

Creates a counting semaphore with specific memory capabilities.

This function is similar to xSemaphoreCreateCounting(), except that it allows the memory allocated for the counting semaphore to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A counting semaphore created using this function must only be deleted using vSemaphoreDeleteWithCaps()

Parameters

- **uxMaxCount** – The maximum count value that can be reached.
- **uxInitialCount** – The count value assigned to the semaphore when it is created.
- **uxMemoryCaps** – Memory capabilities of the counting semaphore’s memory (see esp_heap_caps.h)

Returns Handle to the created counting semaphore or NULL on failure.

static inline SemaphoreHandle_t ** SemaphoreHandle_t xSemaphoreCreateMutexWithCaps (UBaseType_t uxMemoryCaps)

Creates a mutex semaphore with specific memory capabilities.
Chapter 2. API Reference

This function is similar to xSemaphoreCreateMutex(), except that it allows the memory allocated for the mutex semaphore to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A mutex semaphore created using this function must only be deleted using vSemaphoreDeleteWithCaps().

**Parameters**
uxMemoryCaps – Memory capabilities of the mutex semaphore’s memory (see esp_heap_caps.h)

**Returns**
Handle to the created mutex semaphore or NULL on failure.

```c
static inline SemaphoreHandle_t xSemaphoreCreateRecursiveMutexWithCaps(UBaseType_t uxMemoryCaps)
```

Creates a recursive mutex with specific memory capabilities.

This function is similar to xSemaphoreCreateRecursiveMutex(), except that it allows the memory allocated for the recursive mutex to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A recursive mutex created using this function must only be deleted using vSemaphoreDeleteWithCaps().

**Parameters**
uxMemoryCaps – Memory capabilities of the recursive mutex’s memory (see esp_heap_caps.h)

**Returns**
Handle to the created recursive mutex or NULL on failure.

```c
void vSemaphoreDeleteWithCaps(SemaphoreHandle_t xSemaphore)
```

Deletes a semaphore previously created using one of the xSemaphoreCreate...WithCaps() functions.

**Parameters**
uxSemaphore – A handle to the semaphore to be deleted.

```c
static inline StreamBufferHandle_t xStreamBufferCreateWithCaps(size_t xBufferSizeBytes, size_t xTriggerLevelBytes, UBaseType_t uxMemoryCaps)
```

Creates a stream buffer with specific memory capabilities.

This function is similar to xStreamBufferCreate(), except that it allows the memory allocated for the stream buffer to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A stream buffer created using this function must only be deleted using vStreamBufferDeleteWithCaps().

**Parameters**
- xBufferSizeBytes – The total number of bytes the stream buffer will be able to hold at any one time.
- xTriggerLevelBytes – The number of bytes that must be in the stream buffer before unblocking
- uxMemoryCaps – Memory capabilities of the stream buffer’s memory (see esp_heap_caps.h)

**Returns**
Handle to the created stream buffer or NULL on failure.

```c
static inline void vStreamBufferDeleteWithCaps(StreamBufferHandle_t xStreamBuffer)
```

Deletes a stream buffer previously created using xStreamBufferCreateWithCaps().

**Parameters**
uxStreamBuffer – A handle to the stream buffer to be deleted.

```c
static inline MessageBufferHandle_t xMessageBufferCreateWithCaps(size_t xBufferSizeBytes, UBaseType_t uxMemoryCaps)
```
Chapter 2. API Reference

Creates a message buffer with specific memory capabilities.

This function is similar to xMessageBufferCreate(), except that it allows the memory allocated for the message buffer to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** A message buffer created using this function must only be deleted using vMessageBufferDeleteWithCaps()

### Parameters

- **xBufferSizeBytes** - The total number of bytes (not messages) the message buffer will be able to hold at any one time.

- **uxMemoryCaps** - Memory capabilities of the message buffer’s memory (see esp_heap_caps.h)

### Returns

Handle to the created message buffer or NULL on failure.

static inline void vMessageBufferDeleteWithCaps (MessageBufferHandle_t xMessageBuffer)

Deletes a stream buffer previously created using xMessageBufferCreateWithCaps()

### Parameters

- **xMessageBuffer** - A handle to the message buffer to be deleted.

### Event Group

**EventGroupHandle_t xEventGroupCreateWithCaps** (UBaseType_t uxMemoryCaps)

Creates an event group with specific memory capabilities.

This function is similar to xEventGroupCreate(), except that it allows the memory allocated for the event group to have specific capabilities (e.g., MALLOC_CAP_INTERNAL).

**Note:** An event group created using this function must only be deleted using vEventGroupDeleteWithCaps()

### Parameters

- **uxMemoryCaps** - Memory capabilities of the event group’s memory (see esp_heap_caps.h)

### Returns

Handle to the created event group or NULL on failure.

void vEventGroupDeleteWithCaps (EventGroupHandle_t xEventGroup)

Deletes an event group previously created using xEventGroupCreateWithCaps()

### Parameters

- **xEventGroup** - A handle to the event group to be deleted.

### 2.10.13 Heap Memory Allocation

#### Stack and Heap

ESP-IDF applications use the common computer architecture patterns of stack (dynamic memory allocated by program control flow) and heap (dynamic memory allocated by function calls), as well as statically allocated memory (allocated at compile time).

Because ESP-IDF is a multi-threaded RTOS environment, each RTOS task has its own stack. By default, each of these stacks is allocated from the heap when the task is created. (See xTaskCreateStatic() for the alternative where stacks are statically allocated.)

Because ESP32 uses multiple types of RAM, it also contains multiple heaps with different capabilities. A capabilities-based memory allocator allows apps to make heap allocations for different purposes.

For most purposes, the standard libc `malloc()` and `free()` functions can be used for heap allocation without any special consideration.
However, in order to fully make use of all of the memory types and their characteristics, ESP-IDF also has a capabilities-based heap memory allocator. If you want to have memory with certain properties (for example, DMA-Capable Memory or executable-memory), you can create an OR-mask of the required capabilities and pass that to `heap_caps_malloc()`.

### Memory Capabilities

The ESP32 contains multiple types of RAM:

- **DRAM (Data RAM)** is memory used to hold data. This is the most common kind of memory accessed as heap.
- **IRAM (Instruction RAM)** usually holds executable data only. If accessed as generic memory, all accesses must be 32-bit aligned.
- **D/IRAM** is RAM which can be used as either Instruction or Data RAM.

For more details on these internal memory types, see [Memory Types](#).

It’s also possible to connect external SPI RAM to the ESP32 - external RAM can be integrated into the ESP32’s memory map using the flash cache, and accessed similarly to DRAM.

DRAM uses capability `MALLOC_CAP_8BIT` (accessible in single byte reads and writes). To test the free DRAM heap size at runtime, call `heap_caps_get_free_size(MALLOC_CAP_8BIT)`.

When calling `malloc()`, the ESP-IDF `malloc()` implementation internally calls `heap_caps_malloc_default(size)`. This will allocate memory with capability `MALLOC_CAP_DEFAULT`, which is byte-addressable.

Because `malloc()` uses the capabilities-based allocation system, memory allocated using `heap_caps_malloc()` can be freed by calling the standard `free()` function.

### Available Heap

**DRAM** At startup, the DRAM heap contains all data memory which is not statically allocated by the app. Reducing statically allocated buffers will increase the amount of available free heap.

To find the amount of statically allocated memory, use the `idf.py size` command.

**Note:** See the [DRAM (Data RAM)](#DRAM) section for more details about the DRAM usage limitations.

**Note:** At runtime, the available heap DRAM may be less than calculated at compile time, because at startup some memory is allocated from the heap before the FreeRTOS scheduler is started (including memory for the stacks of initial FreeRTOS tasks).

**IRAM** At startup, the IRAM heap contains all instruction memory which is not used by the app executable code. The `idf.py size` command can be used to find the amount of IRAM used by the app.

**D/IRAM** Some memory in the ESP32 is available as either DRAM or IRAM. If memory is allocated from a D/IRAM region, the free heap size for both types of memory will decrease.

**Heap Sizes** At startup, all ESP-IDF apps log a summary of all heap addresses (and sizes) at level Info:
I (252) heap_init: Initializing. RAM available for dynamic allocation:
I (259) heap_init: At 3FFAE6E0 len 00001920 (6 KiB): DRAM
I (265) heap_init: At 3FFB2EC8 len 0002D138 (180 KiB): DRAM
I (272) heap_init: At 3FFE0440 len 00003AE0 (14 KiB): D/IRAM
I (278) heap_init: At 3FFE4350 len 0001BCB0 (111 KiB): D/IRAM
I (284) heap_init: At 4008944C len 00016BB4 (90 KiB): IRAM

Finding available heap  See Heap Information.

Special Capabilities

DMA-Capable Memory  Use the MALLOC_CAP_DMA flag to allocate memory which is suitable for use with hardware DMA engines (for example SPI and I2S). This capability flag excludes any external PSRAM.

32-Bit Accessible Memory  If a certain memory structure is only addressed in 32-bit units, for example an array of ints or pointers, it can be useful to allocate it with the MALLOC_CAP_32BIT flag. This also allows the allocator to give out IRAM memory; something which it can’t do for a normal malloc() call. This can help to use all the available memory in the ESP32.

Please note that on ESP32 series chips, MALLOC_CAP_32BIT cannot be used for storing floating-point variables. This is because MALLOC_CAP_32BIT may return instruction RAM, and the floating-point assembly instructions on ESP32 cannot access instruction RAM.

Memory allocated with MALLOC_CAP_32BIT can only be accessed via 32-bit reads and writes, any other type of access will generate a fatal LoadStoreError exception.

External SPI Memory  When external RAM is enabled, external SPI RAM under 4MiB in size can be allocated using standard malloc calls, or via heap_caps_malloc(MALLOC_CAP_SPIRAM), depending on configuration. See Configuring External RAM for more details.

To use the region above the 4MiB limit, you can use the himem API.

Thread Safety

Heap functions are thread safe, meaning they can be called from different tasks simultaneously without any limitations.

It is technically possible to call malloc, free, and related functions from interrupt handler (ISR) context (see Calling heap related functions from ISR). However this is not recommended, as heap function calls may delay other interrupts. It is strongly recommended to refactor applications so that any buffers used by an ISR are pre-allocated outside of the ISR. Support for calling heap functions from ISRs may be removed in a future update.

Calling heap related functions from ISR

The following functions from the heap component can be called form interrupt handler (ISR):

- heap_caps_malloc()
- heap_caps_malloc_default()
- heap_caps_realloc_default()
- heap_caps_malloc_prefer()
- heap_caps_realloc_prefer()
- heap_caps_calloc_prefer()
- heap_caps_free()
- heap_caps_realloc()
- heap_caps_calloc()
- heap_caps_aligned_alloc()
- heap_caps_aligned_free()
Note however this practice is strongly discouraged.

**Heap Tracing & Debugging**

The following features are documented on the *Heap Memory Debugging* page:

- *Heap Information* (free space, etc.)
- *Heap allocation and free function hooks*
- *Heap Corruption Detection*
- *Heap Tracing* (memory leak detection, monitoring, etc.)

**Implementation Notes**

Knowledge about the regions of memory in the chip comes from the “soc” component, which contains memory layout information for the chip, and the different capabilities of each region. Each region’s capabilities are prioritised, so that (for example) dedicated DRAM and IRAM regions will be used for allocations ahead of the more versatile D/IRAM regions.

Each contiguous region of memory contains its own memory heap. The heaps are created using the *multi_heap* functionality. *multi_heap* allows any contiguous region of memory to be used as a heap.

The heap capabilities allocator uses knowledge of the memory regions to initialize each individual heap. Allocation functions in the heap capabilities API will find the most appropriate heap for the allocation (based on desired capabilities, available space, and preferences for each region’s use) and then calling *multi_heap_malloc()* for the heap situated in that particular region.

Calling *free()* involves finding the particular heap corresponding to the freed address, and then calling *multi_heap_free()* on that particular *multi_heap* instance.

**API Reference - Heap Allocation**

**Header File**

- components/heap/include/esp_heap_caps.h

**Functions**

```c
esp_err_t heap_caps_register_failed_alloc_callback(esp_alloc_failed_hook_t callback)
```

registers a callback function to be invoked if a memory allocation operation fails

**Parameters**

- *callback* – caller defined callback to be invoked

**Returns**

- ESP_OK if callback was registered.

```c
void *heap_caps_malloc(size_t size, uint32_t caps)
```

Allocate a chunk of memory which has the given capabilities.

**Equivalent semantics to libc malloc(), for capability-aware memory.**

**Parameters**

- *size* – Size, in bytes, of the amount of memory to allocate
- *caps* – Bitwise OR of MALLOC_CAP_* flags indicating the type of memory to be returned

**Returns**

- A pointer to the memory allocated on success, NULL on failure

```c
void heap_caps_free(void *ptr)
```

Free memory previously allocated via heap_caps_malloc() or heap_caps_realloc().

**Equivalent semantics to libc free(), for capability-aware memory.**

In IDF, *free(p)* is equivalent to *heap_caps_free(p)*.
**Parameters**

- **ptr** - Pointer to memory previously returned from `heap_caps_malloc()` or `heap_caps_realloc()`. Can be NULL.

```c
void *heap_caps_realloc (void *ptr, size_t size, uint32_t caps)
```

Reallocate memory previously allocated via `heap_caps_malloc()` or `heap_caps_realloc()`.

Equivalent semantics to `libc realloc()`, for capability-aware memory.

In IDF, `realloc(p, s)` is equivalent to `heap_caps_realloc(p, s, MALLOC_CAP_8BIT)`.

`caps` parameter can be different to the capabilities that any original `ptr` was allocated with. In this way, realloc can be used to “move” a buffer if necessary to ensure it meets a new set of capabilities.

**Parameters**

- `ptr` - Pointer to previously allocated memory, or NULL for a new allocation.
- `size` - Size of the new buffer requested, or 0 to free the buffer.
- `caps` - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory desired for the new allocation.

**Returns**

- Pointer to a new buffer of size ‘size’ with capabilities ‘caps’, or NULL if allocation failed.

```c
void *heap_caps_aligned_alloc (size_t alignment, size_t size, uint32_t caps)
```

Allocate an aligned chunk of memory which has the given capabilities.

Equivalent semantics to `libc aligned_alloc()`, for capability-aware memory.

**Parameters**

- `alignment` - How the pointer received needs to be aligned must be a power of two
- `size` - Size, in bytes, of the amount of memory to allocate
- `caps` - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory to be returned

**Returns**

- A pointer to the memory allocated on success, NULL on failure

```c
void heap_caps_aligned_free (void *ptr)
```

Used to deallocate memory previously allocated with `heap_caps_aligned_alloc`.

**Note:** This function is deprecated, please consider using `heap_caps_free()` instead.

```c
void *heap_caps_aligned_calloc (size_t alignment, size_t n, size_t size, uint32_t caps)
```

Allocate an aligned chunk of memory which has the given capabilities. The initialized value in the memory is set to zero.

**Parameters**

- `alignment` - How the pointer received needs to be aligned must be a power of two
- `n` - Number of continuing chunks of memory to allocate
- `size` - Size, in bytes, of a chunk of memory to allocate
- `caps` - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory to be returned

**Returns**

- A pointer to the memory allocated on success, NULL on failure

```c
void *heap_caps_calloc (size_t n, size_t size, uint32_t caps)
```

Allocate a chunk of memory which has the given capabilities. The initialized value in the memory is set to zero.

Equivalent semantics to `libc calloc()`, for capability-aware memory.

In IDF, `calloc(p)` is equivalent to `heap_caps_calloc(p, MALLOC_CAP_8BIT)`.

**Parameters**

- `n` - Number of continuing chunks of memory to allocate
Chapter 2. API Reference

- **size** - Size, in bytes, of a chunk of memory to allocate
- **caps** - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory to be returned

**Returns** A pointer to the memory allocated on success, NULL on failure

```c
size_t heap_caps_get_total_size (uint32_t caps)
```

Get the total size of all the regions that have the given capabilities.

This function takes all regions capable of having the given capabilities allocated in them and adds up the total space they have.

**Parameters**
- **caps** - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

**Returns** Total size in bytes

```c
size_t heap_caps_get_free_size (uint32_t caps)
```

Get the total free size of all the regions that have the given capabilities.

This function takes all regions capable of having the given capabilities allocated in them and adds up the free space they have.

**Parameters**
- **caps** - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

**Returns** Amount of free bytes in the regions

```c
size_t heap_caps_get_minimum_free_size (uint32_t caps)
```

Get the total minimum free memory of all regions with the given capabilities.

This adds all the low watermarks of the regions capable of delivering the memory with the given capabilities.

**Note:** Note that because of heap fragmentation it is probably not possible to allocate a single block of memory of this size. Use heap_caps_get_largest_free_block() for this purpose.

**Parameters**
- **caps** - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

**Returns** Amount of free bytes in the regions

```c
size_t heap_caps_get_largest_free_block (uint32_t caps)
```

Get the largest free block of memory able to be allocated with the given capabilities.

Returns the largest value of \( s \) for which \( \text{heap_caps_malloc}(s, \ caps) \) will succeed.

**Parameters**
- **caps** - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

**Returns** Size of the largest free block in bytes.

```c
void heap_caps_get_info (multi_heap_info_t *info, uint32_t caps)
```

Get heap info for all regions with the given capabilities.

Calls multi_heap_info() on all heaps which share the given capabilities. The information returned is an aggregate across all matching heaps. The meanings of fields are the same as defined for multi_heap_info_t, except that minimum_free_bytes has the same caveats described in heap_caps_get_minimum_free_size().

**Parameters**
- **info** - Pointer to a structure which will be filled with relevant heap metadata.
- **caps** - Bitwise OR of MALLOC_CAP_* flags indicating the type of memory
void heap_caps_print_heap_info (uint32_t caps)
  Print a summary of all memory with the given capabilities.
  Calls multi_heap_info on all heaps which share the given capabilities, and prints a two-line summary for each,
  then a total summary.
  
  Parameters caps – Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

bool heap_caps_check_integrity_all (bool print_errors)
  Check integrity of all heap memory in the system.
  Calls multi_heap_check on all heaps. Optionally print errors if heaps are corrupt.
  Calling this function is equivalent to calling heap_caps_check_integrity with the caps argument set to MAL-
  LOC_CAP_INVALID.

  Note: Please increase the value of CONFIG_ESP_INT_WDT_TIMEOUT_MS when using this API with
  PSRAM enabled.

  Parameters print_errors – Print specific errors if heap corruption is found.
  Returns True if all heaps are valid, False if at least one heap is corrupt.

bool heap_caps_check_integrity (uint32_t caps, bool print_errors)
  Check integrity of all heaps with the given capabilities.
  Calls multi_heap_check on all heaps which share the given capabilities. Optionally print errors if the heaps are
  corrupt.
  See also heap_caps_check_integrity_all to check all heap memory in the system and
  heap_caps_check_integrity_addr to check memory around a single address.

  Note: Please increase the value of CONFIG_ESP_INT_WDT_TIMEOUT_MS when using this API with
  PSRAM capability flag.

  Parameters
  • caps – Bitwise OR of MALLOC_CAP_* flags indicating the type of memory
  • print_errors – Print specific errors if heap corruption is found.
  Returns True if all heaps are valid, False if at least one heap is corrupt.

bool heap_caps_check_integrity_addr (intptr_t addr, bool print_errors)
  Check integrity of heap memory around a given address.
  This function can be used to check the integrity of a single region of heap memory, which contains the given
  address.
  This can be useful if debugging heap integrity for corruption at a known address, as it has a lower over-
  head than checking all heap regions. Note that if the corrupt address moves around between runs (due to
  timing or other factors) then this approach won’t work, and you should call heap_caps_check_integrity or
  heap_caps_check_integrity_all instead.

  Note: The entire heap region around the address is checked, not only the adjacent heap blocks.

  Parameters
  • addr – Address in memory. Check for corruption in region containing this address.
  • print_errors – Print specific errors if heap corruption is found.
  Returns True if the heap containing the specified address is valid, False if at least one heap is
  corrupt or the address doesn’t belong to a heap region.
Chapter 2. API Reference

void heap_caps_malloc_extmem_enable(size_t limit)
Enable malloc() in external memory and set limit below which malloc() attempts are placed in internal memory.

When external memory is in use, the allocation strategy is to initially try to satisfy smaller allocation requests with internal memory and larger requests with external memory. This sets the limit between the two, as well as generally enabling allocation in external memory.

Parameters

limit – Limit, in bytes.

void *heap_caps_malloc_prefer(size_t size, size_t num, ...)
Allocate a chunk of memory as preference in decreasing order.

Attention The variable parameters are bitwise OR of MALLOC_CAP_* flags indicating the type of memory. This API prefers to allocate memory with the first parameter. If failed, allocate memory with the next parameter. It will try in this order until allocating a chunk of memory successfully or fail to allocate memories with any of the parameters.

Parameters

• size – Size, in bytes, of the amount of memory to allocate
• num – Number of variable parameters

Returns A pointer to the memory allocated on success, NULL on failure.

void *heap_caps_realloc_prefer(void *ptr, size_t size, size_t num, ...)
Reallocate a chunk of memory as preference in decreasing order.

Parameters

• ptr – Pointer to previously allocated memory, or NULL for a new allocation.
• size – Size of the new buffer requested, or 0 to free the buffer.
• num – Number of variable parameters

Returns Pointer to a new buffer of size ‘size’, or NULL if allocation failed.

void *heap_caps_calloc_prefer(size_t n, size_t size, size_t num, ...)
Allocate a chunk of memory as preference in decreasing order.

Parameters

• n – Number of continuing chunks of memory to allocate
• size – Size, in bytes, of a chunk of memory to allocate
• num – Number of variable parameters

Returns A pointer to the memory allocated on success, NULL on failure.

void heap_caps_dump(uint32_t caps)
Dump the full structure of all heaps with matching capabilities.

Prints a large amount of output to serial (because of locking limitations, the output bypasses stdout(stderr)). For each (variable sized) block in each matching heap, the following output is printed on a single line:

• Block address (the data buffer returned by malloc is 4 bytes after this if heap debugging is set to Basic, or 8 bytes otherwise).
• Data size (the data size may be larger than the size requested by malloc, either due to heap fragmentation or because of heap debugging level).
• Address of next block in the heap.
• If the block is free, the address of the next free block is also printed.

Parameters

caps – Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

void heap_caps_dump_all(void)
Dump the full structure of all heaps.
Covers all registered heaps. Prints a large amount of output to serial.
Output is the same as for `heap_caps_dump`.

```c
size_t heap_caps_get_allocated_size (void *ptr)
```

Return the size that a particular pointer was allocated with.

---

**Note:** The app will crash with an assertion failure if the pointer is not valid.

**Parameters** `ptr` - Pointer to currently allocated heap memory. Must be a pointer value previously returned by `heap_caps_malloc`, `malloc`, `calloc`, etc. and not yet freed.

**Returns** Size of the memory allocated at this block.

---

**Macros**

- **`HEAP_IRAM_ATTR`**
- **`MALLOC_CAP_EXEC`**
  - Flags to indicate the capabilities of the various memory systems.
  - Memory must be able to run executable code
- **`MALLOC_CAP_32BIT`**
  - Memory must allow for aligned 32-bit data accesses.
- **`MALLOC_CAP_8BIT`**
  - Memory must allow for 8/16/...-bit data accesses.
- **`MALLOC_CAP_DMA`**
  - Memory must be able to accessed by DMA.
- **`MALLOC_CAP_PID2`**
  - Memory must be mapped to PID2 memory space (PIDs are not currently used)
- **`MALLOC_CAP_PID3`**
  - Memory must be mapped to PID3 memory space (PIDs are not currently used)
- **`MALLOC_CAP_PID4`**
  - Memory must be mapped to PID4 memory space (PIDs are not currently used)
- **`MALLOC_CAP_PID5`**
  - Memory must be mapped to PID5 memory space (PIDs are not currently used)
- **`MALLOC_CAP_PID6`**
  - Memory must be mapped to PID6 memory space (PIDs are not currently used)
- **`MALLOC_CAP_PID7`**
  - Memory must be mapped to PID7 memory space (PIDs are not currently used)
- **`MALLOC_CAP_SPIRAM`**
  - Memory must be in SPI RAM.
Chapter 2. API Reference

**MALLOC_CAP_INTERNAL**
Memory must be internal; specifically it should not disappear when flash/spiram cache is switched off.

**MALLOC_CAP_DEFAULT**
Memory can be returned in a non-capability-specific memory allocation (e.g. malloc(), calloc()) call.

**MALLOC_CAP_IRAM_8BIT**
Memory must be in IRAM and allow unaligned access.

**MALLOC_CAP_RETENTION**
Memory must be able to accessed by retention DMA.

**MALLOC_CAP_RTCRAM**
Memory must be in RTC fast memory.

**MALLOC_CAP_INVALID**
Memory cannot be used / list end marker.

### Type Definitions

typedef void (*esp_alloc_failed_hook_t)(size_t size, uint32_t caps, const char* function_name)
callback called when an allocation operation fails, if registered

- **Param size** in bytes of failed allocation
- **Param caps** capabilities requested of failed allocation
- **Param function_name** function which generated the failure

### API Reference - Initialisation

**Header File**

- components/heap/include/esp_heap_caps_init.h

**Functions**

void **heap_caps_init** (void)
Initialize the capability-aware heap allocator.

This is called once in the IDF startup code. Do not call it at other times.

void **heap_caps_enable_nonos_stack_heaps** (void)
Enable heap(s) in memory regions where the startup stacks are located.

On startup, the pro/app CPUs have a certain memory region they use as stack, so we cannot do allocations in the regions these stack frames are. When FreeRTOS is completely started, they do not use that memory anymore and heap(s) there can be enabled.

**esp_err_t** **heap_caps_add_region** (intptr_t start, intptr_t end)
Add a region of memory to the collection of heaps at runtime.

Most memory regions are defined in soc_memory_layout.c for the SoC, and are registered via heap_caps_init(). Some regions can’t be used immediately and are later enabled via heap_caps_enable_nonos_stack_heaps().

Call this function to add a region of memory to the heap at some later time.

This function does not consider any of the “reserved” regions or other data in soc_memory_layout, caller needs to consider this themselves.
All memory within the region specified by start & end parameters must be otherwise unused.

The capabilities of the newly registered memory will be determined by the start address, as looked up in the regions specified in soc_memory_layout.c.

Use heap_caps_add_region_with_caps() to register a region with custom capabilities.

Note: Please refer to following example for memory regions allowed for addition to heap based on an existing region (address range for demonstration purpose only):

<table>
<thead>
<tr>
<th>Existing region:</th>
<th>New region:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x1000 &lt;--&gt; 0x3000</td>
<td>0x1000 &lt;--&gt; 0x3000 (Allowed)</td>
</tr>
<tr>
<td>0x1000 &lt;--&gt; 0x2000 (Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x0000 &lt;--&gt; 0x1000 (Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x3000 &lt;--&gt; 0x4000 (Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x0000 &lt;--&gt; 0x2000 (NOT Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x0000 &lt;--&gt; 0x4000 (NOT Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x1000 &lt;--&gt; 0x4000 (NOT Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x2000 &lt;--&gt; 0x4000 (NOT Allowed)</td>
<td></td>
</tr>
</tbody>
</table>

**Parameters**

- **start** – Start address of new region.
- **end** – End address of new region.

**Returns**

ESP_OK on success, ESP_ERR_INVALID_ARG if a parameter is invalid, ESP_ERR_NOT_FOUND if the specified start address doesn’t reside in a known region, or any error returned by heap_caps_add_region_with_caps().

```c
esp_err_t heap_caps_add_region_with_caps (const uint32_t caps[], intptr_t start, intptr_t end)
```

Add a region of memory to the collection of heaps at runtime, with custom capabilities.

Similar to heap_caps_add_region(), only custom memory capabilities are specified by the caller.

Note: Please refer to following example for memory regions allowed for addition to heap based on an existing region (address range for demonstration purpose only):

<table>
<thead>
<tr>
<th>Existing region:</th>
<th>New region:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x1000 &lt;--&gt; 0x3000</td>
<td>0x1000 &lt;--&gt; 0x3000 (Allowed)</td>
</tr>
<tr>
<td>0x1000 &lt;--&gt; 0x2000 (Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x0000 &lt;--&gt; 0x1000 (Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x3000 &lt;--&gt; 0x4000 (Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x0000 &lt;--&gt; 0x2000 (NOT Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x0000 &lt;--&gt; 0x4000 (NOT Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x1000 &lt;--&gt; 0x4000 (NOT Allowed)</td>
<td></td>
</tr>
<tr>
<td>0x2000 &lt;--&gt; 0x4000 (NOT Allowed)</td>
<td></td>
</tr>
</tbody>
</table>

**Parameters**

- **caps** – Ordered array of capability masks for the new region, in order of priority. Must have length SOC_MEMORY_TYPE_NO_PRIOS. Does not need to remain valid after the call returns.
- **start** – Start address of new region.
- **end** – End address of new region.

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if a parameter is invalid
- ESP_ERR_NO_MEM if no memory to register new heap.
- ESP_ERR_INVALID_SIZE if the memory region is too small to fit a heap
- ESP_FAIL if region overlaps the start and/or end of an existing region
API Reference - Multi Heap API

(Note: The multi heap API is used internally by the heap capabilities allocator. Most IDF programs will never need to call this API directly.)

Header File

- components/heap/include/multi_heap.h

Functions

void *multi_heap_aligned_alloc (multi_heap_handle_t heap, size_t size, size_t alignment)
allocate a chunk of memory with specific alignment

Parameters
- heap - Handle to a registered heap.
- size - size in bytes of memory chunk
- alignment - how the memory must be aligned

Returns pointer to the memory allocated, NULL on failure

void *multi_heap_malloc (multi_heap_handle_t heap, size_t size)
malloc() a buffer in a given heap

Semantics are the same as standard malloc(), only the returned buffer will be allocated in the specified heap.

Parameters
- heap - Handle to a registered heap.
- size - Size of desired buffer.

Returns Pointer to new memory, or NULL if allocation fails.

void multi_heap_aligned_free (multi_heap_handle_t heap, void *p)
free() a buffer aligned in a given heap.

Note: This function is deprecated, consider using multi_heap_free() instead

Parameters
- heap - Handle to a registered heap.
- p - NULL, or a pointer previously returned from multi_heap_aligned_alloc() for the same heap.

void multi_heap_free (multi_heap_handle_t heap, void *p)
free() a buffer in a given heap.

Semantics are the same as standard free(), only the argument ‘p’ must be NULL or have been allocated in the specified heap.

Parameters
- heap - Handle to a registered heap.
- p - NULL, or a pointer previously returned from multi_heap_malloc() or multi_heap_realloc() for the same heap.

void *multi_heap_realloc (multi_heap_handle_t heap, void *p, size_t size)
realloc() a buffer in a given heap.

Semantics are the same as standard realloc(), only the argument ‘p’ must be NULL or have been allocated in the specified heap.

Parameters
- heap - Handle to a registered heap.
- p - NULL, or a pointer previously returned from multi_heap_malloc() or multi_heap_realloc() for the same heap.
• size - Desired new size for buffer.

>Returns New buffer of ‘size’ containing contents of ‘p’, or NULL if reallocation failed.

size_t multi_heap_get_allocated_size(multi_heap_handle_t heap, void *p)
Returns the size that a particular pointer was allocated with.

Parameters
• heap - Handle to a registered heap.
• p - Pointer, must have been previously returned from multi_heap_malloc() or multi_heap_realloc() for the same heap.

Returns Size of the memory allocated at this block. May be more than the original size argument, due to padding and minimum block sizes.

multi_heap_handle_t multi_heap_register(void *start, size_t size)
Register a new heap for use.

This function initialises a heap at the specified address, and returns a handle for future heap operations.

There is no equivalent function for deregistering a heap - if all blocks in the heap are free, you can immediately start using the memory for other purposes.

Parameters
• start - Start address of the memory to use for a new heap.
• size - Size (in bytes) of the new heap.

Returns Handle of a new heap ready for use, or NULL if the heap region was too small to be initialised.

void multi_heap_set_lock(multi_heap_handle_t heap, void *lock)
Associate a private lock pointer with a heap.

The lock argument is supplied to the MULTI_HEAP_LOCK() and MULTI_HEAP_UNLOCK() macros, defined in multi_heap_platform.h.

The lock in question must be recursive.

When the heap is first registered, the associated lock is NULL.

Parameters
• heap - Handle to a registered heap.
• lock - Optional pointer to a locking structure to associate with this heap.

void multi_heap_dump(multi_heap_handle_t heap)
Dump heap information to stdout.

For debugging purposes, this function dumps information about every block in the heap to stdout.

Parameters heap - Handle to a registered heap.

bool multi_heap_check(multi_heap_handle_t heap, bool print_errors)
Check heap integrity.

Walks the heap and checks all heap data structures are valid. If any errors are detected, an error-specific message can be optionally printed to stderr. Print behaviour can be overridden at compile time by defining MULTI_CHECK_FAIL_PRINTF in multi_heap_platform.h.

Note: This function is not thread-safe as it sets a global variable with the value of print_errors.

Parameters
• heap - Handle to a registered heap.
• print_errors - If true, errors will be printed to stderr.

Returns true if heap is valid, false otherwise.
size_t multi_heap_free_size (multi_heap_handle_t heap)

Return free heap size.

Returns the number of bytes available in the heap.

Equivalent to the total_free_bytes member returned by multi_heap_get_heap_info().

Note that the heap may be fragmented, so the actual maximum size for a single malloc() may be lower. To know this size, see the largest_free_block member returned by multi_heap_get_heap_info().

Parameters heap – Handle to a registered heap.

Returns Number of free bytes.

size_t multi_heap_minimum_free_size (multi_heap_handle_t heap)

Return the lifetime minimum free heap size.

Equivalent to the minimum_free_bytes member returned by multi_heap_get_info().

Returns the lifetime “low watermark” of possible values returned from multi_free_heap_size(), for the specified heap.

Parameters heap – Handle to a registered heap.

Returns Number of free bytes.

void multi_heap_get_info (multi_heap_handle_t heap, multi_heap_info_t *info)

Return metadata about a given heap.

Fills a multi_heap_info_t structure with information about the specified heap.

Parameters

• heap – Handle to a registered heap.
• info – Pointer to a structure to fill with heap metadata.

Structures

struct multi_heap_info_t

Structure to access heap metadata via multi_heap_get_info.

Public Members

size_t total_free_bytes

Total free bytes in the heap. Equivalent to multi_free_heap_size().

size_t total_allocated_bytes

Total bytes allocated to data in the heap.

size_t largest_free_block

Size of the largest free block in the heap. This is the largest malloc-able size.

size_t minimum_free_bytes

Lifetime minimum free heap size. Equivalent to multi_minimum_free_heap_size().

size_t allocated_blocks

Number of (variable size) blocks allocated in the heap.

size_t free_blocks

Number of (variable size) free blocks in the heap.
size_t total_blocks
    Total number of (variable size) blocks in the heap.

Type Definitions
typedef struct multi_heap_info *multi_heap_handle_t
    Opaque handle to a registered heap.

2.10.14 Memory Management for MMU Supported Memory

Introduction

ESP32 Memory Management Unit (MMU) is relatively simple. It can do memory address translation between physical memory addresses and virtual memory addresses. So CPU can access physical memories via virtual addresses. There are multiple types of virtual memory addresses, which have different capabilities.

ESP-IDF provides a memory mapping driver that manages the relation between these physical memory addresses and virtual memory addresses, so as to achieve some features such as reading from SPI Flash via a pointer.

Memory mapping driver is actually a capabilities-based virtual memory address allocator that allows apps to make virtual memory address allocations for different purposes. In the following chapters, we call this driver esp_mmap driver.

ESP-IDF also provides a memory synchronisation driver which can be used for potential memory desynchronisation scenarios.

Physical Memory Types

Memory mapping driver currently supports mapping to following physical memory types:

- SPI Flash

Virtual Memory Capabilities

- MMU_MEM_CAP_EXEC. This capability indicates that the virtual memory address has the execute permission. Note this permission scope is within the MMU hardware.
- MMU_MEM_CAP_READ. This capability indicates that the virtual memory address has the read permission. Note this permission scope is within the MMU hardware.
- MMU_MEM_CAP_WRITE. This capability indicates that the virtual memory address has the write permission. Note this permission scope is within the MMU hardware.
- MMU_MEM_CAP_32BIT. This capability indicates that the virtual memory address allows for 32 bits or multiples of 32 bits access.
- MMU_MEM_CAP_8BIT. This capability indicates that the virtual memory address allows for 8 bits or multiples of 8 bits access.

8 MB external memory addresses (from 0x40400000 to 0x40C00000) which have the MMU_MEM_CAP_EXEC and MMU_MEM_CAP_READ capabilities are not available for users to allocate, due to hardware limitations.

You can call esp_mmu_map_get_max_consecutive_free_block_size() to know the largest consecutive mappable block size with certain capabilities.
Memory Management Drivers

Driver Concept

Terminology  The virtual memory pool is made up with one or multiple virtual memory regions, see below figure:

- A virtual memory pool stands for the whole virtual address range that can be mapped to physical memory
- A virtual memory region is a range of virtual address with same attributes
- A virtual memory block is a piece of virtual address range that is dynamically mapped.
- A slot is the virtual address range between two virtual memory blocks.
- A physical memory block is a piece of physical address range that is to-be-mapped or already mapped to a virtual memory block.
- Dynamical mapping is done by calling `esp_mmap` driver API `esp_mmu_map()`, this API will map the given physical memory block to a virtual memory block which is allocated by the `esp_mmap` driver.

Relation between Memory Blocks  When mapping a physical memory block A, block A can have one of the following relations with another previously mapped physical memory block B:

- Enclosed: block A is completely enclosed within block B, see figure below:

  ![Enclosed Diagram]

- Identical: block A is completely the same as block B, see figure below:

  ![Identical Diagram]

  Note `esp_mmap` driver will consider the identical scenario the same as the enclosed scenario.
- Overlapped: block A is overlapped with block B, see figure below:
There is a special condition, when block A entirely encloses block B, see figure below:

\[ \text{esp_mmap} \text{ driver will consider this scenario the same as the overlapped scenario.} \]

**Driver Behaviour**

**Memory Map**

You can call `esp_mmu_map()` to do a dynamical mapping. This API will allocate a certain size of virtual memory block according to the virtual memory capabilities you selected, then map this virtual memory block to the physical memory block as you requested. The `esp_mmap` driver supports mapping to one or more types of physical memory, so you should specify the physical memory target when mapping.

By default, physical memory blocks and virtual memory blocks are one-to-one mapped. This means, when calling `esp_mmu_map()`:

- If it’s the enclosed scenario, this API will return an `ESP_ERR_INVALID_STATE`. The `out_ptr` will be assigned to the start virtual memory address of the previously mapped one which encloses the to-be-mapped one.
- If it’s the identical scenario, this API will behaves exactly the same as the enclosed scenario.
- If it’s the overlapped scenario, this API will by default return an `ESP_ERR_INVALID_ARG`. This means, `esp_mmap` driver by default doesn’t allow mapping a physical memory address to multiple virtual memory addresses.

Specially, you can use `ESP_MMU_MMAP_FLAG_PADDR_SHARED`. This flags stands for one-to-multiple mapping between a physical address and multiple virtual addresses:

- If it’s the overlapped scenario, this API will allocate a new virtual memory block as requested, then map to the given physical memory block.

**Memory Unmap**

You can call `esp_mmu_unmap()` to unmap a previously mapped memory block. This API will return an `ESP_ERR_NOT_FOUND` if you are trying to unmap a virtual memory block that isn’t mapped to any physical memory block yet.

**Memory Address Conversion**

The `esp_mmap` driver provides two helper APIs to do the conversion between virtual memory address and physical memory address.

- `esp_mmu_vaddr_to_paddr()`, convert virtual address to physical address.
- `esp_mmu_paddr_to_vaddr()`, convert physical address to virtual address.
Memory Synchronisation  MMU supported physical memories can be accessed by one or multiple methods. SPI Flash can be accessed by SPI1 (ESP-IDF esp_flash driver APIs), or by pointers. ESP-IDF esp_flash driver APIs have already considered the memory synchronisation, so users don’t need to worry about this.

PSRAM can be accessed by pointers, hardware guarantees the data consistency when PSRAM is only accessed via pointers.

Thread Safety

APIs in esp_mmu_map.h are not guaranteed to be thread-safe.

APIs in esp_cache.h are guaranteed to be thread-safe.

API Reference

API Reference - ESP MMAP Driver

Header File

- components/esp_mmu/include/esp_mmu_map.h

Functions

esp_err_t esp_mmu_map(esp_paddr_t paddr_start, size_t size, mmu_target_t target, mmu_mem_caps_t caps, int flags, void **out_ptr)

Map a physical memory block to external virtual address block, with given capabilities.

Note: This API does not guarantee thread safety

Parameters

- paddr_start –[in] Start address of the physical memory block
- size –[in] Size to be mapped. Size will be rounded up to the nearest multiple of MMU page size
- target –[in] Physical memory target you’re going to map to, see mmu_target_t
- caps –[in] Memory capabilities, see mmu_mem_caps_t
- flags –[in] Mmap flags
- out_ptr –[out] Start address of the mapped virtual memory

Returns

- ESP_OK
- ESP_ERR_INVALID_ARG: Invalid argument, see printed logs
- ESP_ERR_NOT_SUPPORTED: Only on ESP32, PSRAM is not a supported physical memory target
- ESP_ERR_NOT_FOUND: No enough size free block to use
- ESP_ERR_NO_MEM: Out of memory, this API will allocate some heap memory for internal usage
- ESP_ERR_INVALID_STATE: Paddr is mapped already, this API will return corresponding vaddr_start of the previously mapped block. Only to-be-mapped paddr block is totally enclosed by a previously mapped block will lead to this error. (Identical scenario will behave similarly) new_block_start new_block_end !—&amp;#8212; New Block —&amp;#8212;|&amp;#8212; Block —&amp;#8212;&amp;#8212; Block_start block_end

esp_err_t esp_mmu_unmap (void *ptr)

Unmap a previously mapped virtual memory block.
Chapter 2. API Reference

Note: This API does not guarantee thread safety

**Parameters** `ptr` - [in] Start address of the virtual memory

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG: Null pointer
- ESP_ERR_NOT_FOUND: Vaddr is not in external memory, or it’s not mapped yet

```c
esp_err_t esp_mmu_map_get_max_consecutive_free_block_size(mmu_mem_caps_t caps, mmu_target_t target, size_t *out_len)
```

Get largest consecutive free external virtual memory block size, with given capabilities and given physical target.

**Parameters**
- `caps` - [in] Bitwise OR of MMU_MEM_CAP_* flags indicating the memory block
- `target` - [in] Physical memory target you’re going to map to, see mmu_target_t.
- `out_len` - [out] Largest free block length, in bytes.

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG: Invalid arguments, could be null pointer

```c
esp_err_t esp_mmu_map_dump_mapped_blocks(FILE *stream)
```

Dump all the previously mapped blocks

Note: This API shall not be called from an ISR.

Note: This API does not guarantee thread safety

**Parameters** `stream` - stream to print information to; use stdout or stderr to print to the console; use fnmemopen/open_memstream to print to a string buffer.

**Returns**
- ESP_OK

```c
esp_err_t esp_mmu_vaddr_to_paddr(void *vaddr, esp_paddr_t *out_paddr, mmu_target_t *out_target)
```

Convert virtual address to physical address.

**Parameters**
- `vaddr` - [in] Virtual address
- `out_paddr` - [out] Physical address
- `out_target` - [out] Physical memory target, see mmu_target_t

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG: Null pointer, or vaddr is not within external memory
- ESP_ERR_NOT_FOUND: Vaddr is not mapped yet

```c
esp_err_t esp_mmu_paddr_to_vaddr(esp_paddr_t paddr, mmu_target_t target, mmu_vaddr_t type, void **out_vaddr)
```

Convert physical address to virtual address.

**Parameters**
- `paddr` - [in] Physical address
- `target` - [in] Physical memory target, see mmu_target_t
- `type` - [in] Virtual address type, could be either instruction or data
Chapter 2. API Reference

• **out_vaddr**  - [out] Virtual address

**Returns**
- ESP_OK
- ESP_ERR_INVALID_ARG: Null pointer
- ESP_ERR_NOT_FOUND: Paddr is not mapped yet

```c
esp_err_t esp_mmu_paddr_find_caps (const esp_paddr_t paddr, mmu_mem_caps_t *out_caps)
```

If the physical address is mapped, this API will provide the capabilities of the virtual address where the physical address is mapped to.

**Note:** Only return value is ESP_OK (which means physically address is successfully mapped), then caps you get make sense.

**Note:** This API only check one page (see CONFIG_MMU_PAGE_SIZE), starting from the `paddr`

**Parameters**
- **paddr**  - [in] Physical address
- **out_caps**  - [out] Bitwise OR of MMU_MEM_CAP_* flags indicating the capabilities of a virtual address where the physical address is mapped to.

**Returns**
- ESP_OK: Physical address successfully mapped.
- ESP_ERR_INVALID_ARG: Null pointer
- ESP_ERR_NOT_FOUND: Physical address is not mapped successfully.

**Macros**

**ESP_MPU_MMAP_FLAG_PADDR_SHARED**

Share this mapping.

MMU Memory Mapping Driver APIs for MMU supported memory

Driver Backgrounds:

**Type Definitions**

typedef uint32_t esp_paddr_t

Physical memory type.

**API Reference - ESP MSYNC Driver**

**Header File**

- components/esp_mmu/include/esp_cache.h

**Functions**

```c
esp_err_t esp_cache_msync (void *addr, size_t size, int flags)
```

Memory sync between Cache and external memory.

- For cache writeback supported chips (you can refer to SOC_CACHE_WRITEBACK_SUPPORTED in soc_caps.h)
  - this API will do a writeback to synchronise between cache and the PSRAM
– with ESP_CACHE_MSYNC_FLAG_INVALIDATE, this API will also invalidate the values that just written
– note: although ESP32 is with PSRAM, but cache writeback isn’t supported, so this API will do nothing on ESP32
• For other chips, this API will do nothing. The out-of-sync should be already dealt by the SDK
This API is cache-safe and thread-safe

Note: You should not call this during any Flash operations (e.g. esp_flash APIs, nvs and some other APIs that are based on esp_flash APIs)

Note: If XIP_From_PSRAM is enabled (by enabling both CONFIG_SPIRAM_FETCH_INSTRUCTIONS and CONFIG_SPIRAM_RODATA), you can call this API during Flash operations

Parameters
• addr - [in] Starting address to do the msync
• size - [in] Size to do the msync
• flags -[in] Flags, see ESP_CACHE_MSYNC_FLAG_x

Returns
• ESP_OK:
  – Successful msync
  – If this chip doesn’t support cache writeback, if the input addr is a cache supported one, this API will return ESP_OK
• ESP_ERR_INVALID_ARG: Invalid argument, not cache supported addr, see printed logs

Macros

ESP_CACHE_MSYNC_FLAG_INVALIDATE
Do an invalidation with the values that just written.
Cache msync flags

ESP_CACHE_MSYNC_FLAG_UNALIGNED
Allow writeback a block that are not aligned to the data cache line size.

2.10.15 Heap Memory Debugging

Overview

ESP-IDF integrates tools for requesting heap information, detecting heap corruption, and tracing memory leaks. These can help track down memory-related bugs.

For general information about the heap memory allocator, see the Heap Memory Allocation page.

Heap Information

To obtain information about the state of the heap:

• xPortGetFreeHeapSize() is a FreeRTOS function which returns the number of free bytes in the (data memory) heap. This is equivalent to calling heap_caps_get_free_size(MALLOC_CAP_8BIT).
• heap_caps_get_free_size() can also be used to return the current free memory for different memory capabilities.
• heap_caps_get_largest_free_block() can be used to return the largest free block in the heap. This is the largest single allocation which is currently possible. Tracking this value and comparing to total free heap allows you to detect heap fragmentation.
• `xPortGetMinimumEverFreeHeapSize()` and the related `heap_caps_get_minimum_free_size()` can be used to track the heap “low watermark” since boot.
• `heap_caps_get_info()` returns a `multi_heap_info_t` structure which contains the information from the above functions, plus some additional heap-specific data (number of allocations, etc.).
• `heap_caps_print_heap_info()` prints a summary to stdout of the information returned by `heap_caps_get_info()`.
• `heap_caps_dump()` and `heap_caps_dump_all()` will output detailed information about the structure of each block in the heap. Note that this can be large amount of output.

Heap allocation and free function hooks

Heap allocation and free detection hooks allows you to be notified of every successful allocation and free operations:
- Providing a definition of `esp_heap_trace_alloc_hook()` will allow you to be notified of every successful memory allocation operations
- Providing a definition of `esp_heap_trace_free_hook()` will allow you to be notified of every memory free operations

To activate the feature, navigate to Component config -> Heap Memory Debugging in the configuration menu and select Use allocation and free hooks option (see `CONFIG_HEAP_USE_HOOKS`). `esp_heap_trace_alloc_hook()` and `esp_heap_trace_free_hook()` have weak declarations, it is not necessary to provide a declarations for both hooks. Since allocating and freeing memory is allowed even though strongly recommended against, `esp_heap_trace_alloc_hook()` and `esp_heap_trace_free_hook()` can potentially be called from ISR.

Heap Corruption Detection

Heap corruption detection allows you to detect various types of heap memory errors:

- Out of bounds writes & buffer overflow.
- Writes to freed memory.
- Reads from freed or uninitialized memory.

Assertions The heap implementation (`multi_heap.c`, etc.) includes a lot of assertions which will fail if the heap memory is corrupted. To detect heap corruption most effectively, ensure that assertions are enabled in the project configuration menu under Compiler options -> `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL`.

If a heap integrity assertion fails, a line will be printed like `CORRUPT HEAP: multi_heap.c:225 detected at 0x3ffbb71c`. The memory address which is printed is the address of the heap structure which has corrupt content.

It’s also possible to manually check heap integrity by calling `heap_caps_check_integrity_all()` or related functions. This function checks all of requested heap memory for integrity, and can be used even if assertions are disabled. If the integrity check prints an error, it will also contain the address(es) of corrupt heap structures.

Memory Allocation Failed Hook Users can use `heap_caps_register_failed_alloc_callback()` to register a callback that will be invoked every time an allocation operation fails.

Additionally, users can enable the generation of a system abort if an allocation operation fails by following the steps below: - In the project configuration menu, navigate to Component config -> Heap Memory Debugging and select Abort if memory allocation fails option (see `CONFIG_HEAP_ABORT_WHEN_ALLOCATION_FAILS`).

The example below shows how to register an allocation failure callback:

```c
#include "esp_heap_caps.h"

void heap_caps_alloc_failed_hook(size_t requested_size, uint32_t caps, const char *function_name)
{
  // allocation failed callback implementation
}
```
printf("%s was called but failed to allocate %d bytes with 0x%X capabilities.\n", function_name, requested_size, caps);
}

void app_main()
{
    ...
    esp_err_t error = heap_caps_register_failed_alloc_callback(heap_caps_alloc_-
-
failed_hook);
    ...
    void *ptr = heap_caps_malloc(allocation_size, MALLOC_CAP_DEFAULT);
    ...
}

Finding Heap Corruption Memory corruption can be one of the hardest classes of bugs to find and fix, as one area of memory can be corrupted from a totally different place. Some tips:

• A crash with a CORRUPT HEAP: message will usually include a stack trace, but this stack trace is rarely useful. The crash is the symptom of memory corruption when the system realises the heap is corrupt, but usually the corruption happened elsewhere and earlier in time.
• Increasing the Heap memory debugging Configuration level to “Light impact” or “Comprehensive” can give you a more accurate message with the first corrupt memory address.
• Adding regular calls to heap_caps_check_integrity_all() or heap_caps_check_integrity_addr() in your code will help you pin down the exact time that the corruption happened. You can move these checks around to “close in on” the section of code that corrupted the heap.
• Based on the memory address which is being corrupted, you can use JTAG debugging to set a watchpoint on this address and have the CPU halt when it is written to.
• If you don’t have JTAG, but you do know roughly when the corruption happens, then you can set a watchpoint in software just beforehand via esp_cpu_set_watchpoint(). A fatal exception will occur when the watchpoint triggers. The following is an example of how to use the function - esp_cpu_set_watchpoint(0, (void *)addr, 4, ESP_WATCHPOINT_STORE). Note that watchpoints are per-CPU and are set on the current running CPU only, so if you don’t know which CPU is corrupting memory then you will need to call this function on both CPUs.
• For buffer overflows, heap tracing in HEAP_TRACE_ALL mode lets you see which callers are allocating which addresses from the heap. See Heap Tracing To Find Heap Corruption for more details. If you can find the function which allocates memory with an address immediately before the address which is corrupted, this will probably be the function which overflows the buffer.
• Calling heap_caps_dump() or heap_caps_dump_all() can give an indication of what heap blocks are surrounding the corrupted region and may have overflowed/underflowed/etc.

Configuration Temporarily increasing the heap corruption detection level can give more detailed information about heap corruption errors.

In the project configuration menu, under Component config there is a menu Heap memory debugging. The setting CONFIG_HEAP_CORRUPTION_DETECTION can be set to one of three levels:

Basic (no poisoning) This is the default level. No special heap corruption features are enabled, but provided assertions are enabled (the default configuration) then a heap corruption error will be printed if any of the heap’s internal data structures appear overwritten or corrupted. This usually indicates a buffer overrun or out of bounds write.

If assertions are enabled, an assertion will also trigger if a double-free occurs (the same memory is freed twice).

Calling heap_caps_check_integrity() in Basic mode will check the integrity of all heap structures, and print errors if any appear to be corrupted.
**Light Impact**  At this level, heap memory is additionally “poisoned” with head and tail “canary bytes” before and after each block which is allocated. If an application writes outside the bounds of allocated buffers, the canary bytes will be corrupted and the integrity check will fail.

The head canary word is 0xABBA1234 (3412BAAB in byte order), and the tail canary word is 0xBAAD5678 (7856ADBA in byte order).

“Basic” heap corruption checks can also detect most out of bounds writes, but this setting is more precise as even a single byte overrun can be detected. With Basic heap checks, the number of overrun bytes before a failure is detected will depend on the properties of the heap.

Enabling “Light Impact” checking increases memory usage, each individual allocation will use 9 to 12 additional bytes of memory (depending on alignment).

Each time free() is called in Light Impact mode, the head and tail canary bytes of the buffer being freed are checked against the expected values.

When heap_caps_check_integrity() is called, all allocated blocks of heap memory have their canary bytes checked against the expected values.

In both cases, the check is that the first 4 bytes of an allocated block (before the buffer returned to the user) should be the word 0xABBA1234. Then the last 4 bytes of the allocated block (after the buffer returned to the user) should be the word 0xBAAD5678.

Different values usually indicate buffer underrun or overrun, respectively.

**Comprehensive**  This level incorporates the “light impact” detection features plus additional checks for uninitialised-access and use-after-free bugs. In this mode, all freshly allocated memory is filled with the pattern 0xCE, and all freed memory is filled with the pattern 0xFE.

Enabling “Comprehensive” detection has a substantial runtime performance impact (as all memory needs to be set to the allocation patterns each time a malloc/free completes, and the memory also needs to be checked each time.) However, it allows easier detection of memory corruption bugs which are much more subtle to find otherwise. It is recommended to only enable this mode when debugging, not in production.

**Crashes in Comprehensive Mode**  If an application crashes reading/writing an address related to 0xCECECECE in Comprehensive mode, this indicates it has read uninitialized memory. The application should be changed to either use calloc() (which zeroes memory), or initialize the memory before using it. The value 0xCECECECE may also be seen in stack-allocated automatic variables, because in IDF most task stacks are originally allocated from the heap and in C stack memory is uninitialized by default.

If an application crashes and the exception register dump indicates that some addresses or values were 0xFEFEFEFE, this indicates it is reading heap memory after it has been freed (a “use after free bug”). The application should be changed to not access heap memory after it has been freed.

If a call to malloc() or realloc() causes a crash because it expected to find the pattern 0xFEFEFEFE in free memory and a different pattern was found, then this indicates the app has a use-after-free bug where it is writing to memory which has already been freed.

**Manual Heap Checks in Comprehensive Mode**  Calls to heap_caps_check_integrity() may print errors relating to 0xFEFEFEFE, 0xABBA1234 or 0xBAAD5678. In each case the checker is expecting to find a given pattern, and will error out if this is not found:

- For free heap blocks, the checker expects to find all bytes set to 0xFE. Any other values indicate a use-after-free bug where free memory has been incorrectly overwritten.
- For allocated heap blocks, the behaviour is the same as for Light Impact mode. The canary bytes 0xABBA1234 and 0xBAAD5678 are checked at the head and tail of each allocated buffer, and any variation indicates a buffer overrun/underrun.
Heap Task Tracking

Heap Task Tracking can be used to get per task info for heap memory allocation. Application has to specify the heap capabilities for which the heap allocation is to be tracked.

Example code is provided in `system/heap_task_tracking`

Heap Tracing

Heap Tracing allows tracing of code which allocates/frees memory. Two tracing modes are supported:

- **Standalone.** In this mode trace data are kept on-board, so the size of gathered information is limited by the buffer assigned for that purposes. Analysis is done by the on-board code. There are a couple of APIs available for accessing and dumping collected info.
- **Host-based.** This mode does not have the limitation of the standalone mode, because trace data are sent to the host over JTAG connection using app_trace library. Later on they can be analysed using special tools.

Heap tracing can perform two functions:

- Leak checking: find memory which is allocated and never freed.
- Heap use analysis: show all functions that are allocating/freeing memory while the trace is running.

**How To Diagnose Memory Leaks**

If you suspect a memory leak, the first step is to figure out which part of the program is leaking memory. Use the `xPortGetFreeHeapSize()`, `heap_caps_get_free_size()`, or related functions to track memory use over the life of the application. Try to narrow the leak down to a single function or sequence of functions where free memory always decreases and never recovers.

**Standalone Mode**

Once you’ve identified the code which you think is leaking:

- In the project configuration menu, navigate to Component settings -> Heap Memory Debugging -> Heap tracing and select Standalone option (see `CONFIG_HEAP_TRACING_DEST`).
- Call the function `heap_trace_init_standalone()` early in the program, to register a buffer which can be used to record the memory trace.
- Call the function `heap_trace_start()` to begin recording all mallocs/frees in the system. Call this immediately before the piece of code which you suspect is leaking memory.
- Call the function `heap_trace_stop()` to stop the trace once the suspect piece of code has finished executing.
- Call the function `heap_trace_dump()` to dump the results of the heap trace.

An example:

```c
#include "esp_heap_trace.h"
#define NUM_RECORDS 100
static heap_trace_record_t trace_record[NUM_RECORDS]; // This buffer must be in internal RAM
...
void app_main()
{
    ...
    ESP_ERROR_CHECK( heap_trace_init_standalone(trace_record, NUM_RECORDS) );
    ...
}

void some_function()
{
    ESP_ERROR_CHECK( heap_trace_start(HEAP_TRACE_LEAKS) );
}
```

(continues on next page)
The output from the heap trace will look something like this:

```
2 allocations trace (100 entry buffer)
32 bytes (@ 0x3ffaf214) allocated CPU 0 ccount 0x2e9b7384 caller...
    -0x400d276d: leak_some_memory at /path/to/idf/examples/get-started/blink/main/./
        --blink.c:27
0x400d276d: leak_some_memory at /path/to/idf/examples/get-started/blink/main/./
    --blink.c:27
0x400d27c1: blink_task at /path/to/idf/examples/get-started/blink/main/./blink.c:52
8 bytes (@ 0x3ffaf804) allocated CPU 0 ccount 0x2e9b79c0 caller...
    -0x400d2776: leak_some_memory at /path/to/idf/examples/get-started/blink/main/./
        --blink.c:29
0x400d27c1: blink_task at /path/to/idf/examples/get-started/blink/main/./blink.c:52
40 bytes 'leaked' in trace (2 allocations)
total allocations 2 total frees 0
```

(Above example output is using IDF Monitor to automatically decode PC addresses to their source files & line number.)

The first line indicates how many allocation entries are in the buffer, compared to its total size.

In `HEAP_TRACELeaks` mode, for each traced memory allocation which has not already been freed a line is printed with:

- **XX bytes** is the number of bytes allocated
- **@ 0x...** is the heap address returned from malloc/calloc.
- **Internal or PSRAM** is the general location of the allocated memory.
- **CPU x** is the CPU (0 or 1) running when the allocation was made.
- **ccount 0x...** is the CCOUNT (CPU cycle count) register value when the allocation was made. Is different for CPU 0 vs CPU 1.
- **caller 0x...** gives the call stack of the call to malloc()/free(), as a list of PC addresses. These can be decoded to source files and line numbers, as shown above.

The depth of the call stack recorded for each trace entry can be configured in the project configuration menu, under Heap Memory Debugging -> Enable heap tracing -> Heap tracing stack depth. Up to 10 stack frames can be recorded for each allocation (the default is 2). Each additional stack frame increases the memory usage of each heap_trace_record_t record by eight bytes.

Finally, the total number of ‘leaked’ bytes (bytes allocated but not freed while trace was running) is printed, and the total number of allocations this represents.

A warning will be printed if the trace buffer was not large enough to hold all the allocations which happened. If you see this warning, consider either shortening the tracing period or increasing the number of records in the trace buffer.

**Host-Based Mode** Once you’ve identified the code which you think is leaking:

- In the project configuration menu, navigate to Component settings -> Heap Memory Debugging -> `CONFIG_HEAP_TRACING_DEST` and select Host-Based.
- In the project configuration menu, navigate to Component settings -> Application Level Tracing -> `CONFIG_APPTRACE_DESTINATION1` and select Trace memory.
• In the project configuration menu, navigate to Component settings -> Application Level Tracing -> FreeRTOS SystemView Tracing and enable `CONFIG_APPTRACE_SV_ENABLE`.
• Call the function `heap_trace_init_tohost()` early in the program, to initialize JTAG heap tracing module.
• Call the function `heap_trace_start()` to begin recording all mallocs/frees in the system. Call this immediately before the piece of code which you suspect is leaking memory. In host-based mode, the argument to this function is ignored, and the heap tracing module behaves like `HEAP_TRACE_ALL` was passed: all allocations and deallocations are sent to the host.
• Call the function `heap_trace_stop()` to stop the trace once the suspect piece of code has finished executing.

An example:

```c
#include "esp_heap_trace.h"
...
void app_main()
{
    ...
    ESP_ERROR_CHECK( heap_trace_init_tohost() );
    ...
}
void some_function()
{
    ESP_ERROR_CHECK( heap_trace_start(HEAP_TRACE_LEAKS) );
    do_something_you_suspect_is_leaking();
    ESP_ERROR_CHECK( heap_trace_stop() );
    ...
}
```

To gather and analyse heap trace do the following on the host:
1. Build the program and download it to the target as described in Getting Started Guide.
2. Run OpenOCD (see JTAG Debugging).

**Note:** In order to use this feature you need OpenOCD version v0.10.0-esp32-20181105 or later.

3. You can use GDB to start and/or stop tracing automatically. To do this you need to prepare special `gdbinit` file:

```
target remote :3333
mon reset halt
flushregs
tb heap_trace_start
commands
mon esp sysview start file://tmp/heap.svdat
c
end

tb heap_trace_stop
commands
mon esp sysview stop
d
```
Chapter 2. API Reference

Using this file GDB will connect to the target, reset it, and start tracing when program hits breakpoint at `heap_trace_start()`. Trace data will be saved to `/tmp/heap_log.svdat`. Tracing will be stopped when program hits breakpoint at `heap_trace_stop()`.

4. Run GDB using the following command: `xtensa-esp32-elf-gdb -x gdbinit </path/to/program/elf>`

5. Quit GDB when program stops at `heap_trace_stop()`. Trace data are saved in `/tmp/heap.svdat`

6. Run processing script `$IDF_PATH/tools/esp_app_trace/sysviewtrace_proc.py -p -b </path/to/program/elf> /tmp/heap_log.svdat`

The output from the heap trace will look something like this:

Parse trace from '/tmp/heap.svdat'...
Stop parsing trace. (Timeout 0.000000 sec while reading 1 bytes!)
Process events from '[/tmp/heap.svdat]'...

[0.002244575] HEAP: Allocated 1 bytes @ 0x3ffaffd8 from task "alloc" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.002258425] HEAP: Allocated 2 bytes @ 0x3ffaffe0 from task "alloc" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.002563725] HEAP: Freed bytes @ 0x3ffaffe0 from task "free" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:31 (discriminator 9)
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.002782950] HEAP: Freed bytes @ 0x3ffbe0b8 from task "main" on core 0 by:
/home/user/projects/esp-idf/components/freertos/tasks.c:4590
/home/user/projects/esp-idf/components/freertos/tasks.c:4590

[0.002798700] HEAP: Freed bytes @ 0x3ffbe0bc from task "main" on core 0 by:
/home/user/projects/esp-idf/components/freertos/tasks.c:4590
/home/user/projects/esp-idf/components/freertos/tasks.c:4590

[0.102436025] HEAP: Allocated 2 bytes @ 0x3ffaffe0 from task "alloc" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.102449800] HEAP: Allocated 4 bytes @ 0x3ffaffe8 from task "alloc" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.102666150] HEAP: Freed bytes @ 0x3ffaffe8 from task "free" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:31 (discriminator 9)
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.202436200] HEAP: Allocated 3 bytes @ 0x3ffaffe8 from task "alloc" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.202451725] HEAP: Allocated 6 bytes @ 0x3ffafff0 from task "alloc" on core 0 by:
/home/user/projects/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp-idf/components/freertos/port.c:355 (discriminator 1)

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Heap Tracing To Find Heap Corruption

Heap tracing can also be used to help track down heap corruption. When a region in heap is corrupted, it may be from some other part of the program which allocated memory at a nearby address.

If you have some idea at what time the corruption occurred, enabling heap tracing in **HEAP_TRACE_ALL** mode allows you to record all the functions which allocated memory, and the addresses of the allocations.

Using heap tracing in this way is very similar to memory leak detection as described above. For memory which is allocated and not freed, the output is the same. However, records will also be shown for memory which has been freed.

Performance Impact

Enabling heap tracing in menuconfig increases the code size of your program, and has a very small negative impact on performance of heap allocation/free operations even when heap tracing is not running.
When heap tracing is running, heap allocation/free operations are substantially slower than when heap tracing is stopped. Increasing the depth of stack frames recorded for each allocation (see above) will also increase this performance impact.

**False-Positive Memory Leaks** Not everything printed by `heap_trace_dump()` is necessarily a memory leak. Among things which may show up here, but are not memory leaks:

- Any memory which is allocated after `heap_trace_start()` but then freed after `heap_trace_stop()` will appear in the leak dump.
- Allocations may be made by other tasks in the system. Depending on the timing of these tasks, it’s quite possible this memory is freed after `heap_trace_stop()` is called.
- The first time a task uses stdout - for example, when it calls `printf()` - a lock (RTOS mutex semaphore) is allocated by the libc. This allocation lasts until the task is deleted.
- Certain uses of `printf()`, such as printing floating point numbers, will allocate some memory from the heap on demand. These allocations last until the task is deleted.
- The Bluetooth, Wi-Fi, and TCP/IP libraries will allocate heap memory buffers to handle incoming or outgoing data. These memory buffers are usually short-lived, but some may be shown in the heap leak trace if the data was received/transmitted by the lower levels of the network while the leak trace was running.
- TCP connections will continue to use some memory after they are closed, because of the `TIME_WAIT` state. After the `TIME_WAIT` period has completed, this memory will be freed.

One way to differentiate between “real” and “false positive” memory leaks is to call the suspect code multiple times while tracing is running, and look for patterns (multiple matching allocations) in the heap trace output.

### API Reference - Heap Tracing

**Header File**

- `components/heap/include/esp_heap_trace.h`

**Functions**

```c
esp_err_t heap_trace_init_standalone (heap_trace_record_t *record_buffer, size_t num_records)
```

Initialise heap tracing in standalone mode.

This function must be called before any other heap tracing functions.

To disable heap tracing and allow the buffer to be freed, stop tracing and then call `heap_trace_init_standalone(NULL, 0);`

**Parameters**

- `record_buffer` – Provide a buffer to use for heap trace data. Note: External RAM is allowed, but it prevents recording allocations made from ISR’s.
- `num_records` – Size of the heap trace buffer, as number of record structures.

**Returns**

- ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
- ESP_ERR_INVALID_STATE Heap tracing is currently in progress.
- ESP_OK Heap tracing initialised successfully.

```c
esp_err_t heap_trace_init_tohost (void)
```

Initialise heap tracing in host-based mode.

This function must be called before any other heap tracing functions.

**Returns**

- ESP_ERR_INVALID_STATE Heap tracing is currently in progress.
- ESP_OK Heap tracing initialised successfully.
Chapter 2. API Reference

esp_err_t heap_trace_start (heap_trace_mode_t mode)

Start heap tracing. All heap allocations & frees will be traced, until heap_trace_stop() is called.

Note: heap_trace_init_standalone() must be called to provide a valid buffer, before this function is called.

Note: Calling this function while heap tracing is running will reset the heap trace state and continue tracing.

Parameters  

  mode – Mode for tracing.
  • HEAP_TRACE_ALL means all heap allocations and frees are traced.
  • HEAP_TRACE_LEAKS means only suspected memory leaks are traced. (When memory is freed, the record is removed from the trace buffer.)

Returns

  • ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
  • ESP_ERR_INVALID_STATE A non-zero-length buffer has not been set via heap_trace_init_standalone().
  • ESP_OK Tracing is started.

esp_err_t heap_trace_stop (void)

Stop heap tracing.

Returns

  • ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
  • ESP_ERR_INVALID_STATE Heap tracing was not in progress.
  • ESP_OK Heap tracing stopped.

esp_err_t heap_trace_resume (void)

Resume heap tracing which was previously stopped.

Unlike heap_trace_start(), this function does not clear the buffer of any pre-existing trace records.

The heap trace mode is the same as when heap_trace_start() was last called (or HEAP_TRACE_ALL if heap_trace_start() was never called).

Returns

  • ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
  • ESP_ERR_INVALID_STATE Heap tracing was already started.
  • ESP_OK Heap tracing resumed.

size_t heap_trace_get_count (void)

Return number of records in the heap trace buffer.

It is safe to call this function while heap tracing is running.

esp_err_t heap_trace_get (size_t index, heap_trace_record_t *record)

Return a raw record from the heap trace buffer.

Note: It is safe to call this function while heap tracing is running, however in HEAP_TRACE_LEAK mode record indexing may skip entries unless heap tracing is stopped first.

Parameters

  • index – Index (zero-based) of the record to return.
  • record – [out] Record where the heap trace record will be copied.

Returns
Chapter 2. API Reference

- ESP_ERR_NOT_SUPPORTED Project was compiled without heap tracing enabled in menuconfig.
- ESP_ERR_INVALID_STATE Heap tracing was not initialised.
- ESP_ERR_INVALID_ARG Index is out of bounds for current heap trace record count.
- ESP_OK Record returned successfully.

void heap_trace_dump (void)
    Dump heap trace record data to stdout.

Note: It is safe to call this function while heap tracing is running, however in HEAP_TRACE_LEAK mode the dump may skip entries unless heap tracing is stopped first.

void heap_trace_dump_caps (const uint32_t caps)
    Dump heap trace from the memory of the capabilities passed as parameter.

Parameters caps – Capability(ies) of the memory from which to dump the trace. Set MAL-LOC_CAP_INTERNAL to dump heap trace data from internal memory. Set MAL-LOC_CAP_SPIRAM to dump heap trace data from PSRAM. Set both to dump both heap trace data.

esp_err_t heap_trace_summary (heap_trace_summary_t *summary)
    Get summary information about the result of a heap trace.

Note: It is safe to call this function while heap tracing is running.

Structures

struct heap_trace_record_t
    Trace record data type. Stores information about an allocated region of memory.

    Public Members

    uint32_t ccount
        CCOUNT of the CPU when the allocation was made. LSB (bit value 1) is the CPU number (0 or 1).

    void *address
        Address which was allocated. If NULL, then this record is empty.

    size_t size
        Size of the allocation.

    void *allocated_by[CONFIG_HEAP_TRACING_STACK_DEPTH]
        Call stack of the caller which allocated the memory.

    void *freed_by[CONFIG_HEAP_TRACING_STACK_DEPTH]
        Call stack of the caller which freed the memory (all zero if not freed.)

struct heap_trace_summary_t
    Stores information about the result of a heap trace.
Public Members

`heap_trace_mode_t mode`
- The heap trace mode we just completed / are running.

`size_t total_allocations`
- The total number of allocations made during tracing.

`size_t total_frees`
- The total number of frees made during tracing.

`size_t count`
- The number of records in the internal buffer.

`size_t capacity`
- The capacity of the internal buffer.

`size_t high_water_mark`
- The maximum value that ‘count’ got to.

`size_t has_overflowed`
- True if the internal buffer overflowed at some point.

Macros

`CONFIG_HEAP_TRACING_STACK_DEPTH`

Type Definitions

typedef struct `heap_trace_record_t` heap_trace_record_t
- Trace record data type. Stores information about an allocated region of memory.

Enumerations

enum `heap_trace_mode_t`
- Values:
  - enumerator `HEAP_TRACE_ALL`
  - enumerator `HEAP_TRACE_LEAKS`

2.10.16 High Resolution Timer (ESP Timer)
Overview

Although FreeRTOS provides software timers, FreeRTOS software timers have a few limitations:

- Maximum resolution is equal to the RTOS tick period
- Timer callbacks are dispatched from a low-priority timer service (i.e., daemon) task. This task can be preempted by other tasks, leading to decreased precision and accuracy.

Although hardware timers are not subject to the limitations mentioned, they may not be as user-friendly. For instance, application components may require timer events to be triggered at specific future times, but hardware timers typically have only one “compare” value for interrupt generation. This necessitates the creation of an additional system on top of the hardware timer to keep track of pending events and ensure that callbacks are executed when the corresponding hardware interrupts occur.

The hardware timer interrupt’s priority is configured via the `CONFIG_ESP_TIMER_INTERRUPT_LEVEL` option (possible priorities being 1, 2, or 3). Raising the timer interrupt’s priority can reduce the timer processing delay caused by interrupt latency.

`esp_timer` set of APIs provides one-shot and periodic timers, microsecond time resolution, and 64-bit range.

Internally, `esp_timer` uses a 64-bit hardware timer. The exact hardware timer implementation used will depend on the target, where LAC timer is used for ESP32.

Timer callbacks can be dispatched by two methods:

- `ESP_TIMER_TASK`. Available only if `CONFIG_ESP_TIMER_SUPPORTS_TASK_DISPATCH_METHOD` is enabled (by default disabled).
- `ESP_TIMER_ISR`. Available only if `CONFIG_ESP_TIMER_SUPPORTS_ISR_DISPATCH_METHOD` is enabled.

`ESP_TIMER_TASK`. Timer callbacks are dispatched from a high-priority `esp_timer` task. Because all the callbacks are dispatched from the same task, it is recommended to only do the minimal possible amount of work from the callback itself, posting an event to a lower-priority task using a queue instead.

If other tasks with a priority higher than `esp_timer` are running, callback dispatching will be delayed until the `esp_timer` task has a chance to run. For example, this will happen if an SPI Flash operation is in progress.

`ESP_TIMER_ISR`. Timer callbacks are dispatched directly from the timer interrupt handler. This method is useful for some simple callbacks which aim for lower latency.

Creating and starting a timer, and dispatching the callback takes some time. Therefore, there is a lower limit to the timeout value of one-shot `esp_timer`. If `esp_timer_start_once()` is called with a timeout value of less than 20 us, the callback will be dispatched only after approximately 20 us.

Periodic `esp_timer` also imposes a 50 us restriction on the minimal timer period. Periodic software timers with a period of less than 50 us are not practical since they would consume most of the CPU time. Consider using dedicated hardware peripherals or DMA features if you find that a timer with a small period is required.

Using `esp_timer` APIs

A single timer is represented by `esp_timer_handle_t` type. Each timer has a callback function associated with it. This callback function is called from the `esp_timer` task each time the timer elapses.

- To create a timer, call `esp_timer_create()`.
- To delete the timer when it is no longer needed, call `esp_timer_delete()`.

The timer can be started in one-shot mode or in periodic mode.

- To start the timer in one-shot mode, call `esp_timer_start_once()`, passing the time interval after which the callback should be called. When the callback gets called, the timer is considered to be stopped.
- To start the timer in periodic mode, call `esp_timer_start_periodic()`, passing the period with which the callback should be called. The timer keeps running until `esp_timer_stop()` is called.

Note that the timer must not be running when `esp_timer_start_once()` or `esp_timer_start_periodic()` is called. To restart a running timer, call `esp_timer_stop()` first, then call one of the start functions.
Callback Functions

**Note:** Keep the callback functions as short as possible. Otherwise, it will affect all timers.

Timer callbacks that are processed by the ESP_TIMER_ISR method should not call the context switch call - portYIELD_FROM_ISR(). Instead, use the esp_timer_isr_dispatch_need_yield() function. The context switch will be done after all ISR dispatch timers have been processed if required by the system.

### esp_timer During Light-sleep

During Light-sleep, the esp_timer counter stops and no callback functions are called. Instead, the time is counted by the RTC counter. Upon waking up, the system gets the difference between the counters and calls a function that advances the esp_timer counter. Since the counter has been advanced, the system starts calling callbacks that were not called during sleep. The number of callbacks depends on the duration of the sleep and the period of the timers. It can lead to the overflow of some queues. This only applies to periodic timers, since one-shot timers will be called once.

This behavior can be changed by calling esp_timer_stop() before sleeping. In some cases, this can be inconvenient, and instead of the stop function, you can use the skip_unhandled_events option during esp_timer_create(). When the skip_unhandled_events is true, if a periodic timer expires one or more times during Light-sleep, then only one callback is called on wake.

Using the skip_unhandled_events option with automatic Light-sleep (see Power Management APIs) helps to reduce the power consumption of the system when it is in Light-sleep. The duration of Light-sleep is also in part determined by the next event occurs. Timers with skip_unhandled_events option will not wake up the system.

### Handling Callbacks

esp_timer is designed to achieve a high-resolution and low-latency timer with the ability to handle delayed events. If the timer is late, then the callback will be called as soon as possible, and it will not be lost. In the worst case, when the timer has not been processed for more than one period (for periodic timers), the callbacks will be called one after the other without waiting for the set period. This can be bad for some applications, and the skip_unhandled_events option is introduced to eliminate this behavior. If skip_unhandled_events is set, then a periodic timer that has expired multiple times without being able to call the callback will still result in only one callback event once processing is possible.

### Obtaining Current Time

esp_timer also provides a convenience function to obtain the time passed since start-up, with microsecond precision: esp_timer_get_time(). This function returns the number of microseconds since esp_timer was initialized, which usually happens shortly before app_main function is called.

Unlike gettimeofday function, values returned by esp_timer_get_time():

- Start from zero after the chip wakes up from Deep-sleep
- Do not have timezone or DST adjustments applied

### Application Example

The following example illustrates the usage of esp_timer APIs: system/esp_timer.
API Reference

Header File

- components/esp_timer/include/esp_timer.h

Functions

**esp_err_t esp_timer_early_init (void)**
Minimal initialization of esp_timer.

This function can be called very early in startup process, after this call only esp_timer_get_time function can be used.

**Note:** This function is called from startup code. Applications do not need to call this function before using other esp_timer APIs.

**Returns**
- ESP_OK on success

**esp_err_t esp_timer_init (void)**
Initialize esp_timer library.

This function will be called from startup code on every core if CONFIG_ESP_TIMER_ISR_AFFINITY_NO_AFFINITY is enabled, It allocates the timer ISR on MULTIPLE cores and creates the timer task which can be run on any core.

**Note:** This function is called from startup code. Applications do not need to call this function before using other esp_timer APIs. Before calling this function, esp_timer_early_init must be called by the startup code.

**Returns**
- ESP_OK on success
- ESP_ERR_NO_MEM if allocation has failed
- ESP_ERR_INVALID_STATE if already initialized
- other errors from interrupt allocator

**esp_err_t esp_timer_deinit (void)**
De-initialize esp_timer library.

**Note:** Normally this function should not be called from applications

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if not yet initialized

**esp_err_t esp_timer_create (const esp_timer_create_args_t *create_args, esp_timer_handle_t *out_handle)**
Create an esp_timer instance.

**Note:** When done using the timer, delete it with esp_timer_delete function.
Chapter 2. API Reference

Parameters
- **create_args** – Pointer to a structure with timer creation arguments. Not saved by the library, can be allocated on the stack.
- **out_handle [out]** Output, pointer to esp_timer_handle_t variable which will hold the created timer handle.

Returns
- ESP_OK on success
- ESP_ERR_INVALID_ARG if some of the create_args are not valid
- ESP_ERR_INVALID_STATE if esp_timer library is not initialized yet
- ESP_ERR_NO_MEM if memory allocation fails

```c
esp_err_t esp_timer_start_once (esp_timer_handle_t timer, uint64_t timeout_us)
```

Start one-shot timer.

Timer should not be running when this function is called.

Parameters
- **timer** – timer handle created using esp_timer_create
- **timeout_us** – timer timeout, in microseconds relative to the current moment

Returns
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if the timer is already running

```c
esp_err_t esp_timer_start_periodic (esp_timer_handle_t timer, uint64_t period)
```

Start a periodic timer.

Timer should not be running when this function is called. This function will start the timer which will trigger every ‘period’ microseconds.

Parameters
- **timer** – timer handle created using esp_timer_create
- **period** – timer period, in microseconds

Returns
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if the timer is already running

```c
esp_err_t esp_timer_restart (esp_timer_handle_t timer, uint64_t timeout_us)
```

Restart a currently running timer.

If the given timer is a one-shot timer, the timer is restarted immediately and will timeout once in timeout_us microseconds. If the given timer is a periodic timer, the timer is restarted immediately with a new period of timeout_us microseconds.

Parameters
- **timer** – timer Handle created using esp_timer_create
- **timeout_us** – Timeout, in microseconds relative to the current time. In case of a periodic timer, also represents the new period.

Returns
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if the timer is not running

```c
esp_err_t esp_timer_stop (esp_timer_handle_t timer)
```

Stop the timer.

This function stops the timer previously started using esp_timer_start_once or esp_timer_start_periodic.

Parameters **timer** – timer handle created using esp_timer_create

Returns
- ESP_OK on success
- ESP_ERR_INVALID_STATE if the timer is not running
**Chapter 2. API Reference**

**esp_err_t esp_timer_delete (esp_timer_handle_t timer)**

Delete an esp_timer instance.

The timer must be stopped before deleting. A one-shot timer which has expired does not need to be stopped.

**Parameters**
- timer - timer handle allocated using esp_timer_create

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if the timer is running

**int64_t esp_timer_get_time (void)**

Get time in microseconds since boot.

**Returns**
- number of microseconds since underlying timer has been started

**int64_t esp_timer_get_next_alarm (void)**

Get the timestamp when the next timeout is expected to occur.

**Returns**
- Timestamp of the nearest timer event, in microseconds. The timebase is the same as for the values returned by esp_timer_get_time.

**int64_t esp_timer_get_next_alarm_for_wake_up (void)**

Get the timestamp when the next timeout is expected to occur skipping those which have skip_unhandled_events flag.

**Returns**
- Timestamp of the nearest timer event, in microseconds. The timebase is the same as for the values returned by esp_timer_get_time.

**esp_err_t esp_timer_get_period (esp_timer_handle_t timer, uint64_t *period)**

Get the period of a timer.

This function fetches the timeout period of a timer.

**Note:** The timeout period is the time interval with which a timer restarts after expiry. For one-shot timers, the period is 0 as there is no periodicity associated with such timers.

**Parameters**
- timer - timer handle allocated using esp_timer_create
- period - memory to store the timer period value in microseconds

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the arguments are invalid

**esp_err_t esp_timer_get_expiry_time (esp_timer_handle_t timer, uint64_t *expiry)**

Get the expiry time of a one-shot timer.

This function fetches the expiry time of a one-shot timer.

**Note:** This API returns a valid expiry time only for a one-shot timer. It returns an error if the timer handle passed to the function is for a periodic timer.

**Parameters**
- timer - timer handle allocated using esp_timer_create
- expiry - memory to store the timeout value in microseconds

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the arguments are invalid
- ESP_ERR_NOT_SUPPORTED if the timer type is periodic
**esp_err_t esp_timer_dump(FILE *stream)**

Dump the list of timers to a stream.

If CONFIG_ESP_TIMER_PROFILING option is enabled, this prints the list of all the existing timers. Otherwise, only the list active timers is printed.

The format is:

name period alarm times_armed times_triggered total_callback_run_time

where:

name — timer name (if CONFIG_ESP_TIMER_PROFILING is defined), or timer pointer
period — period of timer, in microseconds, or 0 for one-shot timer
alarm-time of the next alarm, in microseconds since boot, or 0 if the timer is not started

The following fields are printed if CONFIG_ESP_TIMER_PROFILING is defined:

times_armed — number of times the timer was armed via esp_timer_start_X

times_triggered — number of times the callback was called
total_callback_run_time — total time taken by callback to execute, across all calls

**Parameters**

- stream (such as stdout) to dump the information to

**Returns**

- ESP_OK on success
- ESP_ERR_NO_MEM if can not allocate temporary buffer for the output

**void esp_timer_isr_dispatch_need_yield(void)**

Requests a context switch from a timer callback function.

This only works for a timer that has an ISR dispatch method. The context switch will be called after all ISR dispatch timers have been processed.

**bool esp_timer_is_active(esp_timer_handle_t timer)**

Returns status of a timer, active or not.

This function is used to identify if the timer is still active or not.

**Parameters**

- timer — timer handle created using esp_timer_create

**Returns**

- 1 if timer is still active
- 0 if timer is not active.

**esp_err_t esp_timer_new_etm_alarm_event(esp_etm_event_handle_t *out_event)**

Get the ETM event handle of esp_timer underlying alarm event.

**Parameters**

- out_event — Returned ETM event handle

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Note:** The created ETM event object can be deleted later by calling esp_etm_del_event

**Note:** The ETM event is generated by the underlying hardware systimer, therefore, if the esp_timer is not clocked by systimer, then no ETM event will be generated.

**Parameters**

- out_event — Returned ETM event handle

**Returns**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Structures**

**struct esp_timer_create_args_t**

Timer configuration passed to esp_timer_create.
Chapter 2. API Reference

Public Members

`esp_timer_cb_t callback`
Function to call when timer expires.

`void *arg`
Argument to pass to the callback.

`esp_timer_dispatch_t dispatch_method`
Call the callback from task or from ISR.

`const char *name`
Timer name, used in esp_timer_dump function.

`bool skip_unhandled_events`
Skip unhandled events for periodic timers.

Type Definitions

typedef struct esp_timer *esp_timer_handle_t
Opaque type representing a single esp_timer.

typedef void (*esp_timer_cb_t)(void *arg)
Timer callback function type.

  Param arg  pointer to opaque user-specific data

Enumerations

enum esp_timer_dispatch_t
Method for dispatching timer callback.

  Values:

  enumerator ESP_TIMER_TASK
  Callback is called from timer task.

  enumerator ESP_TIMER_MAX
  Count of the methods for dispatching timer callback.

2.10.17 Internal and Unstable APIs

This section is listing some APIs that are internal or likely to be changed or removed in the next releases of ESP-IDF.

API Reference

Header File

  • components/esp_rom/include/esp_rom_sys.h
Chapter 2. API Reference

Functions

void esp_rom_software_reset_system (void)
Software Reset digital core include RTC.
It is not recommended to use this function in esp-idf, use esp_restart() instead.

void esp_rom_software_reset_cpu (int cpu_no)
Software Reset cpu core.
It is not recommended to use this function in esp-idf, use esp_restart() instead.

Parameters cpu_no -- The CPU to reset, 0 for PRO CPU, 1 for APP CPU.

int esp_rom_printf (const char *fmt, ...)
Print formatted string to console device.

Note: float and long long data are not supported!

Parameters

• fmt -- Format string
• ... -- Additional arguments, depending on the format string

Returns int: Total number of characters written on success; A negative number on failure.

void esp_rom_delay_us (uint32_t us)
Pauses execution for us microseconds.

Parameters us -- Number of microseconds to pause

void esp_rom_install_channel_putchar(int channel, void (*putc)(char c))
esp_rom_printf can print message to different channels simultaneously. This function can help install the low
level putc function for esp_rom_printf.

Parameters

• channel -- Channel number (starting from 1)
• putc -- Function pointer to the putc implementation. Set NULL can disconnect
esp_rom_printf with putc.

void espRomInstallUartPrintf (void)
Install UART1 as the default console channel, equivalent to esp_rom_install_channel_putchar(1,
esp_rom_uart_putchar)

soc_reset_reason_t esp_rom_get_reset_reason (int cpu_no)
Get reset reason of CPU.

Parameters cpu_no -- CPU number

Returns Reset reason code (see in soc/reset_reasons.h)

void esp_rom_route_intr_matrix (int cpu_core, uint32_t periph_intr_id, uint32_t cpu_intr_num)
Route peripheral interrupt sources to CPU’s interrupt port by matrix.

Usually there’re 4 steps to use an interrupt:

a. Route peripheral interrupt source to CPU. e.g. esp_rom_route_intr_matrix(0,
ETS_WIFI_MAC_INTR_SOURCE, ETS_WMAC_INUM)
b. Set interrupt handler for CPU
c. Enable CPU interrupt
d. Enable peripheral interrupt

Parameters

• cpu_core -- The CPU number, which the peripheral interrupt will inform to
• periph_intr_id -- The peripheral interrupt source number
• cpu_intr_num -- The CPU interrupt number
Chapter 2. API Reference

uint32_t esp_rom_get_cpu_ticks_per_us(void)
Get the real CPU ticks per us.

Returns CPU ticks per us

void esp_rom_set_cpu_ticks_per_us(uint32_t ticks_per_us)
Set the real CPU tick rate.

Note: Call this function when CPU frequency is changed, otherwise the esp_rom_delay_us can be inaccurate.

Parameters ticks_per_us - CPU ticks per us

2.10.18 Inter-Processor Call

Note: The IPC is an Inter-Processor Call and NOT Inter-Process Communication as found on other operating systems.

Overview

Due to the dual core nature of the ESP32, there are instances where a certain callback must be run in the context of a particular CPU such as:

• When allocating an ISR to an interrupt source of a particular CPU (applies to freeing a particular CPU’s interrupt source as well).
• On particular chips (such as the ESP32), accessing memory that is exclusive to a particular CPU (such as RTC Fast Memory).
• Reading the registers/state of another CPU.

The IPC (Inter-Processor Call) feature allows a particular CPU (the calling CPU) to trigger the execution of a callback function on another CPU (the target CPU). The IPC feature allows execution of a callback function on the target CPU in either a task context, or a High Priority Interrupt context (see High Priority Interrupts for more details). Depending on the context that the callback function is executed in, different restrictions apply to the implementation of the callback function.

IPC in Task Context

The IPC feature implements callback execution in a task context by creating an IPC task for each CPU during application startup. When the calling CPU needs to execute a callback on the target CPU, the callback will execute in the context of the target CPU’s IPC task.

When using IPCs in a task context, users need to consider the following:

• IPC callbacks should ideally be simple and short. An IPC callback should avoid attempting to block or yield.
• The IPC tasks are created at the highest possible priority (i.e., configMAX_PRIORITIES - 1) thus the callback should also run at that priority as a result. However, CONFIG_ESP_IPC_USES_CALLERS_PRIORITY is enabled by default which will temporarily lower the priority of the target CPU’s IPC task to the calling CPU before executing the callback.
• Depending on the complexity of the callback, users may need to configure the stack size of the IPC task via CONFIG_ESP_IPC_TASK_STACK_SIZE.
• The IPC feature is internally protected by a mutex. Therefore, simultaneous IPC calls from two or more calling CPUs will be handled on a first come first serve basis.
**API Usage**  Task Context IPC callbacks have the following restrictions:

- The callback must be of type `void func(void *arg)`
- The callback should avoid attempting to block or yield as this will result in the target CPU’s IPC task blocking or yielding.
- The callback must avoid changing any aspect of the IPC task (e.g., by calling `vTaskPrioritySet(NULL, x)`).

The IPC feature offers the API listed below to execute a callback in a task context on a target CPU. The API allows the calling CPU to block until the callback’s execution has completed, or return immediately once the callback’s execution has started.

- `esp_ipc_call()` will trigger an IPC call on the target CPU. This function will block until the target CPU’s IPC task begins execution of the callback.
- `esp_ipc_call_blocking()` will trigger an IPC on the target CPU. This function will block until the target CPU’s IPC task completes execution of the callback.

**IPC in ISR Context**

In some cases, we need to quickly obtain the state of another CPU such as in a core dump, GDB stub, various unit tests, and DPORT workaround. For such scenarios, the IPC feature supports execution of callbacks in a High Priority Interrupt context. The IPC feature implements the High Priority Interrupt context by reserving a High Priority Interrupt on each CPU for IPC usage. When a calling CPU needs to execute a callback on the target CPU, the callback will execute in the context of the High Priority Interrupt of the target CPU.

When using IPCs in High Priority Interrupt context, users need to consider the following:

- Since the callback is executed in a High Priority Interrupt context, the callback must be written entirely in assembly. See the API Usage below for more details regarding writing assembly callbacks.
- The priority of the reserved High Priority Interrupt is dependent on the `CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL` option.
- **When the callback executes:**
  - The calling CPU will disable interrupts of level 3 and lower
  - Although the priority of the reserved interrupt depends on `CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL`, during the execution IPC ISR callback, the target CPU will disable interrupts of level 5 and lower regardless of what `CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL` is set to.

**API Usage**  High Priority Interrupt IPC callbacks have the following restrictions:

- The callback must be of type `void func(void *arg)` but implemented entirely in assembly
- The callback is invoked via the `CALLX0` instruction with register windowing disabled, thus the callback:
  - Must not call any register window related instructions (e.g., `entry` and `retw`).
  - Must not call other C functions as register windowing is disabled
- The callback should be placed in IRAM at a 4-byte aligned address
- (On invocation of/after returning from) the callback, the registers `a2`, `a3`, `a4` are (saved/restored) automatically thus the callback:
  - `a2` will contain the `void *arg` of the callback
  - `a3/a4` are free to use as scratch registers

The IPC feature offers the API listed below to execute a callback in a High Priority Interrupt context.

- `esp_ipc_isr_asm_call()` will trigger an IPC call on the target CPU. This function will busy-wait until the target CPU begins execution of the callback.
- `esp_ipc_isr_asm_call_blocking()` will trigger an IPC call on the target CPU. This function will busy-wait until the target CPU completes execution of the callback.

The following code-blocks demonstrates a High Priority Interrupt IPC callback written in assembly that simply reads the target CPU’s cycle count.
/* esp_test_ipc_isr_get_cycle_count_other_cpu(void *arg) */
// this function reads CCOUNT of the target CPU and stores it in arg.
// use only a2, a3 and a4 regs here.
.section .iram1, "ax"
.align 4
.global esp_test_ipc_isr_get_cycle_count_other_cpu
.type esp_test_ipc_isr_get_cycle_count_other_cpu, @function
// Args:
// a2 - void* arg
esp_test_ipc_isr_get_cycle_count_other_cpu:
rsr.ccount a3
s32i a3, a2, 0
ret

unit32_t cycle_count;
esp_ipc_isr_asm_call_blocking(esp_test_ipc_isr_get_cycle_count_other_cpu, (void *)cycle_count);

Note: The number of scratch registers available for use is sufficient for most simple use cases. But if your callback requires more scratch registers, void *arg can point to a buffer that is used as a register save area. The callback can then save and restore more registers. See the system/ipc/ipc_isr.

Note: For more examples of High Priority Interrupt IPC callbacks, see components/esp_system/port/arch/xtensa/esp_ipc_isr_routines.S and components/esp_system/test/test_ipc_isr.S

The High Priority Interrupt IPC API also provides the following convenience functions that can stall/resume the target CPU. These API utilize the High Priority Interrupt IPC, but supply their own internal callbacks:

- esp_ipc_isr_stall_other_cpu() stalls the target CPU. The calling CPU disables interrupts of level 3 and lower while the target CPU will busy-wait with interrupts of level 5 and lower disabled. The target CPU will busy-wait until esp_ipc_isr_release_other_cpu() is called.
- esp_ipc_isr_release_other_cpu() resumes the target CPU.

API Reference

Header File

- components/esp_system/include/esp_ipc.h

Functions

esp_err_t esp_ipc_call(uint32_t cpu_id, esp_ipc_func_t func, void *arg)

Execute a callback on a given CPU.

Execute a given callback on a particular CPU. The callback must be of type “esp_ipc_func_t” and will be invoked in the context of the target CPU’s IPC task.

- This function will block the target CPU’s IPC task has begun execution of the callback
- If another IPC call is ongoing, this function will block until the ongoing IPC call completes
- The stack size of the IPC task can be configured via the CONFIG_ESP_IPC_TASK_STACK_SIZE option

Note: In single-core mode, returns ESP_ERR_INVALID_ARG for cpu_id 1.
Parameters

• cpu_id - [in] CPU where the given function should be executed (0 or 1)
• func - [in] Pointer to a function of type void func(void* arg) to be executed
• arg - [in] Arbitrary argument of type void* to be passed into the function

Returns

• ESP_ERR_INVALID_ARG if cpu_id is invalid
• ESP_ERR_INVALID_STATE if the FreeRTOS scheduler is not running
• ESP_OK otherwise

`esp_err_t esp_ipc_call_blocking(uint32_t cpu_id, esp_ipc_func_t func, void* arg)`

Execute a callback on a given CPU until and block until it completes.

This function is identical to esp_ipc_call() except that this function will block until the execution of the callback completes.

Note: In single-core mode, returns ESP_ERR_INVALID_ARG for cpu_id 1.

Type Definitions

typedef void(*esp_ipc_func_t)(void* arg)

IPCCallback.

A callback of this type should be provided as an argument when calling esp_ipc_call() or esp_ipc_call_blocking().

Header File

• components/esp_system/include/esp_ipc_isr.h

Functions

void esp_ipc_isr_asm_call(esp_ipc_isr_func_t func, void* arg)

Execute an assembly callback on the other CPU.

Execute a given callback on the other CPU in the context of a High Priority Interrupt.

• This function will busy-wait in a critical section until the other CPU has started execution of the callback
• The callback must be written in assembly, is invoked using a CALLX0 instruction, and has a2, a3, a4 as scratch registers. See docs for more details

Note: This function is not available in single-core mode.

Parameters

• func - [in] Pointer to a function of type void func(void* arg) to be executed
• arg - [in] Arbitrary argument of type void* to be passed into the function
void esp_ipc_isr_asm_call_blocking (esp_isr_func_t func, void *arg)

Execute an assembly callback on the other CPU and busy-wait until it completes.

This function is identical to esp_ipc_isr_asm_call() except that this function will busy-wait until the execution of the callback completes.

**Note:** This function is not available in single-core mode.

**Parameters**
- `func` - [in] Pointer to a function of type void func(void* arg) to be executed
- `arg` - [in] Arbitrary argument of type void* to be passed into the function

void esp_ipc_isr_stall_other_cpu (void)

Stall the other CPU.

This function will stall the other CPU. The other CPU is stalled by busy-waiting in the context of a High Priority Interrupt. The other CPU will not be resumed until esp_ipc_isr_release_other_cpu() is called.

- This function is internally implemented using IPC ISR
- This function is used for DPORT workaround.
- If the stall feature is paused using esp_ipc_isr_stall_pause(), this function will have no effect.

**Note:** This function is not available in single-core mode.

**Note:** It is the caller’s responsibility to avoid deadlocking on spinlocks

void esp_ipc_isr_release_other_cpu (void)

Release the other CPU.

This function will release the other CPU that was previously stalled from calling esp_ipc_isr_stall_other_cpu()

- This function is used for DPORT workaround.
- If the stall feature is paused using esp_ipc_isr_stall_pause(), this function will have no effect.

**Note:** This function is not available in single-core mode.

void esp_ipc_isr_stall_pause (void)

Pause the CPU stall feature.

This function will pause the CPU stall feature. Once paused, calls to esp_ipc_isr_stall_other_cpu() and esp_ipc_isr_release_other_cpu() will have no effect. If a IPC ISR call is already in progress, this function will busy-wait until the call completes before pausing the CPU stall feature.

void esp_ipc_isr_stall_abort (void)

Abort a CPU stall.

This function will abort any stalling routine of the other CPU due to a pervious call to esp_ipc_isr_stall_other_cpu(). This function aborts the stall in a non-recoverable manner, thus should only be called in case of a panic().

- This function is used in panic handling code
void esp_ipc_isr_stall_resume(void)
    Resume the CPU stall feature.
    This function will resume the CPU stall feature that was previously paused by calling esp_ipc_isr_stall_pause().
    Once resumed, calls to esp_ipc_isr_stall_other_cpu() and esp_ipc_isr_release_other_cpu() will have effect again.

Type Definitions
typedef void (*esp_ipc_isr_func_t)(void *arg)
    IPC ISR Callback.
    A callback of this type should be provided as an argument when calling esp_ipc_isr_asm_call() or
    esp_ipc_isr_asm_call_blocking().

2.10.19 Interrupt allocation

Overview

The ESP32 has two cores, with 32 interrupts each. Each interrupt has a certain priority level, most (but not all)
interrupts are connected to the interrupt mux.

Because there are more interrupt sources than interrupts, sometimes it makes sense to share an interrupt in multiple
drivers. The esp_intr_alloc() abstraction exists to hide all these implementation details.

A driver can allocate an interrupt for a certain peripheral by calling esp_intr_alloc() (or
esp_intr_alloc_intrstatus()). It can use the flags passed to this function to set the type of inter-
rupt allocated, specifying a particular level or trigger method. The interrupt allocation code will then find an
applicable interrupt, use the interrupt mux to hook it up to the peripheral, and install the given interrupt handler and
ISR to it.

This code presents two different types of interrupts, handled differently: shared interrupts and non-shared interrupts.
The simplest ones are non-shared interrupts: a separate interrupt is allocated per esp_intr_alloc() call and
this interrupt is solely used for the peripheral attached to it, with only one ISR that will get called. On the other
hand, shared interrupts can have multiple peripherals triggering them, with multiple ISRs being called when one of
the peripherals attached signals an interrupt. Thus, ISRs that are intended for shared interrupts should check the
interrupt status of the peripheral they service in order to check if any action is required.

Non-shared interrupts can be either level- or edge-triggered. Shared interrupts can only be level interrupts due to the
chance of missed interrupts when edge interrupts are used.

For example, let’s say DevA and DevB share an interrupt. DevB signals an interrupt, so INT line goes high. The
ISR handler calls code for DevA but does nothing. Then, ISR handler calls code for DevB, but while doing that,
DevA signals an interrupt. DevB’s ISR is done, it clears interrupt status for DevB and exits interrupt code. Now,
an interrupt for DevA is still pending, but because the INT line never went low, as DevA kept it high even when the
interrupt for DevB was cleared, the interrupt is never serviced.

Multicore issues

Peripherals that can generate interrupts can be divided in two types:

- External peripherals, within the ESP32 but outside the Xtensa cores themselves. Most ESP32 peripherals are
  of this type.
- Internal peripherals, part of the Xtensa CPU cores themselves.

Interrupt handling differs slightly between these two types of peripherals.
### Internal peripheral interrupts

Each Xtensa CPU core has its own set of six internal peripherals:

- Three timer comparators
- A performance monitor
- Two software interrupts.

Internal interrupt sources are defined in `esp_intr_alloc.h` as `ETS_INTERNAL_*_INTR_SOURCE`.

These peripherals can only be configured from the core they are associated with. When generating an interrupt, the interrupt they generate is hard-wired to their associated core; it’s not possible to have, for example, an internal timer comparator of one core generate an interrupt on another core. That is why these sources can only be managed using a task running on that specific core. Internal interrupt sources are still allocatable using `esp_intr_alloc()` as normal, but they cannot be shared and will always have a fixed interrupt level (namely, the one associated in hardware with the peripheral).

### External Peripheral Interrupts

The remaining interrupt sources are from external peripherals. These are defined in `soc/soc.h` as `ETS_*_INTR_SOURCE`.

Non-internal interrupt slots in both CPU cores are wired to an interrupt multiplexer, which can be used to route any external interrupt source to any of these interrupt slots.

- Allocating an external interrupt will always allocate it on the core that does the allocation.
- Freeing an external interrupt must always happen on the same core it was allocated on.
- Disabling and enabling external interrupts from another core is allowed.
- Multiple external interrupt sources can share an interrupt slot by passing `ESP_INTR_FLAG_SHARED` as a flag to `esp_intr_alloc()`.

Care should be taken when calling `esp_intr_alloc()` from a task which is not pinned to a core. During task switching, these tasks can migrate between cores. Therefore it is impossible to tell which CPU the interrupt is allocated on, which makes it difficult to free the interrupt handle and may also cause debugging difficulties. It is advised to use `xTaskCreatePinnedToCore()` with a specific CoreID argument to create tasks that will allocate interrupts. In the case of internal interrupt sources, this is required.

### IRAM-Safe Interrupt Handlers

The `ESP_INTR_FLAG_IRAM` flag registers an interrupt handler that always runs from IRAM (and reads all its data from DRAM), and therefore does not need to be disabled during flash erase and write operations.

This is useful for interrupts which need a guaranteed minimum execution latency, as flash write and erase operations can be slow (erasures can take tens or hundreds of milliseconds to complete).

It can also be useful to keep an interrupt handler in IRAM if it is called very frequently, to avoid flash cache misses.

Refer to the [SPI flash API documentation](#) for more details.

### Multiple Handlers Sharing A Source

Several handlers can be assigned to a same source, given that all handlers are allocated using the `ESP_INTR_FLAG_SHARED` flag. They will all be allocated to the interrupt, which the source is attached to, and called sequentially when the source is active. The handlers can be disabled and freed individually. The source is attached to the interrupt (enabled), if one or more handlers are enabled, otherwise detached. A handler will never be called when disabled, while its source may still be triggered if any one of its handler enabled.

Sources attached to non-shared interrupt do not support this feature.

Though the framework support this feature, you have to use it very carefully. There usually exist two ways to stop an interrupt from being triggered: disable the source or mask peripheral interrupt status. IDF only handles enabling and disabling of the source itself, leaving status and mask bits to be handled by users. Status bits shall either be masked before the handler responsible for it is disabled, either be masked and then properly handled in another enabled interrupt. Please note that leaving some status bits unhandled without masking them, while...
disabling the handlers for them, will cause the interrupt(s) to be triggered indefinitely, resulting therefore in a system crash.

**API Reference**

**Header File**
- components/esp_hw_support/include/esp_intr_alloc.h

**Functions**

`esp_err_t esp_intr_mark_shared` (int intno, int cpu, bool is_in_iram)
Mark an interrupt as a shared interrupt.

This will mark a certain interrupt on the specified CPU as an interrupt that can be used to hook shared interrupt handlers to.

**Parameters**
- **intno** – The number of the interrupt (0-31)
- **cpu** – CPU on which the interrupt should be marked as shared (0 or 1)
- **is_in_iram** – Shared interrupt is for handlers that reside in IRAM and the int can be left enabled while the flash cache is disabled.

**Returns**
ESP_ERR_INVALID_ARG if cpu or intno is invalid ESP_OK otherwise

`esp_err_t esp_intr_reserve` (int intno, int cpu)
Reserve an interrupt to be used outside of this framework.

This will mark a certain interrupt on the specified CPU as reserved, not to be allocated for any reason.

**Parameters**
- **intno** – The number of the interrupt (0-31)
- **cpu** – CPU on which the interrupt should be marked as shared (0 or 1)

**Returns**
ESP_ERR_INVALID_ARG if cpu or intno is invalid ESP_OK otherwise

`esp_err_t esp_intr_alloc` (int source, int flags, intr_handler_t handler, void *arg, intr_handle_t *ret_handle)
Allocate an interrupt with the given parameters.

This finds an interrupt that matches the restrictions as given in the flags parameter, maps the given interrupt source to it and hooks up the given interrupt handler (with optional argument) as well. If needed, it can return a handle for the interrupt as well.

The interrupt will always be allocated on the core that runs this function.

If ESP_INTR_FLAG_IRAM flag is used, and handler address is not in IRAM or RTC_FAST_MEM, then ESP_ERR_INVALID_ARG is returned.

**Parameters**
- **source** – The interrupt source. One of the ETS_*.INTR_SOURCE interrupt mux sources, as defined in soc/soc.h, or one of the internal ETS_INTERNAL_*.INTR_SOURCE sources as defined in this header.
- **flags** – An ORed mask of the ESP_INTR_FLAG_* defines. These restrict the choice of interrupts that this routine can choose from. If this value is 0, it will default to allocating a non-shared interrupt of level 1, 2 or 3. If this is ESP_INTR_FLAG_SHARED, it will allocate a shared interrupt of level 1. Setting ESP_INTR_FLAGINTRDISABLED will return from this function with the interrupt disabled.
- **handler** – The interrupt handler. Must be NULL when an interrupt of level >3 is requested, because these types of interrupts aren’t C-callable.
- **arg** – Optional argument for passed to the interrupt handler
- **ret_handle** – Pointer to an intr_handle_t to store a handle that can later be used to request details or free the interrupt. Can be NULL if no handle is required.

**Returns**
ESP_ERR_INVALID_ARG if the combination of arguments is invalid.
ESP_ERR_NOT_FOUND No free interrupt found with the specified flags ESP_OK otherwise


esp_err_t esp_intr_alloc_intrstatus(int source, int flags, uint32_t intrstatusreg, uint32_t intrstatusmask, intr_handler_t handler, void *arg, intr_handle_t *ret_handle)

Allocate an interrupt with the given parameters.

This essentially does the same as esp_intr_alloc, but allows specifying a register and mask combo. For shared interrupts, the handler is only called if a read from the specified register, ANDed with the mask, returns non-zero. By passing an interrupt status register address and a fitting mask, this can be used to accelerate interrupt handling in the case a shared interrupt is triggered; by checking the interrupt statuses first, the code can decide which ISRs can be skipped.

Parameters

• **source** – The interrupt source. One of the ETS_*_INTR_SOURCE interrupt mux sources, as defined in soc/soc.h, or one of the internal ETS_INTERNAL_*_INTR_SOURCE sources as defined in this header.
• **flags** – An ORed mask of the ESP_INTR_FLAG_* defines. These restrict the choice of interrupts that this routine can choose from. If this value is 0, it will default to allocating a non-shared interrupt of level 1, 2 or 3. If this is ESP_INTR_FLAG_SHARED, it will allocate a shared interrupt of level 1. Setting ESP_INTR_FLAG_INTRDISABLED will return from this function with the interrupt disabled.
• **intrstatusreg** – The address of an interrupt status register
• **intrstatusmask** – A mask. If a read of address intrstatusreg has any of the bits that are 1 in the mask set, the ISR will be called. If not, it will be skipped.
• **handler** – The interrupt handler. Must be NULL when an interrupt of level >3 is requested, because these types of interrupts aren’t C-callable.
• **arg** – Optional argument for passed to the interrupt handler
• **ret_handle** – Pointer to an intr_handle_t to store a handle that can later be used to request details or free the interrupt. Can be NULL if no handle is required.

Returns ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_ERR_NOT_FOUND No free interrupt found with the specified flags ESP_OK otherwise

esp_err_t esp_intr_free(intr_handle_t handle)

Disable and free an interrupt.

Use an interrupt handle to disable the interrupt and release the resources associated with it. If the current core is not the core that registered this interrupt, this routine will be assigned to the core that allocated this interrupt, blocking and waiting until the resource is successfully released.

**Note:** When the handler shares its source with other handlers, the interrupt status bits it’s responsible for should be managed properly before freeing it. see esp_intr_disable for more details. Please do not call this function in esp_ipc_call_blocking.

Parameters **handle** – The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

Returns ESP_ERR_INVALID_ARG the handle is NULL ESP_FAIL failed to release this handle ESP_OK otherwise

int esp_intr_get_cpu(intr_handle_t handle)

Get CPU number an interrupt is tied to.

Parameters **handle** – The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

Returns The core number where the interrupt is allocated

int esp_intr_get_intno(intr_handle_t handle)

Get the allocated interrupt for a certain handle.

Parameters **handle** – The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

Returns The interrupt number
**esp_err_t esp_intr_disable (intr_handle_t handle)**

Disable the interrupt associated with the handle.

**Note:**

a. For local interrupts (ESP_INTERNAL_* sources), this function has to be called on the CPU the interrupt is allocated on. Other interrupts have no such restriction.

b. When several handlers sharing a same interrupt source, interrupt status bits, which are handled in the handler to be disabled, should be masked before the disabling, or handled in other enabled interrupts properly. Miss of interrupt status handling will cause infinite interrupt calls and finally system crash.

**Parameters**
- **handle** - The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

**Returns**
- ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

**esp_err_t esp_intr_enable (intr_handle_t handle)**

Enable the interrupt associated with the handle.

**Note:** For local interrupts (ESP_INTERNAL_* sources), this function has to be called on the CPU the interrupt is allocated on. Other interrupts have no such restriction.

**Parameters**
- **handle** - The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

**Returns**
- ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

**esp_err_t esp_intr_set_in_iram (intr_handle_t handle, bool is_in_iram)**

Set the “in IRAM” status of the handler.

**Note:** Does not work on shared interrupts.

**Parameters**

- **handle** - The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus
- **is_in_iram** - Whether the handler associated with this handle resides in IRAM. Handlers residing in IRAM can be called when cache is disabled.

**Returns**
- ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

**void esp_intr_noniram_disable (void)**

Disable interrupts that aren’t specifically marked as running from IRAM.

**void esp_intr_noniram_enable (void)**

Re-enable interrupts disabled by esp_intr_noniram_disable.

**void esp_intr_enable_source (int inum)**

Enable the interrupt source based on its number

**Parameters**
- **inum** - interrupt number from 0 to 31

**void esp_intr_disable_source (int inum)**

Disable the interrupt source based on its number

**Parameters**
- **inum** - interrupt number from 0 to 31
static inline int esp_intr_flags_to_level (int flags)
    Get the lowest interrupt level from the flags.

    Parameters flags - The same flags that pass to esp_intr_alloc_intrstatus API

Macros

ESP_INTR_FLAG_LEVEL1
    Interrupt allocation flags.
    These flags can be used to specify which interrupt qualities the code calling esp_intr_alloc* needs. Accept a Level 1 interrupt vector (lowest priority)

ESP_INTR_FLAG_LEVEL2
    Accept a Level 2 interrupt vector.

ESP_INTR_FLAG_LEVEL3
    Accept a Level 3 interrupt vector.

ESP_INTR_FLAG_LEVEL4
    Accept a Level 4 interrupt vector.

ESP_INTR_FLAG_LEVEL5
    Accept a Level 5 interrupt vector.

ESP_INTR_FLAG_LEVEL6
    Accept a Level 6 interrupt vector.

ESP_INTR_FLAG_NMI
    Accept a Level 7 interrupt vector (highest priority)

ESP_INTR_FLAG_SHARED
    Interrupt can be shared between ISRs.

ESP_INTR_FLAG_EDGE
    Edge-triggered interrupt.

ESP_INTR_FLAG_IRAM
    ISR can be called if cache is disabled.

ESP_INTR_FLAG_INTRDISABLED
    Return with this interrupt disabled.

ESP_INTR_FLAG_LOWMED
    Low and medium prio interrupts. These can be handled in C.

ESP_INTR_FLAG_HIGH
    High level interrupts. Need to be handled in assembly.

ESP_INTR_FLAG_LEVELMASK
    Mask for all level flags.
ETS_INTERNAL_TIMER0_INTR_SOURCE
Platform timer 0 interrupt source.
The esp_intr_alloc* functions can allocate an int for all ETS_*_INTR_SOURCE interrupt sources that are routed through the interrupt mux. Apart from these sources, each core also has some internal sources that do not pass through the interrupt mux. To allocate an interrupt for these sources, pass these pseudo-sources to the functions.

ETS_INTERNAL_TIMER1_INTR_SOURCE
Platform timer 1 interrupt source.

ETS_INTERNAL_TIMER2_INTR_SOURCE
Platform timer 2 interrupt source.

ETS_INTERNAL_SW0_INTR_SOURCE
Software int source 1.

ETS_INTERNAL_SW1_INTR_SOURCE
Software int source 2.

ETS_INTERNAL_PROFILING_INTR_SOURCE
Int source for profiling.

ETS_INTERNAL_UNUSED_INTR_SOURCE
Interrupt is not assigned to any source.

ETS_INTERNAL_INTR_SOURCE_OFF
Provides SystemView with positive IRQ IDs, otherwise scheduler events are not shown properly

ESP_INTR_ENABLE (inum)
Enable interrupt by interrupt number

ESP_INTR_DISABLE (inum)
Disable interrupt by interrupt number

Type Definitions
typedef void (*intr_handler_t)(void *arg)
Function prototype for interrupt handler function
typedef struct intr_handle_data_t intr_handle_data_t
Interrupt handler associated data structure
typedef intr_handle_data_t *intr_handle_t
Handle to an interrupt handler

2.10.20 Logging library

Overview
The logging library provides two ways for setting log verbosity:

- At compile time: in menuconfig, set the verbosity level using the option \texttt{CONFIG\_LOG\_DEFAULT\_LEVEL}.
Chapter 2. API Reference

- Optionally, also in menuconfig, set the maximum verbosity level using the option `CONFIG_LOG_MAXIMUM_LEVEL`. By default this is the same as the default level, but it can be set higher in order to compile more optional logs into the firmware.

- At runtime: all logs for verbosity levels lower than `CONFIG_LOG_DEFAULT_LEVEL` are enabled by default. The function `esp_log_level_set()` can be used to set a logging level on a per module basis. Modules are identified by their tags, which are human-readable ASCII zero-terminated strings.

There are the following verbosity levels:

- Error (lowest)
- Warning
- Info
- Debug
- Verbose (highest)

**Note:** The function `esp_log_level_set()` cannot set logging levels higher than specified by `CONFIG_LOG_MAXIMUM_LEVEL`. To increase log level for a specific file above this maximum at compile time, use the macro `LOG_LOCAL_LEVEL` (see the details below).

### How to use this library

In each C file that uses logging functionality, define the TAG variable as shown below:

```c
static const char* TAG = "MyModule";
```

Then use one of the logging macros to produce output, e.g:

```c
ESP_LOGW(TAG, "Baud rate error %.1f%. Requested: %d baud, actual: %d baud", error_... 100, baud_req, baud_real);
```

Several macros are available for different verbosity levels:

- `ESP_LOGE` - error (lowest)
- `ESP_LOGW` - warning
- `ESP_LOGI` - info
- `ESP_LOGD` - debug
- `ESP_LOGV` - verbose (highest)

Additionally, there are `ESP_EARLY_LOGx` versions for each of these macros, e.g. `ESP_EARLY_LOGE`. These versions have to be used explicitly in the early startup code only, before heap allocator and syscalls have been initialized. Normal `ESP_LOGx` macros can also be used while compiling the bootloader, but they will fall back to the same implementation as `ESP_EARLY_LOGx` macros.

There are also `ESP_DRAM_LOGx` versions for each of these macros, e.g. `ESP_DRAM_LOGE`. These versions are used in some places where logging may occur with interrupts disabled or with flash cache inaccessible. Use of this macros should be as sparing as possible, as logging in these types of code should be avoided for performance reasons.

**Note:** Inside critical sections interrupts are disabled so it’s only possible to use `ESP_DRAM_LOGx` (preferred) or `ESP_EARLY_LOGx`. Even though it’s possible to log in these situations, it’s better if your program can be structured not to require it.

To override default verbosity level at file or component scope, define the `LOG_LOCAL_LEVEL` macro.

At file scope, define it before including `esp_log.h`, e.g:

```c
#define LOG_LOCAL_LEVEL ESP_LOG_VERBOSE
#include "esp_log.h"
```

At component scope, define it in the component CMakeLists:
target_compile_definitions({${COMPONENT_LIB} PUBLIC "-DLOG_LOCAL_LEVEL=ESP_LOG_←VERBOSE"})

To configure logging output per module at runtime, add calls to the function `esp_log_level_set()` as follows:

```c
esp_log_level_set("*", ESP_LOG_ERROR);  // set all components to ERROR level
esp_log_level_set("wifi", ESP_LOG_WARN);  // enable WARN logs from WiFi stack
esp_log_level_set("dhcpc", ESP_LOG_INFO);  // enable INFO logs from DHCP client
```

**Note:** The “DRAM” and “EARLY” log macro variants documented above do not support per module setting of log verbosity. These macros will always log at the “default” verbosity level, which can only be changed at runtime by calling `esp_log_level("*", level)`.

---

**Logging to Host via JTAG**

By default, the logging library uses the `vprintf`-like function to write formatted output to the dedicated UART. By calling a simple API, all log output may be routed to JTAG instead, making logging several times faster. For details, please refer to Section **Logging to Host**.

**Application Example**

The logging library is commonly used by most esp-idf components and examples. For demonstration of log functionality, check ESP-IDF’s examples directory. The most relevant examples that deal with logging are the following:

- system/ota
- storage/sd_card
- protocols/https_request

**API Reference**

**Header File**

- components/log/include/esp_log.h

**Functions**

```c
void esp_log_level_set (const char *tag, esp_log_level_t level)
```

Set log level for given tag.

If logging for given component has already been enabled, changes previous setting.

**Note:** Note that this function can not raise log level above the level set using `CONFIG_LOG_MAXIMUM_LEVEL` setting in menuconfig. To raise log level above the default one for a given file, define `LOG_LOCAL_LEVEL` to one of the `ESP_LOG_*` values, before including `esp_log.h` in this file.

**Parameters**

- `tag` – Tag of the log entries to enable. Must be a non-NULL zero terminated string. Value “*” resets log level for all tags to the given value.
- `level` – Selects log level to enable. Only logs at this and lower verbosity levels will be shown.

```c
esp_log_level_t esp_log_level_get (const char *tag)
```

Get log level for a given tag, can be used to avoid expensive log statements.

**Parameters**

- `tag` – Tag of the log to query current level. Must be a non-NULL zero terminated string.
Returns The current log level for the given tag

\texttt{vprintf\_like\_t esp\_log\_set\_vprintf(vprintf\_like\_t func)}

Set function used to output log entries.

By default, log output goes to UART0. This function can be used to redirect log output to some other destination, such as file or network. Returns the original log handler, which may be necessary to return output to the previous destination.

\textbf{Note:} Please note that function callback here must be re-entrant as it can be invoked in parallel from multiple thread context.

\textbf{Parameters} func – new Function used for output. Must have same signature as vprintf.
\textbf{Returns} func old Function used for output.

\texttt{uint32\_t esp\_log\_timestamp(void)}

Function which returns timestamp to be used in log output.

This function is used in expansion of ESP_LOGx macros. In the 2nd stage bootloader, and at early application startup stage this function uses CPU cycle counter as time source. Later when FreeRTOS scheduler start running, it switches to FreeRTOS tick count.

For now, we ignore millisecond counter overflow.

\textbf{Returns} timestamp, in milliseconds

\texttt{char *esp\_log\_system\_timestamp(void)}

Function which returns system timestamp to be used in log output.

This function is used in expansion of ESP_LOGx macro to print the system time as “HH:MM:SS.sss”. The system time is initialized to 0 on startup, this can be set to the correct time with an SNTP sync, or manually with standard POSIX time functions.

Currently, this will not get used in logging from binary blobs (i.e. Wi-Fi & Bluetooth libraries), these will still print the RTOS tick time.

\textbf{Returns} timestamp, in “HH:MM:SS.sss”

\texttt{uint32\_t esp\_log\_early\_timestamp(void)}

Function which returns timestamp to be used in log output.

This function uses HW cycle counter and does not depend on OS, so it can be safely used after application crash.

\textbf{Returns} timestamp, in milliseconds

\texttt{void esp\_log\_write(esp\_log\_level\_t level, const char *tag, const char *format, ...)}

Write message into the log.

This function is not intended to be used directly. Instead, use one of ESP_LOGE, ESP_LOGW, ESP_LOGI, ESP_LOGD, ESP_LOGV macros.

This function or these macros should not be used from an interrupt.

\texttt{void esp\_log\_writev(esp\_log\_level\_t level, const char *tag, const char *format, va\_list args)}

Write message into the log, va_list variant.

This function is provided to ease integration toward other logging framework, so that esp_log can be used as a log sink.

\textbf{See also:}

\begin{itemize}
  \item esp_log_write()
\end{itemize}
Macros

**ESP_LOG_BUFFER_HEX_LEVEL** (tag, buffer, buff_len, level)

Log a buffer of hex bytes at specified level, separated into 16 bytes each line.

Parameters

- **tag** – description tag
- **buffer** – Pointer to the buffer array
- **buff_len** – length of buffer in bytes
- **level** – level of the log

**ESP_LOG_BUFFER_CHAR_LEVEL** (tag, buffer, buff_len, level)

Log a buffer of characters at specified level, separated into 16 bytes each line. Buffer should contain only printable characters.

Parameters

- **tag** – description tag
- **buffer** – Pointer to the buffer array
- **buff_len** – length of buffer in bytes
- **level** – level of the log

**ESP_LOG_BUFFER_HEXDUMP** (tag, buffer, buff_len, level)

Dump a buffer to the log at specified level.

The dump log shows just like the one below:

```plaintext
ESP32 is great, | working along with the IDF.
```

It is highly recommended to use terminals with over 102 text width.

Parameters

- **tag** – description tag
- **buffer** – Pointer to the buffer array
- **buff_len** – length of buffer in bytes
- **level** – level of the log

**ESP_LOG_BUFFER_HEX** (tag, buffer, buff_len, level)

Log a buffer of hex bytes at Info level.

See also:

`esp_log_buffer_hex_level`

Parameters

- **tag** – description tag
- **buffer** – Pointer to the buffer array
- **buff_len** – length of buffer in bytes

**ESP_LOG_BUFFER_CHAR** (tag, buffer, buff_len, level)

Log a buffer of characters at Info level. Buffer should contain only printable characters.

See also:

`esp_log_buffer_char_level`

Parameters

- **tag** – description tag
• **buffer** - Pointer to the buffer array
• **buff_len** - Length of buffer in bytes

**ESP_EARLY_LOGE** (tag, format, ...)

Macro to output logs in startup code, before heap allocators and syscalls have been initialized. Log at ESP_LOG_ERROR level.

See also:

printf, ESP_LOGE, ESP_DRAM_LOGE In the future, we want to become compatible with clang. Hence, we provide two versions of the following macros which are using variadic arguments. The first one is using the GNU extension ##__VA_ARGS__. The second one is using the C++20 feature VA_OPT(.). This allows users to compile their code with standard C++20 enabled instead of the GNU extension. Below C++20, we haven’t found any good alternative to using ##__VA_ARGS__.

**ESP_EARLY_LOGW** (tag, format, ...)

Macro to output logs in startup code at ESP_LOG_WARN level.

See also:

ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_EARLY_LOGI** (tag, format, ...)

Macro to output logs in startup code at ESP_LOG_INFO level.

See also:

ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_EARLY_LOGD** (tag, format, ...)

Macro to output logs in startup code at ESP_LOG_DEBUG level.

See also:

ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_EARLY_LOGV** (tag, format, ...)

Macro to output logs in startup code at ESP_LOG_VERBOSE level.

See also:

ESP_EARLY_LOGE, ESP_LOGE, printf

_seESP_LOG_EARLY_ENABLED_ (log_level)

**ESP_LOG_EARLY_IMPL** (tag, format, log_level, log_tag_letter, ...)

**ESP_LOGE** (tag, format, ...)

**ESP_LOGW** (tag, format, ...)

**ESP_LOGI** (tag, format, ...)

**ESP_LOGD** (tag, format, ...)

**ESP_LOGV** (tag, format, ...)
**ESP_LOG_LEVEL** (level, tag, format, ...)

runtime macro to output logs at a specified level.

See also:

`printf`

Parameters

- `tag` - tag of the log, which can be used to change the log level by `esp_log_level_set` at runtime.
- `level` - level of the output log.
- `format` - format of the output log. See `printf`
- `...` - variables to be replaced into the log. See `printf`

**ESP_LOG_LEVEL_LOCAL** (level, tag, format, ...)

runtime macro to output logs at a specified level. Also check the level with `LOG_LOCAL_LEVEL`.

See also:

`printf, ESP_LOG_LEVEL`

**ESP_DRAM_LOGE** (tag, format, ...)

Macro to output logs when the cache is disabled. Log at `ESP_LOG_ERROR` level.

Similar to

Usage: `ESP_DRAM_LOGE(DRAM_STR("my_tag"), "format", or ESP_DRAM_LOGE(TAG, "format", ...)`), where `TAG` is a char* that points to a str in the DRAM.

See also:

`ESP_EARLY_LOGE`, the log level cannot be changed per-tag, however `esp_log_level_set("*", level)` will set the default level which controls these log lines also.

See also:

`esp_rom_printf, ESP_LOGE`

**Note:** Unlike normal logging macros, it’s possible to use this macro when interrupts are disabled or inside an ISR.

---

**Note:** Placing log strings in DRAM reduces available DRAM, so only use when absolutely essential.

**ESP_DRAM_LOGW** (tag, format, ...)

macro to output logs when the cache is disabled at `ESP_LOG_WARN` level.

See also:

`ESP_DRAM_LOGW, ESP_LOGW, esp_rom_printf`
ESP_DRAM_LOGI (tag, format, ...) 
macro to output logs when the cache is disabled at ESP_LOG_INFO level.

See also:
ESP_DRAM_LOGI, ESP_LOGI, esp_rom_printf

ESP_DRAM_LOGD (tag, format, ...) 
macro to output logs when the cache is disabled at ESP_LOG_DEBUG level.

See also:
ESP_DRAM_LOGD, ESP_LOGD, esp_rom_printf

ESP_DRAM_LOGV (tag, format, ...) 
macro to output logs when the cache is disabled at ESP_LOG_VERBOSE level.

See also:
ESP_DRAM_LOGV, ESP_LOGV, esp_rom_printf

Type Definitions
typedef int (*vprintf_like_t)(const char*, va_list)

Enumerations
enum esp_log_level_t
Log level.

Values:

enumerator ESP_LOG_NONE
No log output

enumerator ESP_LOG_ERROR
Critical errors, software module can not recover on its own

enumerator ESP_LOG_WARN
Error conditions from which recovery measures have been taken

enumerator ESP_LOG_INFO
Information messages which describe normal flow of events

enumerator ESP_LOG_DEBUG
Extra information which is not necessary for normal use (values, pointers, sizes, etc).

enumerator ESP_LOG_VERBOSE
Bigger chunks of debugging information, or frequent messages which can potentially flood the output.

2.10.21 Miscellaneous System APIs
Software Reset

To perform software reset of the chip, the `esp_restart()` function is provided. When the function is called, execution of the program stops, both CPUs are reset, the application is loaded by the bootloader and starts execution again.

Additionally, the `esp_register_shutdown_handler()` function can register a routine that will be automatically called before a restart (that is triggered by `esp_restart()`) occurs. This is similar to the functionality of `atexit` POSIX function.

Reset Reason

ESP-IDF applications can be started or restarted due to a variety of reasons. To get the last reset reason, call `esp_reset_reason()` function. See description of `esp_reset_reason_t` for the list of possible reset reasons.

Heap Memory

Two heap-memory-related functions are provided:

- `esp_get_free_heap_size()` returns the current size of free heap memory.
- `esp_get_minimum_free_heap_size()` returns the minimum size of free heap memory that has ever been available (i.e., the smallest size of free heap memory in the application’s lifetime).

Note that ESP-IDF supports multiple heaps with different capabilities. The functions mentioned in this section return the size of heap memory that can be allocated using the `malloc` family of functions. For further information about heap memory, see Heap Memory Allocation.

MAC Address

These APIs allow querying and customizing MAC addresses for different supported network interfaces (e.g., Wi-Fi, Bluetooth, Ethernet).

To fetch the MAC address for a specific network interface (e.g., Wi-Fi, Bluetooth, Ethernet), call the function `esp_read_mac()`.

In ESP-IDF, the MAC addresses for the various network interfaces are calculated from a single base MAC address. By default, the Espressif base MAC address is used. This base MAC address is pre-programmed into the ESP32 eFuse in the factory during production.

<table>
<thead>
<tr>
<th>Interface</th>
<th>MAC Address (4 universally administered, default)</th>
<th>MAC Address (2 universally administered)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wi-Fi Station</td>
<td><code>base_mac</code></td>
<td><code>base_mac</code></td>
</tr>
<tr>
<td>Wi-Fi SoftAP</td>
<td><code>base_mac, +1 to the last octet</code></td>
<td><code>Local MAC</code> (derived from Wi-Fi Station MAC)</td>
</tr>
<tr>
<td>Bluetooth</td>
<td><code>base_mac, +2 to the last octet</code></td>
<td><code>base_mac, +1 to the last octet</code></td>
</tr>
<tr>
<td>Ethernet</td>
<td><code>base_mac, +3 to the last octet</code></td>
<td><code>Local MAC</code> (derived from Bluetooth MAC)</td>
</tr>
</tbody>
</table>

**Note:** The `configuration` configures the number of universally administered MAC addresses that are provided by Espressif.

**Custom Interface MAC** Sometimes you may need to define custom MAC addresses that are not generated from the base MAC address. To set a custom interface MAC address, use the `esp_iface_mac_addr_set()` function. This function allows you to overwrite the MAC addresses of interfaces set (or not yet set) by the base MAC address.
Once a MAC address has been set for a particular interface, it will not be affected when the base MAC address is changed.

**Custom Base MAC** The default base MAC is pre-programmed by Espressif in eFuse BLK0. To set a custom base MAC instead, call the function `esp_iface_mac_addr_set()` with the `ESP_MAC_BASE` argument (or `esp_base_mac_addr_set()`) before initializing any network interfaces or calling the `esp_read_mac()` function. The custom MAC address can be stored in any supported storage device (e.g., flash, NVS).

The custom base MAC addresses should be allocated such that derived MAC addresses will not overlap. Based on the table above, users can configure the option `CONFIG_ESP32_UNIVERSAL_MAC_ADDRESSES` to set the number of valid universal MAC addresses that can be derived from the custom base MAC.

**Note:** It is also possible to call the function `esp_netif_set_mac()` to set the specific MAC used by a network interface after network initialization. But it is recommended to use the base MAC approach documented here to avoid the possibility of the original MAC address briefly appearing on the network before being changed.

**Custom MAC Address in eFuse** When reading custom MAC addresses from eFuse, ESP-IDF provides a helper function `esp__mac_get_custom()`. Users can also use `esp_read_mac()` with the `ESP_MAC_EFUSE_CUSTOM` argument. This loads the MAC address from eFuse BLK3. The `esp__mac_get_custom()` function assumes that the custom base MAC address is stored in the following format:

<table>
<thead>
<tr>
<th>Field</th>
<th># of bits</th>
<th>Range of bits</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>8</td>
<td>191:184</td>
<td>0: invalid, others — valid</td>
</tr>
<tr>
<td>Reserved</td>
<td>128</td>
<td>183:56</td>
<td></td>
</tr>
<tr>
<td>MAC address</td>
<td>48</td>
<td>55:8</td>
<td></td>
</tr>
<tr>
<td>MAC address CRC</td>
<td>8</td>
<td>7:0</td>
<td>CRC-8-CCITT, polynomial 0x07</td>
</tr>
</tbody>
</table>

**Note:** If the 3/4 coding scheme is enabled, all eFuse fields in this block must be burnt at the same time.

Once custom eFuse MAC address has been obtained (using `esp_efuse_mac_get_custom()` or `esp_read_mac()`), you need to set it as the base MAC address. There are two ways to do it:

1. Use an old API: call `esp_base_mac_addr_set()`.
2. Use a new API: call `esp_iface_mac_addr_set()` with the `ESP_MAC_BASE` argument.

**Local Versus Universal MAC Addresses** ESP32 comes pre-programmed with enough valid Espressif universally administered MAC addresses for all internal interfaces. The table above shows how to calculate and derive the MAC address for a specific interface according to the base MAC address. When using a custom MAC address scheme, it is possible that not all interfaces can be assigned with a universally administered MAC address. In these cases, a locally administered MAC address is assigned. Note that these addresses are intended for use on a single local network only.

See this article for the definition of locally and universally administered MAC addresses.

Function `espderive_local_mac()` is called internally to derive a local MAC address from a universal MAC address. The process is as follows:

1. The U/L bit (bit value 0x2) is set in the first octet of the universal MAC address, creating a local MAC address.
2. If this bit is already set in the supplied universal MAC address (i.e., the supplied “universal” MAC address was in fact already a local MAC address), then the first octet of the local MAC address is XORed with 0x4.
Chapter 2. API Reference

Chip Version

`esp_chip_info()` function fills `esp_chip_info_t` structure with information about the chip. This includes the chip revision, number of CPU cores, and a bit mask of features enabled in the chip.

SDK Version

`esp_get_idf_version()` returns a string describing the ESP-IDF version which is used to compile the application. This is the same value as the one available through `IDF_VER` variable of the build system. The version string generally has the format of `git describe` output.

To get the version at build time, additional version macros are provided. They can be used to enable or disable parts of the program depending on the ESP-IDF version.

- `ESP_IDF_VERSION_MAJOR, ESP_IDF_VERSION_MINOR, ESP_IDF_VERSION_PATCH` are defined to integers representing major, minor, and patch version.
- `ESP_IDF_VERSION_VAL` and `ESP_IDF_VERSION` can be used when implementing version checks:

  ```
  #include "esp_idf_version.h"
  
  #if ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)
  // enable functionality present in ESP-IDF v4.0
  #endif
  ```

App Version

The application version is stored in `esp_app_desc_t` structure. It is located in DROM sector and has a fixed offset from the beginning of the binary file. The structure is located after `esp_image_header_t` and `esp_image_segment_header_t` structures. The type of the field version is string and it has a maximum length of 32 chars.

To set the version in your project manually, you need to set the `PROJECT_VER` variable in the `CMakeLists.txt` of your project. In application `CMakeLists.txt`, put `set(PROJECT_VER "0.1.0.1")` before including `project.cmake`.

If the `CONFIG_APP_PROJECT_VER_FROM_CONFIG` option is set, the value of `CONFIG_APP_PROJECT_VER` will be used. Otherwise, if the `PROJECT_VER` variable is not set in the project, it will be retrieved either from the `$PROJECT_PATH/version.txt` file (if present) or using `git describe`. If neither is available, `PROJECT_VER` will be set to “1”. Application can make use of this by calling `esp_app_get_description()` or `esp OTA_get_partition_description()` functions.

API Reference

Header File

- components/esp_system/include/esp_system.h

Functions

```
esp_err_t esp_register_shutdown_handler (shutdown_handler_t handle)

Register shutdown handler.

This function allows you to register a handler that gets invoked before the application is restarted using esp_restart function.

Parameters handle – function to execute on restart

Returns
- ESP_OK on success
- ESP_ERR_INVALID_STATE if the handler has already been registered
- ESP_ERR_NO_MEM if no more shutdown handler slots are available
```
**Chapter 2. API Reference**

\[ \text{esp_err_t } \text{esp_unregister_shutdown_handler}(\text{shutdown_handler_t } \text{handle}) \]

Unregister shutdown handler.

This function allows you to unregister a handler which was previously registered using `esp_register_shutdown_handler` function.

- ESP_OK on success
- ESP_ERR_INVALID_STATE if the given handler has not been registered before

**void esp_restart (void)**

Restart PRO and APP CPUs.

This function can be called both from PRO and APP CPUs. After successful restart, CPU reset reason will be SW_CPU_RESET. Peripherals (except for Wi-Fi, BT, UART0, SPI1, and legacy timers) are not reset. This function does not return.

**esp_reset_reason_t esp_reset_reason (void)**

Get reason of last reset.

Returns See description of esp_reset_reason_t for explanation of each value.

**uint32_t esp_get_free_heap_size (void)**

Get the size of available heap.

**Note**: Note that the returned value may be larger than the maximum contiguous block which can be allocated.

Returns Available heap size, in bytes.

**uint32_t esp_get_free_internal_heap_size (void)**

Get the size of available internal heap.

**Note**: Note that the returned value may be larger than the maximum contiguous block which can be allocated.

Returns Available internal heap size, in bytes.

**uint32_t esp_get_minimum_free_heap_size (void)**

Get the minimum heap that has ever been available.

Returns Minimum free heap ever available

**void esp_system_abort (const char *details)**

Trigger a software abort.

Parameters details – Details that will be displayed during panic handling.

**Type Definitions**

typedef void (*shutdown_handler_t)(void)

Shutdown handler type

**Enumerations**

enum esp_reset_reason_t

Reset reasons.

Values:
enumerator ESP_RST_UNKNOWN
    Reset reason cannot be determined.

enumerator ESP_RST_POWERON
    Reset due to power-on event.

enumerator ESP_RST_EXT
    Reset by external pin (not applicable for ESP32)

enumerator ESP_RST_SW
    Software reset via esp_restart.

enumerator ESP_RST_PANIC
    Software reset due to exception/panic.

enumerator ESP_RST_INT_WDT
    Reset (software or hardware) due to interrupt watchdog.

enumerator ESP_RST_TASK_WDT
    Reset due to task watchdog.

enumerator ESP_RST_WDT
    Reset due to other watchdogs.

enumerator ESP_RST_DEEPSLEEP
    Reset after exiting deep sleep mode.

enumerator ESP_RST_BROWNOUT
    Brownout reset (software or hardware)

enumerator ESP_RST_SDIO
    Reset over SDIO.

Header File

- components/esp_common/include/esp_idf_version.h

Functions

const char *esp_get_idf_version (void)
    Return full IDF version string, same as ‘git describe’ output.

Note: If you are printing the ESP-IDF version in a log file or other information, this function provides more information than using the numerical version macros. For example, numerical version macros don’t differentiate between development, pre-release and release versions, but the output of this function does.

Returns constant string from IDF_VER
Chapter 2. API Reference

Macros

**ESP_IDF_VERSION_MAJOR**
Major version number (X.x.x)

**ESP_IDF_VERSION_MINOR**
Minor version number (x.X.x)

**ESP_IDF_VERSION_PATCH**
Patch version number (x.x.X)

**ESP_IDF_VERSION_VAL**
Macro to convert IDF version number into an integer
To be used in comparisons, such as ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)

**ESP_IDF_VERSION**
Current IDF version, as an integer
To be used in comparisons, such as ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)

Header File

- components/esp_hardware_support/include/esp_mac.h

Functions

**esp_err_t esp_base_mac_addr_set** (const uint8_t *mac)
Set base MAC address with the MAC address which is stored in BLK3 of EFUSE or external storage e.g. flash and EEPROM.
Base MAC address is used to generate the MAC addresses used by network interfaces.
If using a custom base MAC address, call this API before initializing any network interfaces. Refer to the ESP-IDF Programming Guide for details about how the Base MAC is used.

**Note:** Base MAC must be a unicast MAC (least significant bit of first byte must be zero).

**Note:** If not using a valid OUI, set the “locally administered” bit (bit value 0x02 in the first byte) to avoid collisions.

**Parameters**
- **mac** - base MAC address, length: 6 bytes, length: 6 bytes for MAC-48

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG If mac is NULL or is not a unicast MAC

**esp_err_t esp_base_mac_addr_get** (uint8_t *mac)
Return base MAC address which is set using esp_base_mac_addr_set.

**Note:** If no custom Base MAC has been set, this returns the pre-programmed Espressif base MAC address.

**Parameters**
- **mac** - base MAC address, length: 6 bytes, length: 6 bytes for MAC-48

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG If mac is NULL
- ESP_ERR_INVALID_MAC base MAC address has not been set
**esp_err_t esp_efuse_mac_get_custom (uint8_t *mac)**

Return base MAC address which was previously written to BLK3 of EFUSE.

Base MAC address is used to generate the MAC addresses used by the networking interfaces. This API returns the custom base MAC address which was previously written to EFUSE BLK3 in a specified format.

Writing this EFUSE allows setting of a different (non-Espressif) base MAC address. It is also possible to store a custom base MAC address elsewhere, see esp_base_mac_addr_set() for details.

**Note:** This function is currently only supported on ESP32.

**Parameters**
- **mac** – base MAC address, length: 6 bytes/8 bytes. length: 6 bytes for MAC-48 8 bytes for EUI-64 (used for IEEE 802.15.4, if CONFIG_SOC_IEEE802154_SUPPORTED=y)

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG mac is NULL
- ESP_ERR_INVALID_MAC CUSTOM_MAC address has not been set, all zeros (for esp32-xx)
- ESP_ERR_INVALID_VERSION An invalid MAC version field was read from BLK3 of EFUSE (for esp32)
- ESP_ERR_INVALID_CRC An invalid MAC CRC was read from BLK3 of EFUSE (for esp32)

**esp_err_t esp_efuse_mac_get_default (uint8_t *mac)**

Return base MAC address which is factory-programmed by Espressif in EFUSE.

**Parameters**
- **mac** – base MAC address, length: 6 bytes/8 bytes. length: 6 bytes for MAC-48 8 bytes for EUI-64 (used for IEEE 802.15.4, if CONFIG_SOC_IEEE802154_SUPPORTED=y)

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG mac is NULL

**esp_err_t esp_read_mac (uint8_t *mac, esp_mac_type_t type)**

Read base MAC address and set MAC address of the interface.

This function first get base MAC address using esp_base_mac_addr_get(). Then calculates the MAC address of the specific interface requested, refer to ESP-IDF Programming Guide for the algorithm.

The MAC address set by the esp_iface_mac_addr_set() function will not depend on the base MAC address.

**Parameters**
- **mac** – base MAC address, length: 6 bytes/8 bytes. length: 6 bytes for MAC-48 8 bytes for EUI-64 (used for IEEE 802.15.4, if CONFIG_SOC_IEEE802154_SUPPORTED=y)
- **type** – Type of MAC address to return

**Returns**
- ESP_OK on success

**esp_err_t esp_derive_local_mac (uint8_t *local_mac, const uint8_t*universal_mac)**

Derive local MAC address from universal MAC address.

This function copies a universal MAC address and then sets the “locally administered” bit (bit 0x2) in the first octet, creating a locally administered MAC address.

If the universal MAC address argument is already a locally administered MAC address, then the first octet is XORed with 0x4 in order to create a different locally administered MAC address.

**Parameters**
- **local_mac** – base MAC address, length: 6 bytes. length: 6 bytes for MAC-48
- **universal_mac** – Source universal MAC address, length: 6 bytes.

**Returns**
- ESP_OK on success

**esp_err_t esp_iface_mac_addr_set (const uint8_t *mac, esp_mac_type_t type)**

Set custom MAC address of the interface. This function allows you to overwrite the MAC addresses of the interfaces set by the base MAC address.

**Parameters**
Chapter 2. API Reference

- **mac** - MAC address, length: 6 bytes/8 bytes. length: 6 bytes for MAC-48 8 bytes for EUI-64 (used for ESP_MAC_IEEE802154 type, if CONFIG_SOC_IEEE802154_SUPPORTED=y)

- **type** - Type of MAC address

Returns ESP_OK on success

```c
size_t esp_mac_addr_len_get (esp_mac_type_t type)
```

Return the size of the MAC type in bytes.

If CONFIG_SOC_IEEE802154_SUPPORTED is set then for these types:

- ESP_MAC_IEEE802154 is 8 bytes.
- ESP_MAC_BASE, ESP_MAC_EFUSE_FACTORY and ESP_MAC_EFUSE_CUSTOM the MAC size is 6 bytes.
- ESP_MAC_EFUSE_EXT is 2 bytes. If CONFIG_SOC_IEEE802154_SUPPORTED is not set then for all types it returns 6 bytes.

Parameters  
- **type** - Type of MAC address

Returns  
- 0 MAC type not found (not supported) 6 bytes for MAC-48. 8 bytes for EUI-64.

---

**Macros**

- **MAC2STR** (a)

- **MACSTR**

---

**Enumerations**

```c
enum esp_mac_type_t
```

Values:

- **enumerator ESP_MAC_WIFI_STA**  
  MAC for WiFi Station (6 bytes)

- **enumerator ESP_MAC_WIFI_SOFTAP**  
  MAC for WiFi Soft-AP (6 bytes)

- **enumerator ESP_MAC_BT**  
  MAC for Bluetooth (6 bytes)

- **enumerator ESP_MAC_ETH**  
  MAC for Ethernet (6 bytes)

- **enumerator ESP_MAC_IEEE802154**  
  if CONFIG_SOC_IEEE802154_SUPPORTED=y, MAC for IEEE802154 (8 bytes)

- **enumerator ESP_MAC_BASE**  
  Base MAC for that used for other MAC types (6 bytes)

- **enumerator ESP_MAC_EFUSE_FACTORY**  
  MAC_FACTORY eFuse which was burned by Espressif in production (6 bytes)

- **enumerator ESP_MAC_EFUSE_CUSTOM**  
  MAC_CUSTOM eFuse which was can be burned by customer (6 bytes)
enumerator **ESP_MAC_EFUSE_EXT**

if CONFIG_SOC_IEEE802154_SUPPORTED=y, MAC_EXT eFuse which is used as an extender for IEEE802154 MAC (2 bytes)

**Header File**

- components/esp_hw_support/include/esp_chip_info.h

**Functions**

```c
void esp_chip_info(esp_chip_info_t *out_info)
```

Fill an `esp_chip_info_t` structure with information about the chip.

**Parameters**

- `out_info` - [out] structure to be filled

**Structures**

```c
struct esp_chip_info_t
```

The structure represents information about the chip.

**Public Members**

- `esp_chip_model_t model`
  
  chip model, one of `esp_chip_model_t`

- `uint32_t features`
  
  bit mask of CHIP_FEATURE_x feature flags

- `uint16_t revision`
  
  chip revision number (in format MXX; where M - wafer major version, XX - wafer minor version)

- `uint8_t cores`
  
  number of CPU cores

**Macros**

- **CHIP_FEATURE_EMB_FLASH**
  Chip has embedded flash memory.

- **CHIP_FEATURE_WIFI_BGN**
  Chip has 2.4GHz WiFi.

- **CHIP_FEATURE_BLE**
  Chip has Bluetooth LE.

- **CHIP_FEATURE_BT**
  Chip has Bluetooth Classic.

- **CHIP_FEATURE_IEEE802154**
  Chip has IEEE 802.15.4.
CHIP_FEATURE_EMB_PSRAM

Chip has embedded psram.

Enumerations

enum esp_chip_model_t

Chip models.

Values:

enumerator CHIP_ESP32

ESP32.

enumerator CHIP_ESP32S2

ESP32-S2.

enumerator CHIP_ESP32S3

ESP32-S3.

enumerator CHIP_ESP32C3

ESP32-C3.

enumerator CHIP_ESP32C2

ESP32-C2.

enumerator CHIP_ESP32C6

ESP32-C6.

enumerator CHIP_ESP32H2

ESP32-H2.

enumerator CHIP_POSIX_LINUX

The code is running on POSIX/Linux simulator.

Header File

- components/esp_hw_support/include/esp_cpu.h

Functions

void esp_cpu_stall (int core_id)

Stall a CPU core.

Parameters core_id - The core’s ID

void esp_cpu_unstall (int core_id)

Resume a previously stalled CPU core.

Parameters core_id - The core’s ID

void esp_cpu_reset (int core_id)

Reset a CPU core.

Parameters core_id - The core’s ID
void esp_cpu_wait_for_intr (void)
    
    Wait for Interrupt.
    
    This function causes the current CPU core to execute its Wait For Interrupt (WFI or equivalent) instruction. After executing this function, the CPU core will stop execution until an interrupt occurs.

int esp_cpu_get_core_id (void)
    
    Get the current core’s ID.
    
    This function will return the ID of the current CPU (i.e., the CPU that calls this function).
    
    Returns The current core’s ID [0..SOC_CPU_CORES_NUM - 1]

void *esp_cpu_get_sp (void)
    
    Read the current stack pointer address.
    
    Returns Stack pointer address

esp_cpu_cycle_count_t esp_cpu_get_cycle_count (void)
    
    Get the current CPU core’s cycle count.
    
    Each CPU core maintains an internal counter (i.e., cycle count) that increments every CPU clock cycle.
    
    Returns Current CPU’s cycle count, 0 if not supported.

void esp_cpu_set_cycle_count (esp_cpu_cycle_count_t cycle_count)
    
    Set the current CPU core’s cycle count.
    
    Set the given value into the internal counter that increments every CPU clock cycle.
    
    Parameters cycle_count - CPU cycle count

void *esp_cpu_pc_to_addr (uint32_t pc)
    
    Convert a program counter (PC) value to address.
    
    If the architecture does not store the true virtual address in the CPU’s PC or return addresses, this function will convert the PC value to a virtual address. Otherwise, the PC is just returned.
    
    Parameters pc – PC value
    
    Returns Virtual address

void esp_cpu_intr_get_desc (int core_id, int intr_num, esp_cpu_intr_desc_t *intr_desc_ret)
    
    Get a CPU interrupt’s descriptor. Each CPU interrupt has a descriptor describing the interrupt’s capabilities and restrictions. This function gets the descriptor of a particular interrupt on a particular CPU.
    
    Parameters
        • core_id – [in] The core’s ID
        • intr_num – [in] Interrupt number
        • intr_desc_ret – [out] The interrupt’s descriptor

void esp_cpu_intr_set_ivt_addr (const void *ivt_addr)
    
    Set the base address of the current CPU’s Interrupt Vector Table (IVT)
    
    Parameters ivt_addr – Interrupt Vector Table’s base address

bool esp_cpu_intr_has_handler (int intr_num)
    
    Check if a particular interrupt already has a handler function.
    
    Check if a particular interrupt on the current CPU already has a handler function assigned.
    
    Note: This function simply checks if the IVT of the current CPU already has a handler assigned.
    
    Parameters intr_num – Interrupt number (from 0 to 31)
## Chapter 2. API Reference

**Returns** True if the interrupt has a handler function, false otherwise.

```c
void esp_cpu_intr_set_handler(int intr_num, esp_cpu_intr_handler_t handler, void *handler_arg)
```

Set the handler function of a particular interrupt.

Assign a handler function (i.e., ISR) to a particular interrupt on the current CPU.

**Note:** This function simply sets the handler function (in the IVT) and does not actually enable the interrupt.

### Parameters
- `intr_num` - Interrupt number (from 0 to 31)
- `handler` - Handler function
- `handler_arg` - Argument passed to the handler function

```c
void *esp_cpu_intr_get_handler_arg(int intr_num)
```

Get a handler function’s argument of.

Get the argument of a previously assigned handler function on the current CPU.

**Parameters**
- `intr_num` - Interrupt number (from 0 to 31)

**Returns**
- The argument passed to the handler function

```c
void esp_cpu_intr_enable(uint32_t intr_mask)
```

Enable particular interrupts on the current CPU.

**Parameters**
- `intr_mask` - Bit mask of the interrupts to enable

```c
void esp_cpu_intr_disable(uint32_t intr_mask)
```

Disable particular interrupts on the current CPU.

**Parameters**
- `intr_mask` - Bit mask of the interrupts to disable

```c
uint32_t esp_cpu_intr_get_enabled_mask(void)
```

Get the enabled interrupts on the current CPU.

**Returns** Bit mask of the enabled interrupts

```c
void esp_cpu_intr_edge_ack(int intr_num)
```

Acknowledge an edge interrupt.

**Parameters**
- `intr_num` - Interrupt number (from 0 to 31)

```c
void esp_cpu_configure_region_protection(void)
```

Configure the CPU to disable access to invalid memory regions.

```c
esp_err_t esp_cpu_set_breakpoint(int bp_num, const void *bp_addr)
```

Set and enable a hardware breakpoint on the current CPU.

**Note:** This function is meant to be called by the panic handler to set a breakpoint for an attached debugger during a panic.

**Note:** Overwrites previously set breakpoint with same breakpoint number.

**Parameters**
- `bp_num` - Hardware breakpoint number [0..SOC_CPU_BREAKPOINTS_NUM - 1]
- `bp_addr` - Address to set a breakpoint on

**Returns** ESP_OK if breakpoint is set. Failure otherwise
**esp_err_t esp_cpu_clear_breakpoint (int bp_num)**
Clear a hardware breakpoint on the current CPU.

**Note:** Clears a breakpoint regardless of whether it was previously set

**Parameters**
- **bp_num** – Hardware breakpoint number [0..SOC_CPU_BREAKPOINTS_NUM - 1]

**Returns**
- ESP_OK if breakpoint is cleared. Failure otherwise

**esp_err_t esp_cpu_set_watchpoint (int wp_num, const void *wp_addr, size_t size, esp_cpu_watchpoint_trigger_t trigger)**
Set and enable a hardware watchpoint on the current CPU.
Set and enable a hardware watchpoint on the current CPU, specifying the memory range and trigger operation. Watchpoints will break/panic the CPU when the CPU accesses (according to the trigger type) on a certain memory range.

**Note:** Overwrites previously set watchpoint with same watchpoint number.

**Parameters**
- **wp_num** – Hardware watchpoint number [0..SOC_CPU_WATCHPOINTS_NUM - 1]
- **wp_addr** – Watchpoint’s base address
- **size** – Size of the region to watch. Must be one of $2^n$, with n in [0..6].
- **trigger** – Trigger type

**Returns**
- ESP_ERR_INVALID_ARG on invalid arg, ESP_OK otherwise

**esp_err_t esp_cpu_clear_watchpoint (int wp_num)**
Clear a hardware watchpoint on the current CPU.

**Note:** Clears a watchpoint regardless of whether it was previously set

**Parameters**
- **wp_num** – Hardware watchpoint number [0..SOC_CPU_WATCHPOINTS_NUM - 1]

**Returns**
- ESP_OK if watchpoint was cleared. Failure otherwise.

**bool esp_cpu_dbgr_is_attached (void)**
Check if the current CPU has a debugger attached.

**Returns**
- True if debugger is attached, false otherwise

**void esp_cpu_dbgr_break (void)**
Trigger a call to the current CPU’s attached debugger.

**intptr_t esp_cpu_get_call_addr (intptr_t return_address)**
Given the return address, calculate the address of the preceding call instruction. This is typically used to answer the question “where was the function called from?”.

**Parameters**
- **return_address** – The value of the return address register. Typically set to the value of __builtin_return_address(0).

**Returns**
- Address of the call instruction preceding the return address.

**bool esp_cpu_compare_and_set (volatile uint32_t *addr, uint32_t compare_value, uint32_t new_value)**
Atomic compare-and-set operation.

**Parameters**
Chapter 2. API Reference

- **addr** - Address of atomic variable
- **compare_value** - Value to compare the atomic variable to
- **new_value** - New value to set the atomic variable to

**Returns** Whether the atomic variable was set or not

**Structures**

```c
struct esp_cpu_intr_desc_t

CPU interrupt descriptor.
```

Each particular CPU interrupt has an associated descriptor describing that particular interrupt’s characteristics. Call `esp_cpu_intr_get_desc()` to get the descriptors of a particular interrupt.

**Public Members**

```c
int priority
```

Priority of the interrupt if it has a fixed priority, (-1) if the priority is configurable.

```c
esp_cpu_intr_type_t type
```

Whether the interrupt is an edge or level type interrupt, ESP_CPU_INTR_TYPE_NA if the type is configurable.

```c
uint32_t flags
```

Flags indicating extra details.

**Macros**

```c
ESP_CPU_INTR_DESC_FLAG_SPECIAL
```

Interrupt descriptor flags of `esp_cpu_intr_desc_t`.

The interrupt is a special interrupt (e.g., a CPU timer interrupt)

```c
ESP_CPU_INTR_DESC_FLAG_RESVD
```

The interrupt is reserved for internal use

**Type Definitions**

```c
typedef uint32_t esp_cpu_cycle_count_t
```

CPU cycle count type.

This data type represents the CPU’s clock cycle count

```c
typedef void (*esp_cpu_intr_handler_t)(void *arg)
```

CPU interrupt handler type.

**Enumerations**

```c
enum esp_cpu_intr_type_t
```

CPU interrupt type.

**Values:**

- `ESP_CPU_INTR_TYPE_LEVEL`
enumerator ESP_CPU_INTR_TYPE_EDGE

enumerator ESP_CPU_INTR_TYPE_NA

enum esp_cpu_watchpoint_trigger_t
CPU watchpoint trigger type.

Values:

enumerator ESP_CPU_WATCHPOINT_LOAD
enumerator ESP_CPU_WATCHPOINT_STORE
enumerator ESP_CPU_WATCHPOINT_ACCESS

Header File

- components/esp_app_format/include/esp_app_desc.h

Functions

cnst esp_app_desc_t *esp_app_get_description (void)
Return esp_app_desc structure. This structure includes app version.

Return description for running app.

int esp_app_get_elf_sha256 (char *dst, size_t size)
Fill the provided buffer with SHA256 of the ELF file, formatted as hexadecimal, null-terminated. If the buffer size is not sufficient to fit the entire SHA256 in hex plus a null terminator, the largest possible number of bytes will be written followed by a null.

Parameters

- dst - Destination buffer
- size - Size of the buffer

Returns Number of bytes written to dst (including null terminator)

Structures

struct esp_app_desc_t
Description about application.

Public Members

uint32_t magic_word
Magic word ESP_APP_DESC_MAGIC_WORD

uint32_t secure_version
Secure version

uint32_t reserv1[2]
reserv1
Chapter 2. API Reference

```latex
char version[32]
  Application version

char project_name[32]
  Project name

char time[16]
  Compile time

char date[16]
  Compile date

char idf_ver[32]
  Version IDF

uint8_t app_elf_sha256[32]
  sha256 of elf file

uint32_t reserv2[20]
  reserv2
```

**Macros**

**ESP_APP_DESC_MAGIC_WORD**

The magic word for the esp_app_desc structure that is in DROM.

### 2.10.22 Over The Air Updates (OTA)

**OTA Process Overview**

The OTA update mechanism allows a device to update itself based on data received while the normal firmware is running (for example, over Wi-Fi or Bluetooth.)

OTA requires configuring the **Partition Table** of the device with at least two “OTA app slot” partitions (i.e. `ota_0` and `ota_1`) and an “OTA Data Partition”.

The OTA operation functions write a new app firmware image to whichever OTA app slot that is currently not selected for booting. Once the image is verified, the OTA Data partition is updated to specify that this image should be used for the next boot.

**OTA Data Partition**

An OTA data partition (type `data`, subtype `ota`) must be included in the **Partition Table** of any project which uses the OTA functions.

For factory boot settings, the OTA data partition should contain no data (all bytes erased to 0xFF). In this case the esp-idf software bootloader will boot the factory app if it is present in the partition table. If no factory app is included in the partition table, the first available OTA slot (usually `ota_0`) is booted.

After the first OTA update, the OTA data partition is updated to specify which OTA app slot partition should be booted next.
The OTA data partition is two flash sectors (0x2000 bytes) in size, to prevent problems if there is a power failure while it is being written. Sectors are independently erased and written with matching data, and if they disagree a counter field is used to determine which sector was written more recently.

**App rollback**

The main purpose of the application rollback is to keep the device working after the update. This feature allows you to roll back to the previous working application in case a new application has critical errors. When the rollback process is enabled and an OTA update provides a new version of the app, one of three things can happen:

- The application works fine, `esp_ota_mark_app_valid_cancel_rollback()` marks the running application with the state `ESP_OTA_IMG_VALID`. There are no restrictions on booting this application.
- The application has critical errors and further work is not possible, a rollback to the previous application is required, `esp_ota_mark_app_invalid_rollback_and_reboot()` marks the running application with the state `ESP_OTA_IMG_INVALID` and reset. This application will not be selected by the bootloader for boot and will boot the previously working application.
- If the `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` option is set, and a reset occurs without calling either function then the application is rolled back.

**Note:** The state is not written to the binary image of the application but rather to the `otadata` partition. The partition contains a `ota_seq` counter which is a pointer to the slot (ota_0, ota_1, …) from which the application will be selected for boot.

**App OTA State** States control the process of selecting a boot app:

<table>
<thead>
<tr>
<th>States</th>
<th>Restriction of selecting a boot app in bootloader</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_OTA_IMG_VALID</td>
<td>In the restriction. Will be selected.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_UNDEFINED</td>
<td>In the restriction. Will be selected.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_INVALID</td>
<td>Will not be selected.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_ABORTED</td>
<td>Will not be selected.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_NEW</td>
<td><code>CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE</code> option is set it will be selected only once. In bootloader the state immediately changes to <code>ESP_OTA_IMG_PENDING_VERIFY</code>.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_PENDING_VERIFY</td>
<td><code>CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE</code> option is set it will not be selected, and the state will change to <code>ESP_OTA_IMG_ABORTED</code>.</td>
</tr>
</tbody>
</table>

If `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` option is not enabled (by default), then the use of the following functions `esp_ota_mark_app_valid_cancel_rollback()` and `esp_ota_mark_app_invalid_rollback_and_reboot()` are optional, and `ESP_OTA_IMG_NEW` and `ESP_OTA_IMG_PENDING_VERIFY` states are not used.

An option in Kconfig `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` allows you to track the first boot of a new application. In this case, the application must confirm its operability by calling `esp_ota_mark_app_valid_cancel_rollback()` function, otherwise the application will be rolled back upon reboot. It allows you to control the operability of the application during the boot phase. Thus, a new application has only one attempt to boot successfully.

**Rollback Process** The description of the rollback process when `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` option is enabled:

- The new application is successfully downloaded and `esp_ota_set_boot_partition()` function makes this partition bootable and sets the state `ESP_OTA_IMG_NEW`. This state means that the application is new and should be monitored for its first boot.
- Reboot `esp_restart()`.
Chapter 2. API Reference

- The bootloader checks for the ESP_OTA_IMG_PENDING_VERIFY state if it is set, then it will be written to ESP_OTA_IMG_ABORTED.
- The bootloader selects a new application to boot so that the state is not set as ESP_OTA_IMG_INVALID or ESP_OTA_IMG_ABORTED.
- The bootloader checks the selected application for ESP_OTA_IMG_NEW state if it is set, then it will be written to ESP_OTA_IMG_PENDING_VERIFY. This state means that the application requires confirmation of its operability, if this does not happen and a reboot occurs, this state will be overwritten to ESP_OTA_IMG_ABORTED (see above) and this application will no longer be able to start, i.e. there will be a rollback to the previous working application.
- A new application has started and should make a self-test.
- If the self-test has completed successfully, then you must call the function esp_ota_mark_app_valid_cancel_rollback() because the application is awaiting confirmation of operability (ESP_OTA_IMG_PENDING_VERIFY state).
- If the self-test fails then call esp_ota_mark_app_invalid_rollback_and_reboot() function to roll back to the previous working application, while the invalid application is set ESP_OTA_IMG_INVALID state.
- If the application has not been confirmed, the state remains ESP_OTA_IMG_PENDING_VERIFY, and the next boot it will be changed to ESP_OTA_IMG_ABORTED. That will prevent re-boot of this application. There will be a rollback to the previous working application.

**Unexpected Reset** If a power loss or an unexpected crash occurs at the time of the first boot of a new application, it will roll back the application.

Recommendation: Perform the self-test procedure as quickly as possible, to prevent rollback due to power loss.

Only OTA partitions can be rolled back. Factory partition is not rolled back.

**Booting invalid/aborted apps** Booting an application which was previously set to ESP_OTA_IMG_INVALID or ESP_OTA_IMG_ABORTED is possible:

- Get the last invalid application partition esp_ota_get_last_invalid_partition().
- Pass the received partition to esp_ota_set_boot_partition(), this will update the otadata.
- Restart esp_restart(). The bootloader will boot the specified application.

To determine if self-tests should be run during startup of an application, call the esp_ota_get_state_partition() function. If result is ESP_OTA_IMG_PENDING_VERIFY then self-testing and subsequent confirmation of operability is required.

**Where the states are set** A brief description of where the states are set:

- ESP_OTA_IMG_VALID state is set by esp_ota_mark_app_valid_cancel_rollback() function.
- ESP_OTA_IMG_UNDEFINED state is set by esp_ota_set_boot_partition() function if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE option is not enabled.
- ESP_OTA_IMG_NEW state is set by esp_ota_set_boot_partition() function if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE option is enabled.
- ESP_OTA_IMG_INVALID state is set by esp_ota_mark_app_invalid_rollback_and_reboot() function.
- ESP_OTA_IMG_ABORTED state is set if there was no confirmation of the application operability and occurs reboots (if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE option is enabled).
- ESP_OTA_IMG_PENDING_VERIFY state is set in a bootloader if CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE option is enabled and selected app has ESP_OTA_IMG_NEW state.

**Anti-rollback**

Anti-rollback prevents rollback to application with security version lower than one programmed in eFuse of chip.
This function works if set `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK` option. In the bootloader, when selecting a bootable application, an additional security version check is added which is on the chip and in the application image. The version in the bootable firmware must be greater than or equal to the version in the chip. `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK` and `CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE` options are used together. In this case, rollback is possible only on the security version which is equal or higher than the version in the chip.

A typical anti-rollback scheme is

- New firmware released with the elimination of vulnerabilities with the previous version of security.
- After the developer makes sure that this firmware is working. He can increase the security version and release a new firmware.
- Download new application.
- To make it bootable, run the function `esp_ota_set_boot_partition()`. If the security version of the new application is smaller than the version in the chip, the new application will be erased. Update to new firmware is not possible.
- Reboot.
- In the bootloader, an application with a security version greater than or equal to the version in the chip will be selected. If otadata is in the initial state, and one firmware was loaded via a serial channel, whose secure version is higher than the chip, then the secure version of efuse will be immediately updated in the bootloader.
- New application booted. Then the application should perform diagnostics of the operation and if it is completed successfully, you should call `esp_ota_mark_app_valid_cancel_rollback()` function to mark the running application with the ESP_OTA_IMG_VALID state and update the secure version on chip. Note that if was called `esp_ota_mark_app_invalid_rollback_and_reboot()` function a rollback may not happen as the device may not have any bootable apps. It will then return ESP_ERR_OTA_ROLLBACK_FAILED error and stay in the ESP_OTA_IMG_PENDING_VERIFY state.
- The next update of app is possible if a running app is in the ESP_OTA_IMG_VALID state.

Recommendation:

If you want to avoid the download/erase overhead in case of the app from the server has security version lower than the running app, you have to get `new_app_info.secure_version` from the first package of an image and compare it with the secure version of efuse. Use `esp_efuse_check_secure_version(new_app_info.secure_version)` function if it is true then continue downloading otherwise abort.

```c
bool image_header_was_checked = false;
while (1) {
    int data_read = esp_http_client_read(client, ota_write_data, BUFFSIZE);
    ...
    if (data_read > 0) {
        if (image_header_was_checked == false) {
            esp_app_desc_t new_app_info;
            if (data_read > sizeof(esp_image_header_t) + sizeof(esp_image_segment_header_t) + sizeof(esp_app_desc_t)) {
                // check current version with downloading
                if (esp_efuse_check_secure_version(new_app_info.secure_version) == false) {
                    ESP_LOGE(TAG, "This a new app can not be downloaded due to a secure version is lower than stored in efuse.");
                    http_cleanup(client);
                    task_fatal_error();
                }
            }
            image_header_was_checked = true;
            esp_ota_begin(update_partition, OTA_SIZE_UNKNOWN, &update_handle);
        }
    }
    esp_ota_write(update_handle, (const void *)ota_write_data, data_read);
}(continues on next page)
```
Restrictions:

- The number of bits in the secure_version field is limited to 32 bits. This means that only 32 times you can do an anti-rollback. You can reduce the length of this efuse field using CONFIG_BOOTLOADER_APP_SEC_VER_SIZE_EFUSE_FIELD option.
- Anti-rollback works only if the encoding scheme for efuse is set to NONE.
- Factory and Test partitions are not supported in anti rollback scheme and hence partition table should not have partition with SubType set to factory or test.

security_version:

- In application image it is stored in esp_app_desc structure. The number is set CONFIG_BOOTLOADER_APP_SECURE_VERSION.
- In ESP32 it is stored in efuse EFUSE_BLK3_RDATA4_REG. (when a efuse bit is programmed to 1, it can never be reverted to 0). The number of bits set in this register is the security_version from app.

Secure OTA Updates Without Secure boot

The verification of signed OTA updates can be performed even without enabling hardware secure boot. This can be achieved by setting CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT and CONFIG_SECURE_SIGNED_ON_UPDATE_NO_SECURE_BOOT

For more information refer to Signed App Verification Without Hardware Secure Boot

OTA Tool (otatool.py)

The component app_update provides a tool otatool.py for performing OTA partition-related operations on a target device. The following operations can be performed using the tool:

- read contents of otadata partition (read_otadata)
- erase otadata partition, effectively resetting device to factory app (erase_otadata)
- switch OTA partitions (switch_ota_partition)
- erasing OTA partition (erase_ota_partition)
- write to OTA partition (write_ota_partition)
- read contents of OTA partition (read_ota_partition)

The tool can either be imported and used from another Python script or invoked from shell script for users wanting to perform operation programmatically. This is facilitated by the tool’s Python API and command-line interface, respectively.

Python API  Before anything else, make sure that the otatool module is imported.

```python
import sys
import os

tool_path = os.environ("IDF_PATH")  # get value of IDF_PATH from environment
tool_dir = os.path.join(tool_path, "components", "app_update")  # otatool.py --lives in $IDF_PATH/components/app_update

sys.path.append(tool_dir)  # this enables Python to find otatool module
from otatool import *  # import all names inside otatool module
```

The starting point for using the tool’s Python API to do is create a OtatoolTarget object:
Create a `partool.py` target device connected on serial port `/dev/ttyUSB1`

```python
target = OtatoolTarget("/dev/ttyUSB1")
```

The created object can now be used to perform operations on the target device:

```python
# Erase odata, resetting the device to factory app
target.erase_otadata()

# Erase contents of OTA app slot 0
target.erase_ota_partition(0)

# Switch boot partition to that of app slot 1
target.switch_ota_partition(1)

# Read OTA partition 'ota_3' and save contents to a file named 'ota_3.bin'
target.read_ota_partition("ota_3", "ota_3.bin")
```

The OTA partition to operate on is specified using either the app slot number or the partition name.

More information on the Python API is available in the docstrings for the tool.

**Command-line Interface** The command-line interface of `otatool.py` has the following structure:

```bash
otatool.py [command-args] [subcommand] [subcommand-args]
```

- **command-args** - these are arguments that are needed for executing the main...
- **subcommand** - this is the operation to be performed
- **subcommand-args** - these are arguments that are specific to the chosen operation

```bash
# Erase odata, resetting the device to factory app
otatool.py --port "/dev/ttyUSB1" erase_otadata

# Erase contents of OTA app slot 0
otatool.py --port "/dev/ttyUSB1" erase_ota_partition --slot 0

# Switch boot partition to that of app slot 1
otatool.py --port "/dev/ttyUSB1" switch_ota_partition --slot 1

# Read OTA partition 'ota_3' and save contents to a file named 'ota_3.bin'
otatool.py --port "/dev/ttyUSB1" read_ota_partition --name=ota_3 --output=ota_3.bin
```

More information can be obtained by specifying `--help` as argument:

```bash
# Display possible subcommands and show main command argument descriptions
otatool.py --help

# Show descriptions for specific subcommand arguments
otatool.py [subcommand] --help
```

**See also**

- Partition Table documentation
- Partition API
- Lower-Level SPI Flash API
- ESP HTTPS OTA
**Application Example**

End-to-end example of OTA firmware update workflow: system/ota.

**API Reference**

**Header File**

- components/app_update/include/esp_ota_ops.h

**Functions**

const esp_app_desc_t *esp_ota_get_app_description (void)

Return esp_app_desc structure. This structure includes app version.

**Note:** This API is present for backward compatibility reasons. Alternative function with the same functionality is esp_app_get_description

Returns Pointer to esp_app_desc structure.

int esp_ota_get_app_elf_sha256 (char *dst, size_t size)

Fill the provided buffer with SHA256 of the ELF file, formatted as hexadecimal, null-terminated. If the buffer size is not sufficient to fit the entire SHA256 in hex plus a null terminator, the largest possible number of bytes will be written followed by a null.

**Note:** This API is present for backward compatibility reasons. Alternative function with the same functionality is esp_app_get_elf_sha256

**Parameters**

- **dst** – Destination buffer  
- **size** – Size of the buffer  

**Returns** Number of bytes written to dst (including null terminator)

esp_err_t esp_ota_begin (const esp_partition_t *partition, size_t image_size, esp_ota_handle_t *out_handle)

Commence an OTA update writing to the specified partition.

The specified partition is erased to the specified image size.

If image size is not yet known, pass OTA_SIZE_UNKNOWN which will cause the entire partition to be erased.

On success, this function allocates memory that remains in use until esp_ota_end() is called with the returned handle.

**Note:** If the rollback option is enabled and the running application has the ESP OTA_IMG_PENDING_VERIFY state then it will lead to the ESP_ERR_OTA_ROLLBACK_INVALID_STATE error. Confirm the running app before to run download a new app, use esp_ota_mark_app_valid_cancel_rollback() function for it (this should be done as early as possible when you first download a new application).

**Parameters**

- **partition** – Pointer to info for partition which will receive the OTA update. Required.  
- **image_size** – Size of new OTA app image. Partition will be erased in order to receive this size of image. If 0 or OTA_SIZE_UNKNOWN, the entire partition is erased.
- **out_handle** - On success, returns a handle which should be used for subsequent esp_ota_write() and esp_ota_end() calls.

**Returns**
- ESP_OK: OTA operation commenced successfully.
- ESP_ERR_INVALID_ARG: partition or out_handle arguments were NULL, or partition doesn’t point to an OTA app partition.
- ESP_ERR_NO_MEM: Cannot allocate memory for OTA operation.
- ESP_ERR_OTA_PARTITION_CONFLICT: Partition holds the currently running firmware, cannot update in place.
- ESP_ERR_NOT_FOUND: Partition argument not found in partition table.
- ESP_ERR_OTA_SELECT_INFO_INVALID: The OTA data partition contains invalid data.
- ESP_ERR_INVALID_SIZE: Partition doesn’t fit in configured flash size.
- ESP_ERR_FLASH_OP_TIMEOUT or ESP_ERR_FLASH_OP_FAIL: Flash write failed.
- ESP_ERR_OTA_ROLLBACK_INVALID_STATE: If the running app has not confirmed state. Before performing an update, the application must be valid.

```c
esp_err_t esp_ota_write(esp_ota_handle_t handle, const void *data, size_t size)
```

Write OTA update data to partition.

This function can be called multiple times as data is received during the OTA operation. Data is written sequentially to the partition.

**Parameters**
- `handle` - Handle obtained from esp_ota_begin
- `data` - Data buffer to write
- `size` - Size of data buffer in bytes

**Returns**
- ESP_OK: Data was written to flash successfully.
- ESP_ERR_INVALID_ARG: handle is invalid.
- ESP_ERR_OTA_VALIDATE_FAILED: First byte of image contains invalid app image magic byte.
- ESP_ERR_FLASH_OP_TIMEOUT or ESP_ERR_FLASH_OP_FAIL: Flash write failed.
- ESP_ERR_OTA_SELECT_INFO_INVALID: OTA data partition has invalid contents

```c
esp_err_t esp_ota_write_with_offset(esp_ota_handle_t handle, const void *data, size_t size, uint32_t offset)
```

Write OTA update data to partition at an offset.

This function can write data in non-contiguous manner. If flash encryption is enabled, data should be 16 bytes aligned.

**Note:** While performing OTA, if the packets arrive out of order, esp_ota_write_with_offset() can be used to write data in non-contiguous manner. Use of esp_ota_write_with_offset() in combination with esp_ota_write() is not recommended.
Chapter 2. API Reference

- ESP_ERR_FLASH_OP_TIMEOUT or ESP_ERR_FLASH_OP_FAIL: Flash write failed.
- ESP_ERR_OTA_SELECT_INFO_INVALID: OTA data partition has invalid contents

```c
esp_err_t esp_ota_end (esp_ota_handle_t handle)
```

Finish OTA update and validate newly written app image.

**Note:** After calling esp_ota_end(), the handle is no longer valid and any memory associated with it is freed (regardless of result).

**Parameters**
- `handle` – Handle obtained from esp_ota_begin().

**Returns**
- ESP_OK: Newly written OTA app image is valid.
- ESP_ERR_NOT_FOUND: OTA handle was not found.
- ESP_ERR_INVALID_ARG: Handle was never written to.
- ESP_ERR_OTA_VALIDATE_FAILED: OTA image is invalid (either not a valid app image, or if secure boot is enabled - signature failed to verify.)
- ESP_ERR_INVALID_STATE: If flash encryption is enabled, this result indicates an internal error writing the final encrypted bytes to flash.

```c
esp_err_t esp_ota_abort (esp_ota_handle_t handle)
```

Abort OTA update, free the handle and memory associated with it.

**Parameters**
- `handle` – Obtained from esp_ota_begin().

**Returns**
- ESP_OK: Handle and its associated memory is freed successfully.
- ESP_ERR_NOT_FOUND: OTA handle was not found.

```c
esp_err_t esp_ota_set_boot_partition (const esp_partition_t *partition)
```

Configure OTA data for a new boot partition.

**Note:** If this function returns ESP_OK, calling esp_restart() will boot the newly configured app partition.

**Parameters**
- `partition` – Pointer to info for partition containing app image to boot.

**Returns**
- ESP_OK: OTA data updated, next reboot will use specified partition.
- ESP_ERR_INVALID_ARG: partition argument was NULL or didn’t point to a valid OTA partition of type “app”.
- ESP_ERR_OTA_VALIDATE_FAILED: Partition contained invalid app image. Also returned if secure boot is enabled and signature validation failed.
- ESP_ERR_NOT_FOUND: OTA data partition not found.
- ESP_ERR_FLASH_OP_TIMEOUT or ESP_ERR_FLASH_OP_FAIL: Flash erase or write failed.

```c
const esp_partition_t *esp_ota_get_boot_partition (void)
```

Get partition info of currently configured boot app.

If esp_ota_set_boot_partition() has been called, the partition which was set by that function will be returned.

If esp_ota_set_boot_partition() has not been called, the result is usually the same as esp_ota_get_running_partition(). The two results are not equal if the configured boot partition does not contain a valid app (meaning that the running partition will be an app that the bootloader chose via fallback).

If the OTA data partition is not present or not valid then the result is the first app partition found in the partition table. In priority order, this means: the factory app, the first OTA app slot, or the test app partition.
Note that there is no guarantee the returned partition is a valid app. Use esp_image_verify(ESP_IMAGE_VERIFY, ...) to verify if the returned partition contains a bootable image.

**Returns** Pointer to info for partition structure, or NULL if partition table is invalid or a flash read operation failed. Any returned pointer is valid for the lifetime of the application.

```c
const esp_partition_t *esp_ota_get_running_partition (void)
```

Get partition info of currently running app.

This function is different to esp_ota_get_boot_partition() in that it ignores any change of selected boot partition caused by esp_ota_set_boot_partition(). Only the app whose code is currently running will have its partition information returned.

The partition returned by this function may also differ from esp_ota_get_boot_partition() if the configured boot partition is somehow invalid, and the bootloader fell back to a different app partition at boot.

**Returns** Pointer to info for partition structure, or NULL if no partition is found or flash read operation failed. Returned pointer is valid for the lifetime of the application.

```c
const esp_partition_t *esp_ota_get_next_update_partition (const esp_partition_t *start_from)
```

Return the next OTA app partition which should be written with a new firmware. Call this function to find an OTA app partition which can be passed to esp_ota_begin().

Finds next partition round-robin, starting from the current running partition.

**Parameters** `start_from` – If set, treat this partition info as describing the current running partition. Can be NULL, in which case esp_ota_get_running_partition() is used to find the currently running partition. The result of this function is never the same as this argument.

**Returns** Pointer to info for partition which should be updated next. NULL result indicates invalid OTA data partition, or that no eligible OTA app slot partition was found.

```c
esp_err_t esp_ota_get_partition_description (const esp_partition_t *partition, esp_app_desc_t *app_desc)
```

Returns esp_app_desc structure for app partition. This structure includes app version.

**Parameters**
- `partition` – [in] Pointer to app partition. (only app partition)
- `app_desc` – [out] Structure of info about app.

**Returns**
- ESP_OK Successful.
- ESP_ERR_NOT_FOUND app_desc structure is not found. Magic word is incorrect.
- ESP_ERR_NOT_SUPPORTED Partition is not application.
- ESP_ERR_INVALID_ARG Arguments is NULL or if partition’s offset exceeds partition size.
- ESP_ERR_INVALID_SIZE Read would go out of bounds of the partition.
- or one of error codes from lower-level flash driver.

```c
uint8_t esp_ota_get_app_partition_count (void)
```

Returns number of OTA partitions provided in partition table.

**Returns**
- Number of OTA partitions

```c
esp_err_t esp_ota_mark_app_valid_cancel_rollback (void)
```

This function is called to indicate that the running app is working well.

**Returns**
- ESP_OK: if successful.
### `esp_err_t esp_ota_mark_app_invalid_rollback_and_reboot (void)`

This function is called to roll back to the previously workable app with reboot.

If rollback is successful then device will reset else API will return with error code. Checks applications on a flash drive that can be booted in case of rollback. If the flash does not have at least one app (except the running app) then rollback is not possible.

**Returns**
- ESP_FAIL: if not successful.
- ESP_ERR_OTA.Rollback.FAILED: The rollback is not possible due to flash does not have any apps.

### `const esp_partition_t *esp_ota_get_last_invalid_partition (void)`

Returns last partition with invalid state (ESP.OTA.IMG.INVALID or ESP.OTA.IMG.ABORTED).

**Returns**
- partition.

### `esp_err_t esp_ota_get_state_partition (const esp_partition_t *partition, esp_ota_img_states_t *ota_state)`

Returns state for given partition.

**Parameters**
- ota_state – [out] state of partition (if this partition has a record in ootadata).

**Returns**
- ESP_OK: Successful.
- ESP_ERR.INVALID_ARG: partition or ota_state arguments were NULL.
- ESP_ERR.NOT_SUPPORTED: partition is not ota.
- ESP_ERR.NOT.FOUND: Partition table does not have ootadata or state was not found for given partition.

### `esp_err_t esp_ota_erase_last_boot_app_partition (void)`

Erase previous boot app partition and corresponding ootadata select for this partition.

When current app is marked to as valid then you can erase previous app partition.

**Returns**
- ESP_OK: Successful, otherwise ESP.ERR.

### `bool esp_ota_check_rollback_is_possible (void)`

Checks applications on the slots which can be booted in case of rollback.

These applications should be valid (marked in ootadata as not UNDEFINED, INVALID or ABORTED and crc is good) and be able booted, and secure_version of app >= secure_version of efuse (if anti-rollback is enabled).

**Returns**
- True: Returns true if the slots have at least one app (except the running app).
- False: The rollback is not possible.

### Macros

**OTA SIZE UNKNOWN**

Used for esp_ota_begin() if new image size is unknown

**OTA WITH SEQUENTIAL WRITES**

Used for esp_ota_begin() if new image size is unknown and erase can be done in incremental manner (assuming write operation is in continuous sequence)

**ESP.ERR.OTA.BASE**

Base error code for ota_ops api
Chapter 2. API Reference

ESP_ERR_OTA_PARTITION_CONFLICT
Error if request was to write or erase the current running partition

ESP_ERR_OTA_SELECT_INFO_INVALID
Error if OTA data partition contains invalid content

ESP_ERR_OTA_VALIDATE_FAILED
Error if OTA app image is invalid

ESP_ERR_OTA_SMALL_SEC_VER
Error if the firmware has a secure version less than the running firmware.

ESP_ERR_OTA_ROLLBACK_FAILED
Error if flash does not have valid firmware in passive partition and hence rollback is not possible

ESP_ERR_OTA_ROLLBACK_INVALID_STATE
Error if current active firmware is still marked in pending validation state (ESP_OTA_IMG_PENDING_VERIFY), essentially first boot of firmware image post upgrade and hence firmware upgrade is not possible

Type Definitions
typedef uint32_t esp_ota_handle_t
Opaque handle for an application OTA update.
esp_ota_begin() returns a handle which is then used for subsequent calls to esp_ota_write() and esp_ota_end().

Debugging OTA Failure

2.10.23 Performance Monitor

The Performance Monitor component provides APIs to use ESP32 internal performance counters to profile functions and applications.

Application Example

An example which combines performance monitor is provided in examples/system/perfmon directory. This example initializes the performance monitor structure and execute them with printing the statistics.

High level API Reference

Header Files

• perfmon/include/perfmon.h

API Reference

Header File

• components/perfmon/include/xtensa_perfmon_access.h
Fig. 41: How to Debug When OTA Fails (click to enlarge)
Chapter 2. API Reference

Functions

```c
esp_err_t xtensa_perfmon_init (int id, uint16_t select, uint16_t mask, int kernelcnt, int tracelevel)
Init Performance Monitor.

Parameters
•  id – [in] performance counter number
•  select – [in] select value from PMCTRLx register
•  mask – [in] mask value from PMCTRLx register
•  kernelcnt – [in] kernelcnt value from PMCTRLx register
•  tracelevel – [in] tracelevel value from PMCTRLx register

Returns
•  ESP_OK on success
•  ESP_ERR_INVALID_ARG if one of the arguments is not correct
```

```c
esp_err_t xtensa_perfmon_reset (int id)
Reset PM counter.

Parameters id – [in] performance counter number

Returns
•  ESP_OK on success
•  ESP_ERR_INVALID_ARG if id out of range
```

```c
void xtensa_perfmon_start (void)
Start PM counters.

Start all PM counters synchronously. Write 1 to the PGM register

void xtensa_perfmon_stop (void)
Stop PM counters.

Stop all PM counters synchronously. Write 0 to the PGM register

uint32_t xtensa_perfmon_value (int id)
Read PM counter.

Read value of defined PM counter.

Parameters id – [in] performance counter number

Returns
•  Performance counter value

esp_err_t xtensa_perfmon_overflow (int id)
Read PM overflow state.

Read overflow value of defined PM counter.

Parameters id – [in] performance counter number

Returns
•  ESP_OK if there is no overflow (overflow = 0)
•  ESP_FAIL if overflow occure (overflow = 1)

void xtensa_perfmon_dump (void)
Dump PM values.

Dump all PM register to the console.
```

Header File

- components/perfmon/include/xtensa_perfmon_apis.h
Chapter 2. API Reference

Functions

`esp_err_t xtensa_perfmon_exec(const xtensa_perfmon_config_t *config)`

Execute PM.

Execute performance counter for dedicated function with defined parameters

Parameters `config` — [in] pointer to the configuration structure

Returns

- ESP_OK if no errors
- ESP_ERR INVALID_ARG if one of the required parameters not defined
- ESP_FAIL - counter overflow

`void xtensa_perfmon_viewCb(void *params, uint32_t select, uint32_t mask, uint32_t value)`

Dump PM results.

Callback to dump perfmon result to a FILE* stream specified in perfmon_config_t::callback_params. If callback_params is set to NULL, will print to stdout

Parameters

- `params` — [in] used parameters passed from configuration (callback_params). This parameter expected as FILE* hanle, where data will be stored. If this parameter NULL, then data will be stored to the stdout.
- `select` — [in] select value for current counter
- `mask` — [in] mask value for current counter
- `value` — [in] counter value for current counter

Structures

`struct xtensa_perfmon_config`  

Performance monitor configuration structure.

Structure to configure performance counter to measure dedicated function

Public Members

`int repeat_count`  

how much times function will be called before the callback will be repeated

`float max_deviation`  

Difference between min and max counter number 0..1, 0 - no difference, 1 - not used

`void *call_params`  

This pointer will be passed to the call_function as a parameter

`void (*call_function)(void *params)`  

pointer to the function that have to be called

`void (*callback)(void *params, uint32_t select, uint32_t mask, uint32_t value)`  

pointer to the function that will be called with result parameters

`void *callback_params`  

parameter that will be passed to the callback

`int tracelevel`  

trace level for all counters. In case of negative value, the filter will be ignored. If it’s >=0, then the perfmon will count only when interrupt level > tracelevel. It’s useful to monitor interrupts.
uint32_t counters_size
   amount of counter in the list

const uint32_t *select_mask
   list of the select/mask parameters

Type Definitions

typedef struct xtensa_perfmon_config xtensa_perfmon_config_t
   Performance monitor configuration structure.
   Structure to configure performance counter to measure dedicated function

2.10.24 Power Management

Overview

Power management algorithm included in ESP-IDF can adjust the advanced peripheral bus (APB) frequency, CPU
frequency, and put the chip into light sleep mode to run an application at smallest possible power consumption, given
the requirements of application components.

Application components can express their requirements by creating and acquiring power management locks.
For example:

• Driver for a peripheral clocked from APB can request the APB frequency to be set to 80 MHz while the
  peripheral is used.
• RTOS can request the CPU to run at the highest configured frequency while there are tasks ready to run.
• A peripheral driver may need interrupts to be enabled, which means it will have to request disabling light sleep.

Since requesting higher APB or CPU frequencies or disabling light sleep causes higher current consumption, please
keep the usage of power management locks by components to a minimum.

Configuration

Power management can be enabled at compile time, using the option CONFIG_PM_ENABLE.

Enabling power management features comes at the cost of increased interrupt latency. Extra latency depends on
a number of factors, such as the CPU frequency, single/dual core mode, whether or not frequency switch needs
to be done. Minimum extra latency is 0.2 us (when the CPU frequency is 240 MHz and frequency scaling is not
enabled). Maximum extra latency is 40 us (when frequency scaling is enabled, and a switch from 40 MHz to 80 MHz
is performed on interrupt entry).

Dynamic frequency scaling (DFS) and automatic light sleep can be enabled in an application by calling
the function esp_pm_configure(). Its argument is a structure defining the frequency scaling settings,
esp_pm_config_t. In this structure, three fields need to be initialized:

• max_freq_mhz: Maximum CPU frequency in MHz, i.e., the frequency used when the
  ESP_PM_CPU_FREQ_MAX lock is acquired. This field will usually be set to the default CPU frequency.
• min_freq_mhz: Minimum CPU frequency in MHz, i.e., the frequency used when only the
  ESP_PM_APB_FREQ_MAX lock is acquired. This field can be set to the XTAL frequency value, or the XTAL
  frequency divided by an integer. Note that 10 MHz is the lowest frequency at which the default REF_TICK
clock of 1 MHz can be generated.
• `light_sleep_enable`: Whether the system should automatically enter light sleep when no locks are acquired (`true/false`).

Alternatively, if you enable the option `CONFIG_PM_DFS_INIT_AUTO` in menuconfig, the maximum CPU frequency will be determined by the `CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ` setting, and the minimum CPU frequency will be locked to the XTAL frequency.

**Note:** Automatic light sleep is based on FreeRTOS Tickless Idle functionality. If automatic light sleep is requested while the option `CONFIG_FREERTOS_USE_TICKLESS_IDLE` is not enabled in menuconfig, `esp_pm_configure()` will return the error `ESP_ERR_NOT_SUPPORTED`.

**Note:** In light sleep, peripherals are clock gated, and interrupts (from GPIOs and internal peripherals) will not be generated. A wakeup source described in the `Sleep Modes` documentation can be used to trigger wakeup from the light sleep state.

For example, the EXT0 and EXT1 wakeup sources can be used to wake up the chip via a GPIO.

**Power Management Locks**

Applications have the ability to acquire/release locks in order to control the power management algorithm. When an application acquires a lock, the power management algorithm operation is restricted in a way described below. When the lock is released, such restrictions are removed.

Power management locks have acquire/release counters. If the lock has been acquired a number of times, it needs to be released the same number of times to remove associated restrictions.

ESP32 supports three types of locks described in the table below.

<table>
<thead>
<tr>
<th>Lock</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>ESP_PM_CPU_FREQ_MAX</code></td>
<td>Requests CPU frequency to be at the maximum value set with <code>esp_pm_configure()</code>. For ESP32, this value can be set to 80 MHz, 160 MHz, or 240 MHz.</td>
</tr>
<tr>
<td><code>ESP_PM_APB_FREQ_MAX</code></td>
<td>Requests the APB frequency to be at the maximum supported value. For ESP32, this is 80 MHz.</td>
</tr>
<tr>
<td><code>ESP_PM_NO_LIGHT_SLEEP</code></td>
<td>Disables automatic switching to light sleep.</td>
</tr>
</tbody>
</table>

**ESP32 Power Management Algorithm**

The table below shows how CPU and APB frequencies will be switched if dynamic frequency scaling is enabled. You can specify the maximum CPU frequency with either `esp_pm_configure()` or `CONFIG_ESP_DEFAULT_CPU_FREQ_MHZ`. 

---

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Release v5.1.2
### Max CPU Frequency Set

<table>
<thead>
<tr>
<th>Lock Acquisition</th>
<th>CPU and APB Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>240</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Any of ESP_PM_CPU_FREQ_MAX or ESP_PM_APB_FREQ_MAX acquired | CPU: 240 MHz  
APB: 80 MHz |
| None | Min values for both frequencies set with esp_pm_configure() |
| **160** | | |
| ESP_PM_CPU_FREQ_MAX acquired | CPU: 160 MHz  
APB: 80 MHz |
| ESP_PM_APB_FREQ_MAX acquired, ESP_PM_CPU_FREQ_MAX not acquired | CPU: 80 MHz  
APB: 80 MHz |
| None | Min values for both frequencies set with esp_pm_configure() |
| **80** | | |
| Any of ESP_PM_CPU_FREQ_MAX or ESP_PM_APB_FREQ_MAX acquired | CPU: 80 MHz  
APB: 80 MHz |
| None | Min values for both frequencies set with esp_pm_configure() |

If none of the locks are acquired, and light sleep is enabled in a call to `esp_pm_configure()`, the system will go into light sleep mode. The duration of light sleep will be determined by:

- FreeRTOS tasks blocked with finite timeouts
- Timers registered with `High resolution timer` APIs

Light sleep duration will be chosen to wake up the chip before the nearest event (task being unblocked, or timer elapses).

To skip unnecessary wake-up, you can consider initializing an `esp_timer` with the `skip_unhandled_events` option as true. Timers with this flag will not wake up the system and it helps to reduce consumption.

### Dynamic Frequency Scaling and Peripheral Drivers

When DFS is enabled, the APB frequency can be changed multiple times within a single RTOS tick. The APB frequency change does not affect the operation of some peripherals, while other peripherals may have issues. For example, Timer Group peripheral timers will keep counting, however, the speed at which they count will change proportionally to the APB frequency.

Peripheral clock sources such as REF_TICK, XTAL, RC_FAST (i.e. RTC_8M), their frequencies will not be influenced by APB frequency. And therefore, to ensure the peripheral behaves consistently during DFS, it is recommended to select one of these clocks as the peripheral clock source. For more specific guidelines, please refer to the “Power Management” section of each peripheral’s “API Reference > Peripherals API” page.

Currently, the following peripheral drivers are aware of DFS and will use the ESP_PM_APB_FREQ_MAX lock for the duration of the transaction:

- SPI master
Chapter 2. API Reference

- I2C
- I2S (If the APLL clock is used, then it will use the ESP_PM_NO_LIGHT_SLEEP lock)
- SDMMC

The following drivers will hold the ESP_PM_APB_FREQ_MAX lock while the driver is enabled:

- **SPI slave**: between calls to `spi_slave_initialize()` and `spi_slave_free()`.
- **GPTimer**: between calls to `gptimer_enable()` and `gptimer_disable()`.
- **Ethernet**: between calls to `esp_eth_driver_install()` and `esp_eth_driver_uninstall()`.
- **WiFi**: between calls to `esp_wifi_start()` and `esp_wifi_stop()`. If modem sleep is enabled, the lock will be released for the periods of time when radio is disabled.
- **TWAI**: between calls to `twai_driver_install()` and `twai_driver_uninstall()` (only when the clock source is set to `TWAI_CLK_SRC_APB`).
- **Bluetooth**: between calls to `esp_bt_controller_enable()` and `esp_bt_controller_disable()`. If Bluetooth modem sleep is enabled, the ESP_PM_APB_FREQ_MAX lock will be released for the periods of time when radio is disabled. However the ESP_PM_NO_LIGHT_SLEEP lock will still be held, unless `CONFIG_BTDM_CTRL_LOW_POWER_CLOCK` option is set to “External 32kHz crystal”.

The following peripheral drivers are not aware of DFS yet. Applications need to acquire/release locks themselves, when necessary:

- **PCNT**
- **Sigma-delta**
- **The legacy timer group driver**
- **MCPWM**

Light-sleep Peripheral Power Down

**API Reference**

**Header File**

- `components/esp_pm/include/esp_pm.h`

**Functions**

- `esp_err_t esp_pm_configure (const void * config)`
  
  Set implementation-specific power management configuration.

  **Parameters**
  
  `config` - pointer to implementation-specific configuration structure (e.g. `esp_pm_config_esp32`)

  **Returns**
  
  - ESP_OK on success
  - ESP_ERR_INVALID_ARG if the configuration values are not correct
  - ESP_ERR_NOT_SUPPORTED if certain combination of values is not supported, or if `CONFIG_PM_ENABLE` is not enabled in `sdkconfig`

- `esp_err_t esp_pm_get_configuration (void * config)`

  Get implementation-specific power management configuration.

  **Parameters**
  
  `config` - pointer to implementation-specific configuration structure (e.g. `esp_pm_config_esp32`)

  **Returns**
  
  - ESP_OK on success
  - ESP_ERR_INVALID_ARG if the pointer is null
**esp_err_t esp_pm_lock_create** (esp_pm_lock_type_t lock_type, int arg, const char *name, esp_pm_lock_handle_t *out_handle)

Initialize a lock handle for certain power management parameter.

When lock is created, initially it is not taken. Call esp_pm_lock_acquire to take the lock.

This function must not be called from an ISR.

**Parameters**
- **lock_type** – Power management constraint which the lock should control
- **arg** – Argument, value depends on lock_type, see esp_pm_lock_type_t
- **name** – Arbitrary string identifying the lock (e.g. “wifi” or “spi”). Used by the esp_pm_dump_locks function to list existing locks. May be set to NULL. If not set to NULL, must point to a string which is valid for the lifetime of the lock.
- **out_handle** – [out] Handle returned from this function. Use this handle when calling esp_pm_lock_delete, esp_pm_lock_acquire, esp_pm_lock_release. Must not be NULL.

**Returns**
- ESP_OK on success
- ESP_ERR_NO_MEM if the lock structure cannot be allocated
- ESP_ERR_INVALID_ARG if out_handle is NULL or type argument is not valid
- ESP_ERR_NOT_SUPPORTED if CONFIG_PM_ENABLE is not enabled in sdkconfig

**esp_err_t esp_pm_lock_acquire** (esp_pm_lock_handle_t handle)

Take a power management lock.

Once the lock is taken, power management algorithm will not switch to the mode specified in a call to esp_pm_lock_create, or any of the lower power modes (higher numeric values of ‘mode’).

The lock is recursive, in the sense that if esp_pm_lock_acquire is called a number of times, esp_pm_lock_release has to be called the same number of times in order to release the lock.

This function may be called from an ISR.

This function is not thread-safe w.r.t. calls to other esp_pm_lock_* functions for the same handle.

**Parameters** handle – Handle obtained from esp_pm_lock_create function

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_NOT_SUPPORTED if CONFIG_PM_ENABLE is not enabled in sdkconfig

**esp_err_t esp_pm_lock_release** (esp_pm_lock_handle_t handle)

Release the lock taken using esp_pm_lock_acquire.

Call to this functions removes power management restrictions placed when taking the lock.

Locks are recursive, so if esp_pm_lock_acquire is called a number of times, esp_pm_lock_release has to be called the same number of times in order to actually release the lock.

This function may be called from an ISR.

This function is not thread-safe w.r.t. calls to other esp_pm_lock_* functions for the same handle.

**Parameters** handle – Handle obtained from esp_pm_lock_create function

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if lock is not acquired
- ESP_ERR_NOT_SUPPORTED if CONFIG_PM_ENABLE is not enabled in sdkconfig

**esp_err_t esp_pm_lock_delete** (esp_pm_lock_handle_t handle)

Delete a lock created using esp_pm_lock.

The lock must be released before calling this function.

This function must not be called from an ISR.
Chapter 2. API Reference

**Parameters** handle – handle obtained from esp_pm_lock_create function

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle argument is NULL
- ESP_ERR_INVALID_STATE if the lock is still acquired
- ESP_ERR_NOT_SUPPORTED if CONFIG_PM_ENABLE is not enabled in sdkconfig

```c
esp_err_t esp_pm_dump_locks(FILE *stream)
```

Dump the list of all locks to stderr

This function dumps debugging information about locks created using esp_pm_lock_create to an output stream.

This function must not be called from an ISR. If esp_pm_lock_acquire/release are called while this function is running, inconsistent results may be reported.

**Parameters** stream – stream to print information to; use stdout or stderr to print to the console; use fmemopen/open_memstream to print to a string buffer.

**Returns**
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if CONFIG_PM_ENABLE is not enabled in sdkconfig

**Structures**

```c
struct esp_pm_config_t
```

Power management config.

Pass a pointer to this structure as an argument to esp_pm_configure function.

**Public Members**

```c
int max_freq_mhz
```

Maximum CPU frequency, in MHz

```c
int min_freq_mhz
```

Minimum CPU frequency to use when no locks are taken, in MHz

```c
bool light_sleep_enable
```

Enter light sleep when no locks are taken

**Type Definitions**

```c
typedef esp_pm_config_t esp_pm_config.esp32_t
```

backward compatibility newer chips no longer require this typedef

```c
typedef esp_pm_config_t esp_pm_config.esp32s2_t
```

```c
typedef esp_pm_config_t esp_pm_config.esp32s3_t
```

```c
typedef esp_pm_config_t esp_pm_config.esp32c3_t
```

```c
typedef esp_pm_config_t esp_pm_config.esp32c2_t
```

```c
typedef esp_pm_config_t esp_pm_config.esp32c6_t
```
typedef struct esp_pm_lock *esp_pm_lock_handle_t
  Opaque handle to the power management lock.

Enumerations

enum esp_pm_lock_type_t
  Power management constraints.
  
  Values:

  enumerator ESP_PM_CPU_FREQ_MAX
    Require CPU frequency to be at the maximum value set via esp_pm_configure. Argument is unused and should be set to 0.

  enumerator ESP_PM_APB_FREQ_MAX
    Require APB frequency to be at the maximum value supported by the chip. Argument is unused and should be set to 0.

  enumerator ESP_PM_NO_LIGHT_SLEEP
    Prevent the system from going into light sleep. Argument is unused and should be set to 0.

2.10.25 POSIX Threads Support

Overview

ESP-IDF is based on FreeRTOS but offers a range of POSIX-compatible APIs that allow easy porting of third party code. This includes support for common parts of the POSIX Threads “pthreads” API.

POSIX Threads are implemented in ESP-IDF as wrappers around equivalent FreeRTOS features. The runtime memory or performance overhead of using the pthreads API is quite low, but not every feature available in either pthreads or FreeRTOS is available via the ESP-IDF pthreads support.

Pthreads can be used in ESP-IDF by including standard pthread.h header, which is included in the toolchain libc. An additional ESP-IDF specific header, esp_pthread.h, provides additional non-POSIX APIs for using some ESP-IDF features with pthreads.

C++ Standard Library implementations for std::thread, std::mutex, std::condition_variable, etc. are implemented using pthreads (via GCC libstdc++). Therefore, restrictions mentioned here also apply to the equivalent C++ standard library functionality.

RTOS Integration

Unlike many operating systems using POSIX Threads, ESP-IDF is a real-time operating system with a real-time scheduler. This means that a thread will only stop running if a higher priority task is ready to run, the thread blocks on an OS synchronization structure like a mutex, or the thread calls any of the functions sleep, vTaskDelay(), or usleep.

Note: If calling a standard libc or C++ sleep function, such as usleep defined in unistd.h, then the task will only block and yield the CPU if the sleep time is longer than one FreeRTOS tick period. If the time is shorter, the thread will busy-wait instead of yielding to another RTOS task.

By default, all POSIX Threads have the same RTOS priority, but it is possible to change this by calling a custom API.
Standard features

The following standard APIs are implemented in ESP-IDF.

Refer to standard POSIX Threads documentation, or pthread.h, for details about the standard arguments and behaviour of each function. Differences or limitations compared to the standard APIs are noted below.

Thread APIs

- **pthread_create()** - The attr argument is supported for setting stack size and detach state only. Other attribute fields are ignored. Unlike FreeRTOS task functions, the start_routine function is allowed to return. A “detached” type thread is automatically deleted if the function returns. The default “joinable” type thread will be suspended until pthread_join() is called on it.

- **pthread_join()**
- **pthread_detach()**
- **pthread_exit()**
- **sched_yield()**
- **pthread_self()** - An assert will fail if this function is called from a FreeRTOS task which is not a pthread.
- **pthread_equal()**

Thread Attributes

- **pthread_attr_init()**
- **pthread_attr_destroy()** - This function doesn’t need to free any resources and instead resets the attr structure to defaults (implementation is same as pthread_attr_init()).
- **pthread_attr_getstacksize() / pthread_attr_setstacksize()**
- **pthread_attr_getdetachstate() / pthread_attr_setdetachstate()**

Once

- **pthread_once()**

Static initializer constant PTHREAD_ONCE_INIT is supported.

Note: This function can be called from tasks created using either pthread or FreeRTOS APIs

Mutexes

POSIX Mutexes are implemented as FreeRTOS Mutex Semaphores (normal type for “fast” or “error check” mutexes, and Recursive type for “recursive” mutexes). This means that they have the same priority inheritance behaviour as mutexes created with xSemaphoreCreateMutex().

- **pthread_mutex_init()**
- **pthread_mutex_destroy()**
- **pthread_mutex_lock()**
- **pthread_mutex_timedlock()**
- **pthread_mutex_trylock()**
- **pthread_mutex_unlock()**
- **pthread_mutexattr_init()**
- **pthread_mutexattr_destroy()**
- **pthread_mutexattr_gettype() / pthread_mutexattr_settype()**

Static initializer constant PTHREAD_MUTEX_INITIALIZER is supported, but the non-standard static initializer constants for other mutex types are not supported.

Note: These functions can be called from tasks created using either pthread or FreeRTOS APIs
Chapter 2. API Reference

Condition Variables

- `pthread_cond_init()` - The `attr` argument is not implemented and is ignored.
- `pthread_cond_destroy()`
- `pthread_cond_signal()`
- `pthread_cond_broadcast()`
- `pthread_cond_wait()`
- `pthread_cond_timedwait()`

Static initializer constant `PTHREAD_COND_INITIALIZER` is supported.

- The resolution of `pthread_cond_timedwait()` timeouts is the RTOS tick period (see `CONFIG_FREERTOS_HZ`). Timeouts may be delayed up to one tick period after the requested timeout.

Note: These functions can be called from tasks created using either pthread or FreeRTOS APIs

Semaphore

In IDF, POSIX `unnamed` semaphores are implemented. The accessible API is described below. It implements semaphores as specified in the POSIX standard, unless specified otherwise.

- `sem_init()`
- `sem_destroy()`
  - `pshared` is ignored. Semaphores can always be shared between FreeRTOS tasks.
- `sem_post()`
  - If the semaphore has a value of `SEM_VALUE_MAX` already, -1 is returned and `errno` is set to `EAGAIN`.
- `sem_wait()`
- `sem_trywait()`
- `sem_timedwait()`
  - The time value passed by abstime will be rounded up to the next FreeRTOS tick.
  - The actual timeout will happen after the tick the time was rounded to and before the following tick.
  - It is possible, though unlikely, that the task is preempted directly after the timeout calculation, delaying the timeout of the following blocking operating system call by the duration of the preemption.
- `sem_getvalue()`

Read/Write Locks

- `pthread_rwlock_init()` - The `attr` argument is not implemented and is ignored.
- `pthread_rwlock_destroy()`
- `pthread_rwlock_rdlock()`
- `pthread_rwlock_wrlock()`
- `pthread_rwlock_unlock()`

Static initializer constant `PTHREAD_RWLOCK_INITIALIZER` is supported.

Note: These functions can be called from tasks created using either pthread or FreeRTOS APIs

Thread-Specific Data

- `pthread_key_create()` - The `destr_function` argument is supported and will be called if a thread function exits normally, calls `pthread_exit()`, or if the underlying task is deleted directly using the FreeRTOS function `vTaskDelete()`.
- `pthread_key_delete()`
- `pthread_setspecific()` / `pthread_getspecific()`

Note: These functions can be called from tasks created using either pthread or FreeRTOS APIs. When calling these functions from tasks created using FreeRTOS APIs, `CONFIG_FREERTOS_TLSP_DELETION_CALLBACKS` config
option must be enabled to ensure the thread-specific data is cleaned up before the task is deleted.

Note: There are other options for thread local storage in ESP-IDF, including options with higher performance. See Thread Local Storage.

Not Implemented

The `pthread.h` header is a standard header and includes additional APIs and features which are not implemented in ESP-IDF. These include:

- `pthread_cancel()` returns `ENOSYS` if called.
- `pthread_condattr_init()` returns `ENOSYS` if called.

Other POSIX Threads functions (not listed here) are not implemented and will produce either a compiler or a linker error if referenced from an ESP-IDF application. If you identify a useful API that you would like to see implemented in ESP-IDF, please open a feature request on GitHub <https://github.com/espressif/esp-idf/issues> with the details.

ESP-IDF Extensions

The API `esp_pthread_set_cfg()` defined in the `esp_pthreads.h` header offers custom extensions to control how subsequent calls to `pthread_create()` will behave. Currently, the following configuration can be set:

- Default stack size of new threads, if not specified when calling `pthread_create()` (overrides `CONFIG_PTHREAD_TASK_STACK_SIZE_DEFAULT`).
- RTOS priority of new threads (overrides `CONFIG_PTHREAD_TASK_PRIO_DEFAULT`).
- Core affinity / core pinning of new threads (overrides `CONFIG_PTHREAD_TASK_CORE_DEFAULT`).
- FreeRTOS task name for new threads (overrides `CONFIG_PTHREAD_TASK_NAME_DEFAULT`).

This configuration is scoped to the calling thread (or FreeRTOS task), meaning that `esp_pthread_set_cfg()` can be called independently in different threads or tasks. If the `inherit_cfg` flag is set in the current configuration then any new thread created will inherit the creator’s configuration (if that thread calls `pthread_create()` recursively), otherwise the new thread will have the default configuration.

Examples

- `system/pthread` demonstrates using the pthreads API to create threads
- `cxx/pthread` demonstrates using C++ Standard Library functions with threads

API Reference

Header File

- `components/pthread/include/esp_pthread.h`

Functions

`esp_pthread_CFG_t esp_pthread_get_default_config(void)`

Creates a default pthread configuration based on the values set via menuconfig.

**Returns** A default configuration structure.
Chapter 2. API Reference

```c
esp_err_t esp_pthread_set_cfg(const esp_pthread_cfg_t *cfg)
```
Configure parameters for creating pthread.
This API allows you to configure how the subsequent pthread_create() call will behave. This call can be used to setup configuration parameters like stack size, priority, configuration inheritance etc.
If the ‘inherit’ flag in the configuration structure is enabled, then the same configuration is also inherited in the thread subtree.

**Note:** Passing non-NULL attributes to pthread_create() will override the stack_size parameter set using this API

**Parameters**
- `cfg` - The pthread config parameters

**Returns**
- ESP_OK if configuration was successfully set
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_INVALID_ARG if stack_size is less than PTHREAD_STACK_MIN

```c
esp_err_t esp_pthread_get_cfg(esp_pthread_cfg_t *p)
```
Get current pthread creation configuration.
This will retrieve the current configuration that will be used for creating threads.

**Parameters**
p - Pointer to the pthread config structure that will be updated with the currently configured parameters

**Returns**
- ESP_OK if the configuration was available
- ESP_ERR_NOT_FOUND if a configuration wasn’t previously set

```c
esp_err_t esp_pthread_init (void)
```
Initialize pthread library.

**Structures**

```c
struct esp_pthread_cfg_t
```
pthread configuration structure that influences pthread creation

**Public Members**

```c
size_t stack_size
```
The stack size of the pthread.

```c
size_t prio
```
The thread’s priority.

```c
bool inherit_cfg
```
Inherit this configuration further.

```c
const char *thread_name
```
The thread name.

```c
int pin_to_core
```
The core id to pin the thread to. Has the same value range as xCoreId argument of xTaskCreatePinnedToCore.
Macros

PTHREAD_STACK_MIN

2.10.26 Random Number Generation

ESP32 contains a hardware random number generator, values from it can be obtained using the APIs `esp_random()` and `esp_fill_random()`.

The hardware RNG produces true random numbers under any of the following conditions:

- RF subsystem is enabled (i.e. Wi-Fi or Bluetooth are enabled).
- An internal entropy source has been enabled by calling `bootloader_random_enable()` and not yet disabled by calling `bootloader_random_disable()`.
- While the ESP-IDF Second stage bootloader is running. This is because the default ESP-IDF bootloader implementation calls `bootloader_random_enable()` when the bootloader starts, and `bootloader_random_disable()` before executing the app.

When any of these conditions are true, samples of physical noise are continuously mixed into the internal hardware RNG state to provide entropy. Consult the ESP32 Technical Reference Manual > Random Number Generator (RNG) [PDF] chapter for more details.

If none of the above conditions are true, the output of the RNG should be considered pseudo-random only.

Startup

During startup, ESP-IDF bootloader temporarily enables a non-RF entropy source (internal reference voltage noise) that provides entropy for any first boot key generation. However, after the app starts executing then normally only pseudo-random numbers are available until Wi-Fi or Bluetooth are initialized.

To re-enable the entropy source temporarily during app startup, or for an application that does not use Wi-Fi or Bluetooth, call the function `bootloader_random_enable()` to re-enable the internal entropy source. The function `bootloader_random_disable()` must be called to disable the entropy source again before using ADC, I2S, Wi-Fi or Bluetooth.

**Note:** The entropy source enabled during the boot process by the ESP-IDF Second Stage Bootloader will seed the internal RNG state with some entropy. However, the internal hardware RNG state is not large enough to provide a continuous stream of true random numbers. This is why a continuous entropy source must be enabled whenever true random numbers are required.

**Note:** If an application requires a source of true random numbers but it is not possible to permanently enable a hardware entropy source, consider using a strong software DRBG implementation such as the mbedTLS CTR-DRBG or HMAC-DRBG, with an initial seed of entropy from hardware RNG true random numbers.

API Reference

Header File

- `components/esp_hw_support/include/esp_random.h`

Functions
uint32_t esp_random (void)
    Get one random 32-bit word from hardware RNG.
    If Wi-Fi or Bluetooth are enabled, this function returns true random numbers. In other situations, if true
    random numbers are required then consult the ESP-IDF Programming Guide “Random Number Generation”
    section for necessary prerequisites.
    This function automatically busy-waits to ensure enough external entropy has been introduced into the hardware
    RNG state, before returning a new random number. This delay is very short (always less than 100 CPU cycles).

    **Returns** Random value between 0 and UINT32_MAX

void esp_fill_random (void *buf, size_t len)
    Fill a buffer with random bytes from hardware RNG.

    **Note:** This function is implemented via calls to esp_random(), so the same constraints apply.

**Parameters**

- **buf** – Pointer to buffer to fill with random numbers.
- **len** – Length of buffer in bytes

**Header File**

- components/bootloader_support/include/bootloader_random.h

**Functions**

void bootloader_random_enable (void)
    Enable an entropy source for RNG if RF subsystem is disabled.

    The exact internal entropy source mechanism depends on the chip in use but all SoCs use the SAR ADC
to continuously mix random bits (an internal noise reading) into the HWRNG. Consult the SoC Technical
Reference Manual for more information.

    Can also be called from app code, if true random numbers are required without initialized RF subsystem. This
might be the case in early startup code of the application when the RF subsystem has not started yet or if the
RF subsystem should not be enabled for power saving.


    **Warning:** This function is not safe to use if any other subsystem is accessing the RF subsystem or the
ADC at the same time!

void bootloader_random_disable (void)
    Disable entropy source for RNG.

    Disables internal entropy source. Must be called after bootloader_random_enable() and before RF subsystem
features, ADC, or I2S (ESP32 only) are initialized.

    Consult the ESP-IDF Programming Guide “Random Number Generation” section for details.

void bootloader_fill_random (void *buffer, size_t length)
    Fill buffer with ‘length’ random bytes.

    **Note:** If this function is being called from app code only, and never from the bootloader, then it’s better to
call esp_fill_random().
Parameters

- **buffer** - Pointer to buffer
- **length** - This many bytes of random data will be copied to buffer

getrandom

A compatible version of the Linux `getrandom()` function is also provided for ease of porting:

```c
#include <sys/random.h>

ssize_t getrandom(void *buf, size_t buflen, unsigned int flags);
```

This function is implemented by calling `esp_fill_random()` internally.

The `flags` argument is ignored, this function is always non-blocking but the strength of any random numbers is dependent on the same conditions described above.

Return value is -1 (with `errno` set to `EFAULT`) if the `buf` argument is NULL, and equal to `buflen` otherwise.

### 2.10.27 Sleep Modes

**Overview**

ESP32 contains the following power saving modes: Light-sleep, and Deep-sleep.

In Light-sleep mode, the digital peripherals, most of the RAM, and CPUs are clock-gated and their supply voltage is reduced. Upon exit from Light-sleep, the digital peripherals, RAM, and CPUs resume operation and their internal states are preserved.

In Deep-sleep mode, the CPUs, most of the RAM, and all digital peripherals that are clocked from APB_CLK are powered off. The only parts of the chip that remain powered on are:

- RTC controller
- ULP coprocessor
- RTC fast memory
- RTC slow memory

There are several wakeup sources in Deep-sleep and Light-sleep modes. These sources can also be combined so that the chip will wake up when any of the sources are triggered. Wakeup sources can be enabled using `esp_sleep_enable_X_wakeup` APIs and can be disabled using `esp_sleep_disable_wakeup_source()` API. Next section describes these APIs in detail. Wakeup sources can be configured at any moment before entering Light-sleep or Deep-sleep mode.

Additionally, the application can force specific powerdown modes for RTC peripherals and RTC memories using `esp_sleep_pd_config()` API.

Once wakeup sources are configured, the application can enter sleep mode using `esp_light_sleep_start()` or `esp_deep_sleep_start()` APIs. At this point, the hardware will be configured according to the requested wakeup sources, and the RTC controller will either power down or power off the CPUs and digital peripherals.

**Wi-Fi/Bluetooth and Sleep Modes**

In Deep-sleep and Light-sleep modes, the wireless peripherals are powered down. Before entering Deep-sleep or Light-sleep modes, the application must disable Wi-Fi and Bluetooth using the appropriate calls (i.e., `esp_bluedroid_disable()`, `esp_bt_controller_disable()`, `esp_wifi_stop()`). Wi-Fi and
Bluetooth connections will not be maintained in Deep-sleep or Light-sleep mode, even if these functions are not called.

If Wi-Fi/Bluetooth connections need to be maintained, enable Wi-Fi/Bluetooth Modem-sleep mode and automatic Light-sleep feature (see *Power Management APIs*). This will allow the system to wake up from sleep automatically when required by the Wi-Fi/Bluetooth driver, thereby maintaining the connection.

**Wakeup Sources**

**Timer**  
The RTC controller has a built-in timer which can be used to wake up the chip after a predefined amount of time. Time is specified at microsecond precision, but the actual resolution depends on the clock source selected for RTC SLOW_CLK.

For details on RTC clock options, see *ESP32 Technical Reference Manual > ULP Coprocessor* [PDF].

RTC peripherals or RTC memories don’t need to be powered on during sleep in this wakeup mode.

*esp_sleep_enable_timer_wakeup()* function can be used to enable sleep wakeup using a timer.

**Touchpad**  
The RTC IO module contains the logic to trigger wakeup when a touch sensor interrupt occurs. To wakeup from a touch sensor interrupt, users need to configure the touch pad interrupt before the chip enters Deep-sleep or Light-sleep modes.

Revisions 0 and 1 of ESP32 only support this wakeup mode when RTC peripherals are not forced to be powered on (i.e., ESP_PD_DOMAIN_RTC_PERIPH should be set to ESP_PD_OPTION_AUTO).

*esp_sleep_enable_touchpad_wakeup()* function can be used to enable this wakeup source.

**External Wakeup (ext0)**  
The RTC IO module contains the logic to trigger wakeup when one of RTC GPIOs is set to a predefined logic level. RTC IO is part of the RTC peripherals power domain, so RTC peripherals will be kept powered on during Deep-sleep if this wakeup source is requested.

The RTC IO module is enabled in this mode, so internal pullup or pulldown resistors can also be used. They need to be configured by the application using *rtc_gpio_pullup_en()* and *rtc_gpio_pulldown_en()* functions before calling *esp_deep_sleep_start()*.

In revisions 0 and 1 of ESP32, this wakeup source is incompatible with ULP and touch wakeup sources.

*esp_sleep_enable_ext0_wakeup()* function can be used to enable this wakeup source.

**Warning:** After waking up from sleep, the IO pad used for wakeup will be configured as RTC IO. Therefore, before using this pad as digital GPIO, users need to reconfigure it using *rtc_gpio_deinit()* function.

**External Wakeup (ext1)**  
The RTC controller contains the logic to trigger wakeup using multiple RTC GPIOs. One of the following two logic functions can be used to trigger wakeup:

- wake up if any of the selected pins is high (ESP_EXT1_WAKEUP_ANY_HIGH)
- wake up if all the selected pins are low (ESP_EXT1_WAKEUP_ALL_LOW)

This wakeup source is implemented by the RTC controller. As such, RTC peripherals and RTC memories can be powered down in this mode. However, if RTC peripherals are powered down, internal pullup and pulldown resistors will be disabled if we don’t use the HOLD feature. To use internal pullup or pulldown resistors, request the RTC peripherals power domain to be kept on during sleep, and configure pullup/pulldown resistors using rtc_gpio functions before entering sleep:

```
esp_sleep_pd_config(ESP_PD_DOMAIN_RTC_PERIPH, ESP_PD_OPTION_ON);
rtc_gpio_pullup_dis(gpio_num);
rtc_gpio_pulldown_en(gpio_num);
```
If we turn off the `RTC_PERIPH` domain, we will use the HOLD feature to maintain the pull-up and pull-down on the pins during sleep. HOLD feature will be acted on the pin internally before the system entering sleep, and this can further reduce power consumption:

```c
rtc_gpio_pullup_dis(gpio_num);
rtc_gpio_pulldown_en(gpio_num);
```

If certain chips lack the `RTC_PERIPH` domain, we can only use the HOLD feature to maintain the pull-up and pull-down on the pins during sleep:

```c
gpio_pullup_dis(gpio_num);
gpio_pulldown_en(gpio_num);
```

**Warning:**
- To use the EXT1 wakeup, the IO pad(s) are configured as RTC IO. Therefore, before using these pads as digital GPIOs, users need to reconfigure them by calling the `rtc_gpio_deinit()` function.
- If the RTC peripherals are configured to be powered down (which is by default), the wakeup IOs will be set to the holding state before entering sleep. Therefore, after the chip wakes up from Light-sleep, please call `rtc_gpio_hold_dis` to disable the hold function to perform any pin re-configuration. For Deep-sleep wakeup, this is already being handled at the application startup stage.

`esp_sleep_enable_ext1_wakeup()` function can be used to enable this wakeup source.

**ULP Coprocessor Wakeup**  ULP coprocessor can run while the chip is in sleep mode, and may be used to poll sensors, monitor ADC or touch sensor values, and wake up the chip when a specific event is detected. ULP coprocessor is part of the RTC peripherals power domain, and it runs the program stored in RTC slow memory. RTC slow memory will be powered on during sleep if this wakeup mode is requested. RTC peripherals will be automatically powered on before ULP coprocessor starts running the program; once the program stops running, RTC peripherals are automatically powered down again.

Revisions 0 and 1 of ESP32 only support this wakeup mode when RTC peripherals are not forced to be powered on (i.e., `ESP_PD_DOMAIN_RTC_PERIPH` should be set to `ESP_PD_OPTION_AUTO`).

`esp_sleep_enable_ulp_wakeup()` function can be used to enable this wakeup source.

**GPIO Wakeup (Light-sleep Only)**  In addition to EXT0 and EXT1 wakeup sources described above, one more method of wakeup from external inputs is available in Light-sleep mode. With this wakeup source, each pin can be individually configured to trigger wakeup on high or low level using `gpio_wakeup_enable()` function. Unlike EXT0 and EXT1 wakeup sources, which can only be used with RTC IOs, this wakeup source can be used with any IO (RTC or digital).

`esp_sleep_enable_gpio_wakeup()` function can be used to enable this wakeup source.

**Warning:**  Before entering Light-sleep mode, check if any GPIO pin to be driven is part of the VDD_SDIO power domain. If so, this power domain must be configured to remain ON during sleep.

For example, on ESP32-WROOM-32 board, GPIO16 and GPIO17 are linked to VDD_SDIO power domain. If they are configured to remain high during Light-sleep, the power domain should be configured to remain powered ON. This can be done with `esp_sleep_pd_config()`:

```c
esp_sleep_pd_config(ESP_PD_DOMAIN_VDDSDIO, ESP_PD_OPTION_ON);
```

**UART Wakeup (Light-sleep Only)**  When ESP32 receives UART input from external devices, it is often necessary to wake up the chip when input data is available. The UART peripheral contains a feature which allows waking up the chip from Light-sleep when a certain number of positive edges on RX pin are seen. This number of positive edges...
can be set using `uart_set_wakeup_threshold()` function. Note that the character which triggers wakeup (and any characters before it) will not be received by the UART after wakeup. This means that the external device typically needs to send an extra character to the ESP32 to trigger wakeup before sending the data.

`esp_sleep_enable_uart_wakeup()` function can be used to enable this wakeup source.

### Power-down of RTC Peripherals and Memories

By default, `esp_deep_sleep_start()` and `esp_light_sleep_start()` functions will power down all RTC power domains which are not needed by the enabled wakeup sources. To override this behaviour, `esp_sleep_pd_config()` function is provided.

Note: in revision 0 of ESP32, RTC fast memory will always be kept enabled in Deep-sleep, so that the Deep-sleep stub can run after reset. This can be overridden, if the application doesn’t need clean reset behaviour after Deep-sleep.

If some variables in the program are placed into RTC slow memory (for example, using `RTC_DATA_ATTR` attribute), RTC slow memory will be kept powered on by default. This can be overridden using `esp_sleep_pd_config()` function, if desired.

### Power-down of Flash

By default, to avoid potential issues, `esp_light_sleep_start()` function will **not** power down flash. To be more specific, it takes time to power down the flash and during this period the system may be woken up, which then actually powers up the flash before this flash could be powered down completely. As a result, there is a chance that the flash may not work properly.

So, in theory, it’s ok if you only wake up the system after the flash is completely powered down. However, in reality, the flash power-down period can be hard to predict (for example, this period can be much longer when you add filter capacitors to the flash’s power supply circuit) and uncontrollable (for example, the asynchronous wake-up signals make the actual sleep time uncontrollable).

**Warning:** If a filter capacitor is added to your flash power supply circuit, please do everything possible to avoid powering down flash.

Therefore, it’s recommended not to power down flash when using ESP-IDF. For power-sensitive applications, it’s recommended to use Kconfig option `CONFIG_ESP_SLEEP_FLASH_LEAKAGE_WORKAROUND` to reduce the power consumption of the flash during light sleep, instead of powering down the flash.

It is worth mentioning that PSRAM has a similar Kconfig option `CONFIG_ESP_SLEEP_PSRAM_LEAKAGE_WORKAROUND`.

However, for those who have fully understood the risk and are still willing to power down the flash to further reduce the power consumption, please check the following mechanisms:

- Setting Kconfig option `CONFIG_ESP_SLEEP_POWER_DOWN_FLASH` only powers down the flash when the RTC timer is the only wake-up source and the sleep time is longer than the flash power-down period.
- Calling `esp_sleep_pd_config(ESP_PD_DOMAIN_VDDSDIO, ESP_PD_OPTION_OFF)` powers down flash when the RTC timer is not enabled as a wakeup source or the sleep time is longer than the flash power-down period.

**Note:**

- ESP-IDF does not provide any mechanism that can power down the flash in all conditions when light sleep.
- `esp_deep_sleep_start()` function will force power down flash regardless of user configuration.
Chapter 2. API Reference

Entering Light-sleep

`esp_light_sleep_start()` function can be used to enter Light-sleep once wakeup sources are configured. It is also possible to enter Light-sleep with no wakeup sources configured. In this case, the chip will be in Light-sleep mode indefinitely until external reset is applied.

Entering Deep-sleep

`esp_deep_sleep_start()` function can be used to enter Deep-sleep once wakeup sources are configured. It is also possible to enter Deep-sleep with no wakeup sources configured. In this case, the chip will be in Deep-sleep mode indefinitely until external reset is applied.

Configuring IOs

Some ESP32 IOs have internal pullups or pulldowns, which are enabled by default. If an external circuit drives this pin in Deep-sleep mode, current consumption may increase due to current flowing through these pullups and pulldowns.

To isolate a pin to prevent extra current draw, call `rtc_gpio_isolate()` function.

For example, on ESP32-WROVER module, GPIO12 is pulled up externally, and it also has an internal pulldown in the ESP32 chip. This means that in Deep-sleep, some current will flow through these external and internal resistors, increasing Deep-sleep current above the minimal possible value.

Add the following code before `esp_deep_sleep_start()` to remove such extra current:

```c
rtc_gpio_isolate(GPIO_NUM_12);
```

UART Output Handling

Before entering sleep mode, `esp_deep_sleep_start()` will flush the contents of UART FIFOs.

When entering Light-sleep mode using `esp_light_sleep_start()`, UART FIFOs will not be flushed. Instead, UART output will be suspended, and remaining characters in the FIFO will be sent out after wakeup from Light-sleep.

Checking Sleep Wakeup Cause

`esp_sleep_get_wakeup_cause()` function can be used to check which wakeup source has triggered wakeup from sleep mode.

For touchpad, it is possible to identify which touch pin has caused wakeup using `esp_sleep_get_touchpad_wakeup_status()` functions.

For ext1 wakeup sources, it is possible to identify which touch pin has caused wakeup using `esp_sleep_get_ext1_wakeup_status()` functions.

Disable Sleep Wakeup Source

Previously configured wakeup sources can be disabled later using `esp_sleep_disable_wakeup_source()` API. This function deactivates trigger for the given wakeup source. Additionally, it can disable all triggers if the argument is `ESP_SLEEP_WAKEUP_ALL`. 
Chapter 2. API Reference

Application Example

- **protocols/sntp**: the implementation of basic functionality of Deep-sleep, where ESP module is periodically woken up to retrieve time from NTP server.
- **wifi/power_save**: the implementation of Wi-Fi Modem-sleep example.
- **bluetooth/nimble/power_save**: the implementation of Bluetooth Modem-sleep example.
- **system/deep_sleep**: the usage of various Deep-sleep wakeup triggers and ULP coprocessor programming.

API Reference

Header File

- components/esp_hw_support/include/esp_sleep.h

Functions

```c
esp_err_t esp_sleep_disable_wakeup_source(esp_sleep_source_t source)
```

Disable wakeup source.

This function is used to deactivate wake up trigger for source defined as parameter of the function.

See docs/sleep-modes.rst for details.

**Note:** This function does not modify wake up configuration in RTC. It will be performed in esp_deep_sleep_start/esp_light_sleep_start function.

**Parameters**

- source -- number of source to disable of type esp_sleep_source_t

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_STATE if trigger was not active

```c
esp_err_t esp_sleep_enable_ulp_wakeup(void)
```

Enable wakeup by ULP coprocessor.

**Note:** On ESP32, ULP wakeup source cannot be used when RTC_PERIPH power domain is forced, to be powered on (ESP_PD_OPTION_ON) or when ext0 wakeup source is used.

**Returns**

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if additional current by touch (CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT) is enabled.
- ESP_ERR_INVALID_STATE if ULP co-processor is not enabled or if wakeup triggers conflict

```c
esp_err_t esp_sleep_enable_timer_wakeup(uint64_t time_in_us)
```

Enable wakeup by timer.

**Parameters**

- time_in_us -- time before wakeup, in microseconds

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if value is out of range (TBD)
### esp_err_t esp_sleep_enable_touchpad_wakeup (void)

Enable wakeup by touch sensor.

**Note:** On ESP32, touch wakeup source cannot be used when RTC_PERIPH power domain is forced to be powered on (ESP_PD_OPTION_ON) or when ext0 wakeup source is used.

**Note:** The FSM mode of the touch button should be configured as the timer trigger mode.

#### Returns
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if additional current by touch (CONFIG_RTC_EXT_CRYST_ADDIT_CURRENT) is enabled.
- ESP_ERR_INVALID_STATE if wakeup triggers conflict

### touch_pad_t esp_sleep_get_touchpad_wakeup_status (void)

Get the touch pad which caused wakeup.

If wakeup was caused by another source, this function will return TOUCH_PAD_MAX;

**Returns**
- touch pad which caused wakeup

### bool esp_sleep_is_valid_wakeup_gpio (gpio_num_t gpio_num)

Returns true if a GPIO number is valid for use as wakeup source.

**Note:** For SoCs with RTC IO capability, this can be any valid RTC IO input pin.

#### Parameters
- gpio_num: Number of the GPIO to test for wakeup source capability

#### Returns
- True if this GPIO number will be accepted as a sleep wake source.

### esp_err_t esp_sleep_enable_ext0_wakeup (gpio_num_t gpio_num, int level)

Enable wakeup using a pin.

This function uses external wakeup feature of RTC_IO peripheral. It will work only if RTC peripherals are kept on during sleep.

This feature can monitor any pin which is an RTC IO. Once the pin transitions into the state given by level argument, the chip will be woken up.

**Note:** This function does not modify pin configuration. The pin is configured in esp_deep_sleep_start/esp_light_sleep_start, immediately before entering sleep mode.

**Note:** ESP32: ext0 wakeup source cannot be used together with touch or ULP wakeup sources.

#### Parameters
- gpio_num: GPIO number used as wakeup source. Only GPIOs with the RTC functionality can be used. For different SoCs, the related GPIOs are:
  - ESP32: 0, 2, 4, 12-15, 25-27, 32-39;
  - ESP32-S2: 0-21;
  - ESP32-S3: 0-21.
- level: input level which will trigger wakeup (0=low, 1=high)

#### Returns
- ESP_OK on success
ESP_ERR_INVALID_ARG if the selected GPIO is not an RTC GPIO, or the mode is invalid
ESP_ERR_INVALID_STATE if wakeup triggers conflict

**esp_err_t esp_sleep_enable_ext1_wakeup** (uint64_t mask, esp_sleep_ext1_wakeup_mode_t mode)

Enable wakeup using multiple pins.

This function uses external wakeup feature of RTC controller. It will work even if RTC peripherals are shut down during sleep.

This feature can monitor any number of pins which are in RTC IOs. Once any of the selected pins goes into the state given by mode argument, the chip will be woken up.

**Note:** This function does not modify pin configuration. The pins are configured in esp_deep_sleep_start/esp_light_sleep_start, immediately before entering sleep mode.

**Note:** Internal pullups and pulldowns don’t work when RTC peripherals are shut down. In this case, external resistors need to be added. Alternatively, RTC peripherals (and pullups/pulldowns) may be kept enabled using esp_sleep_pd_config function. If we turn off the RTC_PERIPH domain or certain chips lack the RTC_PERIPH domain, we will use the HOLD feature to maintain the pull-up and pull-down on the pins during sleep. HOLD feature will be acted on the pin internally before the system entering sleep, and this can further reduce power consumption.

**Parameters**
- **mask** – bit mask of GPIO numbers which will cause wakeup. Only GPIOs which have RTC functionality can be used in this bit map. For different SoCs, the related GPIOs are:
  - ESP32: 0, 2, 4, 12-15, 25-27, 32-39
  - ESP32-S2: 0-21
  - ESP32-S3: 0-21
  - ESP32-C6: 0-7
  - ESP32-H2: 7-14
- **mode** – select logic function used to determine wakeup condition: When target chip is ESP32:
  - ESP_EXT1_WAKEUP_ALL_LOW: wake up when all selected GPIOs are low
  - ESP_EXT1_WAKEUP_ANY_HIGH: wake up when any of the selected GPIOs is high
When target chip is ESP32-S2, ESP32-S3, ESP32-C6 or ESP32-H2:
  - ESP_EXT1_WAKEUP_ANY_LOW: wake up when any of the selected GPIOs is low
  - ESP_EXT1_WAKEUP_ANY_HIGH: wake up when any of the selected GPIOs is high

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if any of the selected GPIOs is not an RTC GPIO, or mode is invalid

**esp_err_t esp_sleep_enable_gpio_wakeup** (void)

Enable wakeup from light sleep using GPIOs.

Each GPIO supports wakeup function, which can be triggered on either low level or high level. Unlike EXT0 and EXT1 wakeup sources, this method can be used both for all IOs: RTC IOs and digital IOs. It can only be used to wakeup from light sleep though.

To enable wakeup, first call gpio_wakeup_enable, specifying gpio number and wakeup level, for each GPIO which is used for wakeup. Then call this function to enable wakeup feature.

**Note:** On ESP32, GPIO wakeup source can not be used together with touch or ULP wakeup sources.
Returns

- ESP_OK on success
- ESP_ERR_INVALID_STATE if wakeup triggers conflict

`esp_err_t esp_sleep_enable_uart_wakeup` (int uart_num)
Enable wakeup from light sleep using UART.
Use `uart_set_wakeup_threshold` function to configure UART wakeup threshold.
Wakeup from light sleep takes some time, so not every character sent to the UART can be received by the application.

Note: ESP32 does not support wakeup from UART2.

Parameters

- `uart_num` - UART port to wake up from

Returns

- ESP_OK on success
- ESP_ERR_INVALID_ARG if wakeup from given UART is not supported

`esp_err_t esp_sleep_enable_bt_wakeup` (void)
Enable wakeup by bluetooth.

Returns

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if wakeup from bluetooth is not supported

`esp_err_t esp_sleep_disable_bt_wakeup` (void)
Disable wakeup by bluetooth.

Returns

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if wakeup from bluetooth is not supported

`esp_err_t esp_sleep_enable_wifi_wakeup` (void)
Enable wakeup by WiFi MAC.

Returns

- ESP_OK on success

`esp_err_t esp_sleep_disable_wifi_wakeup` (void)
Disable wakeup by WiFi MAC.

Returns

- ESP_OK on success

`esp_err_t esp_sleep_enable_wifi_beacon_wakeup` (void)
Enable beacon wakeup by WiFi MAC, it will wake up the system into modem state.

Returns

- ESP_OK on success

`esp_err_t esp_sleep_disable_wifi_beacon_wakeup` (void)
Disable beacon wakeup by WiFi MAC.

Returns

- ESP_OK on success

`uint64_t esp_sleep_get_ext1_wakeup_status` (void)
Get the bit mask of GPIOs which caused wakeup (ext1)
If wakeup was caused by another source, this function will return 0.

Returns

- bit mask, if GPIO caused wakeup, BIT(n) will be set
**esp_err_t esp_sleep_pd_config(esp_sleep_pd_domain_t domain, esp_sleep_pd_option_t option)**

Set power down mode for an RTC power domain in sleep mode.

If not set set using this API, all power domains default to ESP_PD_OPTION_AUTO.

**Parameters**
- **domain** - power domain to configure
- **option** - power down option (ESP_PD_OPTION_OFF, ESP_PD_OPTION_ON, or ESP_PD_OPTION_AUTO)

**Returns**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if either of the arguments is out of range

**esp_err_t esp_deep_sleep_try_to_start(void)**

Enter deep sleep with the configured wakeup options.

The reason for the rejection can be such as a short sleep time.

**Note:** In general, the function does not return, but if the sleep is rejected, then it returns from it.

**Returns**
- No return - If the sleep is not rejected.
- ESP_ERR_SLEEP_REJECT sleep request is rejected (wakeup source set before the sleep request)

**void esp_deep_sleep_start(void)**

Enter deep sleep with the configured wakeup options.

**Note:** The function does not do a return (no rejection). Even if wakeup source set before the sleep request it goes to deep sleep anyway.

**esp_err_t esp_light_sleep_start(void)**

Enter light sleep with the configured wakeup options.

**Returns**
- ESP_OK on success (returned after wakeup)
- ESP_ERR_SLEEP_REJECT sleep request is rejected (wakeup source set before the sleep request)
- ESP_ERR_SLEEP_TOO_SHORT_SLEEP_DURATION after deducting the sleep flow overhead, the final sleep duration is too short to cover the minimum sleep duration of the chip, when rtc timer wakeup source enabled

**esp_err_t esp_deep_sleep_try(uint64_t time_in_us)**

Enter deep-sleep mode.

The device will automatically wake up after the deep-sleep time. Upon waking up, the device calls deep sleep wake stub, and then proceeds to load application.

Call to this function is equivalent to a call to esp_deep_sleep_enable_timer_wakeup followed by a call to esp_deep_sleep_start.

**Parameters**
- **time_in_us** - deep-sleep time, unit: microsecond

**Returns**
- No return - If the sleep is not rejected.
- ESP_ERR_SLEEP_REJECT sleep request is rejected (wakeup source set before the sleep request)
Chapter 2. API Reference

void esp_deep_sleep(uint64_t time_in_us)

Enter deep-sleep mode.

The device will automatically wake up after the deep-sleep time. Upon waking up, the device calls deep sleep wake stub, and then proceeds to load application.

Call to this function is equivalent to a call to esp_deep_sleep_enable_timer_wakeup followed by a call to esp_deep_sleep_start.

**Note:** The function does not do a return (no rejection). Even if wake-up source set before the sleep request it goes to deep sleep anyway.

**Parameters**

```
time_in_us  – deep-sleep time, unit: microsecond
```

**esp_err_t esp_deep_sleep_register_hook (esp_deep_sleep_cb_t new_dslp_cb)**

Register a callback to be called from the deep sleep prepare.

**Warning:** deep sleep callbacks should without parameters, and MUST NOT, UNDER ANY CIRCUMSTANCES, CALL A FUNCTION THAT MIGHT BLOCK.

**Parameters**

```
new_dslp_cb – Callback to be called
```

**Returns**

- ESP_OK: Callback registered to the deep sleep misc_modules_sleep_prepare
- ESP_ERR_NO_MEM: No more hook space for register the callback

void esp_deep_sleep_deregister_hook (esp_deep_sleep_cb_t old_dslp_cb)

Unregister a deep sleep callback.

**Parameters**

```
old_dslp_cb – Callback to be unregistered
```

**esp_sleep_wakeup_cause_t esp_sleep_get_wakeup_cause (void)**

Get the wake up source which caused wake-up from sleep.

**Returns**

cause of wake up from last sleep (deep sleep or light sleep)

void esp_wake_deep_sleep (void)

Default stub to run on wake from deep sleep.

Allows for executing code immediately on wake from sleep, before the software bootloader or ESP-IDF app has started up.

This function is weak-linked, so you can implement your own version to run code immediately when the chip wakes from sleep.

See docs/deep-sleep-stub.rst for details.

void esp_set_deep_sleep_wake_stub (esp_deep_sleep_wake_stub_fn_t new_stub)

Install a new stub at runtime to run on wake from deep sleep.

If implementing esp_wake_deep_sleep() then it is not necessary to call this function.

However, it is possible to call this function to substitute a different deep sleep stub. Any function used as a deep sleep stub must be marked RTC_IRAM_ATTR, and must obey the same rules given for esp_wake_deep_sleep().

void esp_set_deep_sleep_wake_stub_default_entry (void)

Set wake stub entry to default esp_wake_stub_entry

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**Esp摆深觉睡醒stub_fn_t esp_get_deep_sleep_wake_stub (void)**

Get current wake from deep sleep stub.

**Returns** Return current wake from deep sleep stub, or NULL if no stub is installed.

`void esp_default_wake_deep_sleep (void)`

The default esp-idf-provided esp_wake_deep_sleep() stub.

See docs/deep-sleep-stub.rst for details.

`void esp_deep_sleep_disable_rom_logging (void)`

Disable logging from the ROM code after deep sleep.

Using LSB of RTC_STORE4.

`void esp_sleep_config_gpio_isolate (void)`

Configure to isolate all GPIO pins in sleep state.

`void esp_sleep_enable_gpio_switch (bool enable)`

Enable or disable GPIO pins status switching between slept status and waked status.

**Parameters** `enable` — decide whether to switch status or not

**Macros**

`ESP_PD_DOMAIN_RTC8M`

**Type Definitions**

`typedef void (*esp_deep_sleep_cb_t)(void)`

`typedef esp_sleep_source_t esp_sleep_wakeup_cause_t`

`typedef void (*esp_deep_sleep_wake_stub_fn_t)(void)`

Function type for stub to run on wake from sleep.

**Enumerations**

`enum esp_sleep_ext1_wakeup_mode_t` — Logic function used for EXT1 wake mode.

Values:

- `enumerator ESP_EXT1_WAKEUP_ALL_LOW` — Wake the chip when all selected GPIOs go low.

- `enumerator ESP_EXT1_WAKEUP_ANY_HIGH` — Wake the chip when any of the selected GPIOs go high.

`enum esp_sleep_pd_domain_t` — Power domains which can be powered down in sleep mode.

Values:

- `enumerator ESP_PD_DOMAIN_RTC_PERIPH` — RTC IO, sensors and ULP co-processor.
enumerator `ESP_PD_DOMAIN_RTC_SLOW_MEM`  
RTC slow memory.

enumerator `ESP_PD_DOMAIN_RTC_FAST_MEM`  
RTC fast memory.

enumerator `ESP_PD_DOMAIN_XTAL`  
XTAL oscillator.

enumerator `ESP_PD_DOMAIN_RC_FAST`  
Internal Fast oscillator.

enumerator `ESP_PD_DOMAIN_VDDSDIO`  
VDD_SDIO.

enumerator `ESP_PD_DOMAIN_MODEM`  
MODEM, includes WiFi, Bluetooth and IEEE802.15.4.

enumerator `ESP_PD_DOMAIN_MAX`  
Number of domains.

enum `esp_sleep_pd_option_t`  
Power down options.

Values:

enumerator `ESP_PD_OPTION_OFF`  
Power down the power domain in sleep mode.

enumerator `ESP_PD_OPTION_ON`  
Keep power domain enabled during sleep mode.

enumerator `ESP_PD_OPTION_AUTO`  
Keep power domain enabled in sleep mode, if it is needed by one of the wakeup options. Otherwise power it down.

enum `esp_sleep_source_t`  
Sleep wakeup cause.

Values:

enumerator `ESP_SLEEP_WAKEUP_UNDEFINED`  
In case of deep sleep, reset was not caused by exit from deep sleep.

enumerator `ESP_SLEEP_WAKEUP_ALL`  
Not a wakeup cause, used to disable all wakeup sources with esp_sleep_disable_wakeup_source.

enumerator `ESP_SLEEP_WAKEUP_EXT0`  
Wakeup caused by external signal using RTC_IO.
enumerator `ESP_SLEEP_WAKEUP_EXT1`
  Wakeup caused by external signal using RTC_CNTL.

e enumerator `ESP_SLEEP_WAKEUP_TIMER`
  Wakeup caused by timer.

e enumerator `ESP_SLEEP_WAKEUP_TOUCHPAD`
  Wakeup caused by touchpad.

e enumerator `ESP_SLEEP_WAKEUP_UPL`
  Wakeup caused by ULP program.

e enumerator `ESP_SLEEP_WAKEUP_GPIO`
  Wakeup caused by GPIO (light sleep only on ESP32, S2 and S3)

e enumerator `ESP_SLEEP_WAKEUP_UART`
  Wakeup caused by UART (light sleep only)

e enumerator `ESP_SLEEP_WAKEUP_WIFI`
  Wakeup caused by WIFI (light sleep only)

e enumerator `ESP_SLEEP_WAKEUP_COCPU`
  Wakeup caused by COCPU int.

e enumerator `ESP_SLEEP_WAKEUP_COCPU_TRAP_TRIG`
  Wakeup caused by COCPU crash.

e enumerator `ESP_SLEEP_WAKEUP_BT`
  Wakeup caused by BT (light sleep only)

e enum `esp_sleep_mode_t`
  Sleep mode.
  Values:

  e enumerator `ESP_SLEEP_MODE_LIGHT_SLEEP`
    light sleep mode

  e enumerator `ESP_SLEEP_MODE_DEEP_SLEEP`
    deep sleep mode

e enum [anonymous]
  Values:

  e enumerator `ESP_ERR_SLEEP_REJECT`

  e enumerator `ESP_ERR_SLEEP_TOO_SHORT_SLEEP_DURATION`
2.10.28  SoC Capabilities

This section lists definitions of the ESP32’s SoC hardware capabilities. These definitions are commonly used in IDF to control which hardware dependent features are supported and thus compiled into the binary.

**Note:** These defines are currently not considered to be part of the public API, and may be changed at any time.

**API Reference**

**Header File**

- components/soc/esp32/include/soc/soc_caps.h

**Macros**

- SOC_CAPS_ECO_VER_MAX
- SOC_ADC_SUPPORTED
- SOC_DAC_SUPPORTED
- SOC_UART_SUPPORTED
- SOC_MCPWM_SUPPORTED
- SOC_GPTIMER_SUPPORTED
- SOC_SDMMC_HOST_SUPPORTED
- SOC_BT_SUPPORTED
- SOC_PCNT_SUPPORTED
- SOC_WIFI_SUPPORTED
- SOC_SDIO_SLAVE_SUPPORTED
- SOC_TWAI_SUPPORTED
- SOC_EMAC_SUPPORTED
- SOC_ulp_SUPPORTED
- SOC_CCOMP_TIMER_SUPPORTED
- SOC_RTC_FAST_MEM_SUPPORTED
SOC_RTC_SLOW_MEM_SUPPORTED
SOC_RTC_MEM_SUPPORTED
SOC_I2S_SUPPORTED
SOC_RMT_SUPPORTED
SOC_SDM_SUPPORTED
SOC_GPSPI_SUPPORTED
SOC_LEDC_SUPPORTED
SOC_I2C_SUPPORTED
SOC_SUPPORT_COEXISTENCE
SOC_AES_SUPPORTED
SOC_MPI_SUPPORTED
SOC_SHA_SUPPORTED
SOC_FLASH_ENC_SUPPORTED
SOC_SECURE_BOOT_SUPPORTED
SOC_TOUCH_SENSOR_SUPPORTED
SOC_BOD_SUPPORTED
SOC_ULP_FSM_SUPPORTED
SOC_DPORT_WORKAROUND
SOC_DPORT_WORKAROUND_DIS_INTERRUPT_LVL
SOC_XTAL_SUPPORT_26M
SOC_XTAL_SUPPORT_40M
SOC_XTAL_SUPPORT_AUTO_DETECT
SOC_ADC_RTC_CTRL_SUPPORTED
< SAR ADC Module
Chapter 2. API Reference

SOC_ADC_DIG_CTRL_SUPPORTED

SOC_ADC_DMA_SUPPORTED

SOC_ADC_DIG_SUPPORTED_UNIT (UNIT)

SOC_ADC_PERIPH_NUM

SOC_ADC_CHANNEL_NUM (PERIPH_NUM)

SOC_ADC_MAX_CHANNEL_NUM

SOC_ADC_ATTEN_NUM
  Digital

SOC_ADC_DIGI_CONTROLLER_NUM

SOC_ADC_PATT_LEN_MAX

SOC_ADC_DIGI_MIN_BITWIDTH

SOC_ADC_DIGI_MAX_BITWIDTH

SOC_ADC_DIGI_RESULTgetBytes

SOC_ADC_DIGI_DATA_BYTES_PER_CONV

SOC_ADC_SAMPLE_FREQ_THRES_HIGH

SOC_ADC_SAMPLE_FREQ_THRES_LOW
  RTC

SOC_ADC_RTC_MIN_BITWIDTH

SOC_ADC_RTC_MAX_BITWIDTH

SOC_SHARED_IDCACHE_SUPPORTED

SOC_IDCACHE_PER_CORE

SOC_CPU_CORES_NUM

SOC_CPU_INTR_NUM

SOC_CPU_HAS_FPU

SOC_CPU_BREAKPOINTS_NUM
Chapter 2. API Reference

SOC_CPU_WATCHPOINTS_NUM

SOC_CPU_WATCHPOINT_SIZE

SOC_DAC_CHAN_NUM

SOC_DAC_RESOLUTION

SOC_DAC_DMA_16BIT_ALIGN

SOC_GPIO_PORT

SOC_GPIO_PIN_COUNT

SOC_GPIO_VALID_GPIO_MASK

SOC_GPIO_VALID_OUTPUT_GPIO_MASK

SOC_GPIO_VALID_DIGITAL_IO_PAD_MASK

SOC_I2C_NUM

SOC_I2C_FIFO_LEN
   I2C hardware FIFO depth

SOC_I2C_CMD_REG_NUM
   Number of I2C command registers

SOC_I2C_SUPPORT_SLAVE

SOC_I2C_SUPPORT_APB

SOC_I2S_NUM

SOC_I2S_HW_VERSION_1

SOC_I2S_SUPPORTS_APLL

SOC_I2S_SUPPORTS_PLL_F160M

SOC_I2S_SUPPORTS_PDM

SOC_I2S_SUPPORTS_PDM_TX

SOC_I2S_PDM_MAX_TX_LINES
Chapter 2. API Reference

SOC_I2S_SUPPORTEDS_PDM_RX
SOC_I2S_PDM_MAX_RX_LINES
SOC_I2S_SUPPORTEDS_ADC_DAC
SOC_I2S_SUPPORTEDS_ADC
SOC_I2S_SUPPORTEDS_DAC
SOC_I2S_SUPPORTEDS_LCD_CAMERA
SOC_I2S_TRANS_SIZE_ALIGN_WORD
SOC_I2S_LCD_I80_VARIANT
SOC_LCD_I80_SUPPORTED
   Intel 8080 LCD is supported
SOC_LCD_I80_BUSES
   Both I2S0/1 have LCD mode
SOC_LCD_I80_BUS_WIDTH
   Intel 8080 bus width
SOC_LEDC_HAS_TIMER_SPECIFIC_MUX
SOC_LEDC_SUPPORT_APB_CLOCK
SOC_LEDC_SUPPORT_REF_TICK
SOC_LEDC_SUPPORT_HS_MODE
SOC_LEDC_CHANNEL_NUM
SOC_LEDC_TIMER_BIT_WIDTH
SOC_MCPWM_GROUPS
   2 MCPWM groups on the chip (i.e., the number of independent MCPWM peripherals)
SOC_MCPWM_TIMERS_PER_GROUP
   The number of timers that each group has.
SOC_MCPWM_OPERATORS_PER_GROUP
   The number of operators that each group has.
**SOC_MCPWM_COMPARATORS_PER_OPERATOR**
The number of comparators that each operator has.

**SOC_MCPWM_GENERATORS_PER_OPERATOR**
The number of generators that each operator has.

**SOC_MCPWM_TRIGGERS_PER_OPERATOR**
The number of triggers that each operator has.

**SOC_MCPWM_GPIO_FAULTS_PER_GROUP**
The number of GPIO fault signals that each group has.

**SOC_MCPWM_CAPTURE_TIMERS_PER_GROUP**
The number of capture timers that each group has.

**SOC_MCPWM_CAPTURE_CHANNELS_PER_TIMER**
The number of capture channels that each capture timer has.

**SOC_MCPWM_GPIO_SYNCHROS_PER_GROUP**
The number of GPIO synchros that each group has.

**SOC_MMU_PERIPH_NUM**

**SOC_MMU_LINEAR_ADDRESS_REGION_NUM**

**SOC_MPU_CONFIGURABLE_REGIONS_SUPPORTED**

**SOC_MPU_MIN_REGION_SIZE**

**SOC_MPU_REGIONS_MAX_NUM**

**SOC_MPU_REGION_RO_SUPPORTED**

**SOC_MPU_REGION_WO_SUPPORTED**

**SOC_PCNT_GROUPS**

**SOC_PCNT_UNITS_PER_GROUP**

**SOC_PCNT_CHANNELS_PER_UNIT**

**SOC_PCNT_THRES_POINT_PER_UNIT**

**SOC_RMT_GROUPS**

One RMT group
Chapter 2. API Reference

**SOC_RMT_TX_CANDIDATES_PER_GROUP**
Number of channels that capable of Transmit in each group

**SOC_RMT_RX_CANDIDATES_PER_GROUP**
Number of channels that capable of Receive in each group

**SOC_RMT_CHANNELS_PER_GROUP**
Total 8 channels

**SOC_RMT_MEM_WORDS_PER_CHANNEL**
Each channel owns 64 words memory

**SOC_RMT_SUPPORT_REF_TICK**
Support set REF_TICK as the RMT clock source

**SOC_RMT_SUPPORT_APB**
Support set APB as the RMT clock source

**SOC_RMT_CHANNEL_CLK_INDEPENDENT**
Can select different source clock for each channel

**SOC_RTCIO_PIN_COUNT**

**SOC_RTCIO_INPUT_OUTPUT_SUPPORTED**

**SOC_RTCIO_HOLD_SUPPORTED**

**SOC_RTCIO_WAKE_SUPPORTED**

**SOC_SDM_GROUPS**

**SOC_SDM_CHANNELS_PER_GROUP**

**SOC_SDM_CLK_SUPPORT_APB**

**SOC_SPI_HD_BOTH_INOUT_SUPPORTED**

**SOC_SPI_AS_CS_SUPPORTED**

**SOC_SPI_PERIPH_NUM**

**SOC_SPI_DMA_CHAN_NUM**

**SOC_SPI_PERIPH_CS_NUM** (i)

**SOC_SPI_MAX_CS_NUM**
SOC_SPI_SUPPORT_CLK_APB
SOC_SPI_MAXIMUM_BUFFER_SIZE
SOC_SPI_MAX_PRE_DIVIDER
SOC_MEMSPI_SRC_FREQ_80M_SUPPORTED
SOC_MEMSPI_SRC_FREQ_40M_SUPPORTED
SOC_MEMSPI_SRC_FREQ_26M_SUPPORTED
SOC_MEMSPI_SRC_FREQ_20M_SUPPORTED
SOC_SPI_PERIPH_SUPPORT_MULTILINE_MODE(spi_host)

SOC_TIMER_GROUPS
SOC_TIMER_GROUP_TIMERS_PER_GROUP
SOC_TIMER_GROUP_COUNTER_BIT_WIDTH
SOC_TIMER_GROUP_TOTAL_TIMERS
SOC_TIMER_GROUP_SUPPORT_APB

SOC_TOUCH_VERSION_1
   Hardware version of touch sensor

SOC_TOUCH_SENSOR_NUM

SOC_TOUCH_PAD_MEASURE_WAIT_MAX
   The timer frequency is 8Mhz, the max value is 0xff

SOC_TOUCH_PAD_THRESHOLD_MAX
   If set touch threshold max value, The touch sensor can’t be in touched status

SOC_TWAI_CONTROLLER_NUM

SOC_TWAI_BRP_MIN

SOC_TWAI_BRP_MAX

SOC_TWAI_CLK_SUPPORT_APB

SOC_TWAI_SUPPORT_MULTI_ADDRESS_LAYOUT
Chapter 2. API Reference

SOC_UART_NUM

SOC_UART_SUPPORT_APB_CLK
Support APB as the clock source

SOC_UART_SUPPORT_REF_TICK
Support REF_TICK as the clock source

SOC_UART_FIFO_LEN
The UART hardware FIFO length

SOC_UART_BITRATE_MAX
Max bit rate supported by UART

SOC_SPIRAM_SUPPORTED

SOC_SPI_MEM_SUPPORT_CONFIG_GPIO_BY_EFUSE

SOC_SHA_SUPPORT_PARALLEL_ENG

SOC_SHA_SUPPORT_SHA1

SOC_SHA_SUPPORT_SHA256

SOC_SHA_SUPPORT_SHA384

SOC_SHA_SUPPORT_SHA512

SOC_RSA_MAX_BIT_LEN

SOC_AES_SUPPORT_AES_128

SOC_AES_SUPPORT_AES_192

SOC_AES_SUPPORT_AES_256

SOC_SECURE_BOOT_V1

SOC_EFUSE_SECURE_BOOT_KEY_DIGESTS

SOC_FLASH_ENCRYPTED_XTS_AES_BLOCK_MAX

SOC_PHY_DIG_REGS_MEM_SIZE

SOC_PM_SUPPORT_EXT0_WAKEUP
Chapter 2. API Reference

SOC_PM_SUPPORT_EXT1_WAKEUP

SOC_PM_SUPPORT_EXT_WAKEUP
    Compatible to the old version of IDF

SOC_PM_SUPPORT_TOUCH_SENSOR_WAKEUP
    Supports waking up from touch pad trigger

SOC_PM_SUPPORT_RTC_PERIPH_PD

SOC_PM_SUPPORT_RTC_FAST_MEM_PD

SOC_PM_SUPPORT_RTC_SLOW_MEM_PD

SOC_PM_SUPPORT_RC_FAST_PD

SOC_PM_SUPPORT_VDDSDIO_PD

SOC_PM_SUPPORT_MODEM_PD
    Modem here includes wifi and btdm

SOC_CONFIGURABLE_VDDSDIO_SUPPORTED

SOC_CLK_APLL_SUPPORTED

SOC_APLL_MULTIPLIER_OUT_MIN_HZ

SOC_APLL_MULTIPLIER_OUT_MAX_HZ

SOC_APLL_MIN_HZ

SOC_APLL_MAX_HZ

SOC_CLK_RC_FAST_D256_SUPPORTED

SOC_RTC_SLOW_CLK_SUPPORT_RC_FAST_D256

SOC_CLK_RC_FAST_SUPPORT_CALIBRATION

SOC_CLK_XTAL32K_SUPPORTED
    Support to connect an external low frequency crystal

SOC_SDMMC_USE_IOMUX

SOC_SDMMC_NUM_SLOTS
Chapter 2. API Reference

SOC_WIFI_WAPI_SUPPORT
Support WAPI

SOC_WIFI_CSI_SUPPORT
Support CSI

SOC_WIFI_MESH_SUPPORT
Support WIFI MESH

SOC_WIFI_SUPPORT_VARIABLE_BEACON_WINDOW
Support delta early time for rf phy on/off

SOC_WIFI_NAN_SUPPORT
Support WIFI Aware (NAN)

SOC_BLE_SUPPORTED
Support Bluetooth Low Energy hardware

SOC_BLE_MESH_SUPPORTED
Support BLE MESH

SOC_BT_CLASSIC_SUPPORTED
Support Bluetooth Classic hardware

SOC_BLE_DEVICE_PRIVACY_SUPPORTED
Support BLE device privacy mode

SOC_BLUFI_SUPPORTED
Support BLUFI

SOC_ULP_HAS_ADC

SOC_PHY_COMBO_MODULE
Support Wi-Fi, BT and BLE

2.10.29 System Time

Overview

ESP32 uses two hardware timers for the purpose of keeping system time. System time can be kept by using either one or both of the hardware timers depending on the application’s purpose and accuracy requirements for system time. The two hardware timers are:

- **RTC timer**: This timer allows time keeping in various sleep modes, and can also persist time keeping across any resets (with the exception of power-on resets which reset the RTC timer). The frequency deviation depends on the RTC Timer Clock Sources and affects the accuracy only in sleep modes, in which case the time will be measured at 6.6667 μs resolution.
High-resolution timer: This timer is not available in sleep modes and will not persist over a reset, but has greater accuracy. The timer uses the APB_CLK clock source (typically 80 MHz), which has a frequency deviation of less than ±10 ppm. Time will be measured at 1 μs resolution.

The possible combinations of hardware timers used to keep system time are listed below:

- RTC and high-resolution timer (default)
- RTC
- High-resolution timer
- None

It is recommended that users stick to the default option as it provides the highest accuracy. However, users can also select a different setting via the CONFIG_NEWLIB_TIME_SYSCALL configuration option.

RTC Timer Clock Sources

The RTC timer has the following clock sources:

- Internal 150 kHz RC oscillator (default): Features the lowest Deep-sleep current consumption and no dependence on any external components. However, the frequency stability of this clock source is affected by temperature fluctuations, so time may drift in both Deep-sleep and Light-sleep modes.
- External 32 kHz crystal: Requires a 32 kHz crystal to be connected to the 32K_XP and 32K_XN pins. This source provides a better frequency stability at the expense of a slightly higher (by 1 μA) Deep-sleep current consumption.
- External 32 kHz oscillator at 32K_XN pin: Allows using 32 kHz clock generated by an external circuit. The external clock signal must be connected to the 32K_XN pin. The amplitude should be less than 1.2 V for sine wave signal and less than 1 V for square wave signal. Common mode voltage should be in the range of 0.1 < Vcm < 0.5xVamp, where Vamp stands for signal amplitude. In this case, the 32K_XN pin cannot be used as a GPIO pin.
- Internal 8.5 MHz oscillator, divided by 256 (~33 kHz): Provides better frequency stability than the Internal 150 kHz RC oscillator at the expense of a higher (by 5 μA) Deep-sleep current consumption. It also does not require external components.

The choice depends on your requirements for system time accuracy and power consumption in sleep modes. To modify the RTC clock source, set CONFIG_RTC_CLK_SRC in project configuration.

More details about the wiring requirements for the external crystal or external oscillator, please refer to ESP32 Hardware Design Guidelines.

Get Current Time

To get the current time, use the POSIX function gettimeofday(). Additionally, you can use the following standard C library functions to obtain time and manipulate it:

```c
gettimeofday
time
asctime
clock
ctime
difftime
gmtime
localtime
mktime
strftime
adjtime*
```

To stop smooth time adjustment and update the current time immediately, use the POSIX function settimeofday().

If you need to obtain time with one second resolution, use the following code snippet:
**Chapter 2. API Reference**

```c
#include <time.h>
#include <string.h>
#include <sys/time.h>

void SetCurrentTime() {
    time_t now;
    struct tm timeinfo;

    time(&now);
    // Set timezone to China Standard Time
    setenv("TZ", "CST-8", 1);
    tzset();

    localtime_r(&now, &timeinfo);
    strftime(strftime_buf, sizeof(strftime_buf), "%c", &timeinfo);
    ESP_LOGI(TAG, "The current date/time in Shanghai is: %s", strftime_buf);
}
```

If you need to obtain time with one microsecond resolution, use the code snippet below:

```c
#include <sys/time.h>

void GetTimeWithMicrosecondResolution() {
    struct timeval tv_now;
    gettimeofday(&tv_now, NULL);
    int64_t time_us = (int64_t)tv_now.tv_sec * 1000000L + (int64_t)tv_now.tv_usec;
}
```

### SNTP Time Synchronization

To set the current time, you can use the POSIX functions `settimeofday()` and `adjtime()`. They are used internally in the lwIP SNTP library to set current time when a response from the NTP server is received. These functions can also be used separately from the lwIP SNTP library.

Some lwIP APIs, including SNTP functions, are not thread safe, so it is recommended to use `esp_netif component` when interacting with SNTP module.

To initialize a particular SNTP server and also start the SNTP service, simply create a default SNTP server configuration with a particular server name, then call `esp_netif_sntp_init()` to register that server and start the SNTP service.

```c
esp_sntp_config_t config = ESP_NETIF_SNTP_DEFAULT_CONFIG("pool.ntp.org");
esp_netif_sntp_init(&config);
```

This code automatically performs time synchronization once a reply from the SNTP server is received. Sometimes it is useful to wait until the time gets synchronized, `esp_netif_sntp_sync_wait()` can be used for this purpose:

```c
if (esp_netif_sntp_sync_wait(pdMS_TO_TICKS(10000)) != ESP_OK) {
    printf("Failed to update system time within 10s timeout");
}
```

To configure multiple NTP servers (or use more advanced settings, such as DHCP provided NTP servers), please refer to the detailed description of SNTP API in `esp_netif` documentation.

The lwIP SNTP library could work in one of the following sync modes:

- **SNTP_SYNC_MODE_IMMED** (default): Updates system time immediately upon receiving a response from the SNTP server after using `settimeofday()`.
- **SNTP_SYNC_MODE_SMOOTH**: Updates time smoothly by gradually reducing time error using the function `adjtime()`. If the difference between the SNTP response time and system time is more than 35 minutes, update system time immediately by using `settimeofday()`.

If you want to choose the **SNTP_SYNC_MODE_SMOOTH** mode, please set the `esp_sntp_config::smooth` to `true` in the SNTP configuration struct. Otherwise (and by default) the **SNTP_SYNC_MODE_IMMED** mode will be used.

For setting a callback function that is called when time gets synchronized, use the `esp_sntp_config::sync_cb` field in the configuration struct.

An application with this initialization code will periodically synchronize the time. The time synchronization period is determined by `CONFIG_LWIP_SNTP_UPDATE_DELAY` (the default value is one hour). To modify the variable,
set `CONFIG_LWIP_SNTP_UPDATE_DELAY` in project configuration.

A code example that demonstrates the implementation of time synchronization based on the lwIP SNTP library is provided in the `protocols/sntp` directory.

Note that it’s also possible to use lwIP API directly, but care must be taken to thread safety. Here we list the thread-safe APIs:

- `sntp_set_time_sync_notification_cb()` can be used to set a callback function that will notify of the time synchronization process.
- `sntp_get_sync_status()` and `sntp_set_sync_status()` can be used to get/set time synchronization status.
- `sntp_set_sync_mode()` can be used to set the synchronization mode.
- `esp_sntp_setoperatingmode()` sets the preferred operating mode.
- `esp_sntp_init()` initializes SNTP module.
- `esp_sntp_setservername()` configures one SNTP server.

**Timezones**

To set the local timezone, use the following POSIX functions:

1. Call `setenv()` to set the `TZ` environment variable to the correct value based on the device location. The format of the time string is the same as described in the GNU libc documentation (although the implementation is different).
2. Call `tzset()` to update C library runtime data for the new timezone.

Once these steps are completed, call the standard C library function `localtime()`, and it will return the correct local time taking into account the timezone offset and daylight saving time.

**Year 2036 and 2038 Overflow Issues**

**SNTP/NTP 2036 Overflow** SNTP/NTP timestamps are represented as 64-bit unsigned fixed point numbers, where the first 32 bits represent the integer part, and the last 32 bits represent the fractional part. The 64-bit unsigned fixed point number represents the number of seconds since 00:00 on 1st of January 1900, thus SNTP/NTP times will overflow in the year 2036.

To address this issue, lifetime of the SNTP/NTP timestamps has been extended by convention by using the MSB (bit 0 by convention) of the integer part to indicate time ranges between years 1968 to 2104 (see RFC2030 for more details). This convention is implemented in lwIP library SNTP module. Therefore SNTP-related functions in ESP-IDF are future-proof until year 2104.

**Unix Time 2038 Overflow** Unix time (type `time_t`) was previously represented as a 32-bit signed integer, leading to an overflow in year 2038 (i.e., Y2K38 issue). To address the Y2K38 issue, ESP-IDF uses a 64-bit signed integer to represent `time_t` starting from release v5.0, thus deferring `time_t` overflow for another 292 billion years.

**API Reference**

**Header File**

- `components/lwip/include/apps/esp_sntp.h`

**Functions**

```c
void sntp_sync_time (struct timeval *tv)
```

This function updates the system time.

This is a weak-linked function. It is possible to replace all SNTP update functionality by placing a `sntp_sync_time()` function in the app firmware source. If the default implementation is used, calling `sntp_set_sync_mode()` allows the time synchronization mode to be changed to instant or smooth. If a callback
function is registered via sntp_set_time_sync_notification_cb(), it will be called following time synchroniza-

tion.

    Parameters tv – Time received from SNTP server.

    void sntp_set_sync_mode (sntp_sync_mode_t sync_mode)

    Set the sync mode.

    Modes allowed: SNTP_SYNC_MODE_IMMED and SNTP_SYNC_MODE_SMOOTH.

    Parameters sync_mode – Sync mode.

    sntp_sync_mode_t sntp_get_sync_mode (void)

    Get set sync mode.

    Returns SNTP_SYNC_MODE_IMMED: Update time immediately.

    SNTP_SYNC_MODE_SMOOTH: Smooth time updating.

    sntp_sync_status_t sntp_get_sync_status (void)

    Get status of time sync.

    After the update is completed, the status will be returned as SNTP_SYNC_STATUS_COMPLETED. After

    that, the status will be reset to SNTP_SYNC_STATUS_RESET. If the update operation is not completed yet,

    the status will be SNTP_SYNC_STATUS_RESET. If a smooth mode was chosen and the synchronization is

    still continuing (adjtime works), then it will be SNTP_SYNC_STATUS_IN_PROGRESS.

    Returns SNTP_SYNC_STATUS_RESET: Reset status. SNTP_SYNC_STATUS_COMPLETED:

    Time is synchronized. SNTP_SYNC_STATUS_IN_PROGRESS: Smooth time sync in

    progress.

    void sntp_set_sync_status (sntp_sync_status_t sync_status)

    Set status of time sync.

    Parameters sync_status – status of time sync (see sntp_sync_status_t)

    void sntp_set_time_sync_notification_cb (sntp_time_sync_callback_t callback)

    Set a callback function for time synchronization notification.

    Parameters callback – a callback function

    void sntp_set_sync_interval (uint32_t interval_ms)

    Set the sync interval of SNTP operation.

    Note: SNTPv4 RFC 4330 enforces a minimum sync interval of 15 seconds. This sync interval will be used in

    the next attempt update time through SNTP. To apply the new sync interval call the sntp_restart() function,

    otherwise, it will be applied after the last interval expired.

    Parameters interval_ms – The sync interval in ms. It cannot be lower than 15 seconds, oth-

    erwise 15 seconds will be set.

    uint32_t sntp_get_sync_interval (void)

    Get the sync interval of SNTP operation.

    Returns the sync interval

    bool sntp_restart (void)

    Restart SNTP.

    Returns True - Restart False - SNTP was not initialized yet

    void esp_sntp_setoperatingmode (esp_sntp_operatingmode_t operating_mode)

    Sets SNTP operating mode. The mode has to be set before init.

    Parameters operating_mode – Desired operating mode

    void esp_sntp_init (void)

    Init and start SNTP service.
void **esp_sntp_stop**(void)

Stops SNTP service.

void **esp_sntp_setserver**(u8_t idx, const ip_addr_t *addr)

Sets SNTP server address.

**Parameters**
- **idx** - Index of the server
- **addr** - IP address of the server

void **esp_sntp_setservername**(u8_t idx, const char *server)

Sets SNTP hostname.

**Parameters**
- **idx** - Index of the server
- **server** - Name of the server

const char **esp_sntp_getservername**(u8_t idx)

Gets SNTP server name.

**Parameters**
- **idx** - Index of the server

Returns
Name of the server

const ip_addr_t **esp_sntp_getserver**(u8_t idx)

Get SNTP server IP.

**Parameters**
- **idx** - Index of the server

Returns
IP address of the server

bool **esp_sntp_enabled**(void)

Checks if sntp is enabled.

**Returns**
true if sntp module is enabled

static inline void **sntp_setoperatingmode**(u8_t operating_mode)

if not build within lwip, provide translating inlines, that will warn about thread safety

static inline void **sntp_servermode_dhcp**(int set_servers_from_dhcp)

static inline void **sntp_setservername**(u8_t idx, const char *server)

static inline void **sntp_init**(void)

static inline const char **sntp_getservername**(u8_t idx)

static inline const ip_addr_t **sntp_getserver**(u8_t idx)

**Macros**

**esp_sntp_sync_time**

Aliases for esp_sntp prefixed API (inherently thread safe)

**esp_sntp_set_sync_mode**

**esp_sntp_get_sync_mode**

**esp_sntp_get_sync_status**

**esp_sntp_set_sync_status**
**Chapter 2. API Reference**

`esp_sntp_set_time_sync_notification_cb`

`esp_sntp_set_sync_interval`

`esp_sntp_get_sync_interval`

`esp_sntp_restart`

`SNTP_OPMODE_POLL`

---

**Type Definitions**

typedef void (*sntp_sync_time_cb_t)(struct timeval *tv)

SNTP callback function for notifying about time sync event.

**Param** tv Time received from SNTP server.

---

**Enumerations**

gen enum sntp_sync_mode_t

SNTP time update mode.

Values:

enumerator `SNTP_SYNC_MODE_IMMED`

Update system time immediately when receiving a response from the SNTP server.

enumerator `SNTP_SYNC_MODE_SMOOTH`

Smooth time updating. Time error is gradually reduced using adjtime function. If the difference between
SNTP response time and system time is large (more than 35 minutes) then update immediately.

gen enum sntp_sync_status_t

SNTP sync status.

Values:

enumerator `SNTP_SYNC_STATUS_RESET`

enumerator `SNTP_SYNC_STATUS_COMPLETED`

enumerator `SNTP_SYNC_STATUS_IN_PROGRESS`


gen enum esp_sntp_operatingmode_t

SNTP operating modes per lwip SNTP module.

Values:

enumerator `ESP_SNTP_OPMODE_POLL`

enumerator `ESP_SNTP_OPMODE_LISTENONLY`
2.10.30 The himem allocation API

Overview

The ESP32 can access external SPI RAM transparently, so you can use it as normal memory in your program code. However, because the address space for external memory is limited in size, only the first 4MiB can be used as such. Access to the remaining memory is still possible, however this needs to go through a bankswitching scheme controlled by the himem API.

Specifically, what is implemented by the himem API is a bankswitching scheme. Hardware-wise, the 4MiB region for external SPI RAM is mapped into the CPU address space by a MMU, which maps a configurable 32K bank/page of external SPI RAM into each of the 32K pages in the 4MiB region accessed by the CPU. For external memories that are <=4MiB, this MMU is configured to unity mapping, effectively mapping each CPU address 1-to-1 to the external SPI RAM address.

In order to use the himem API, you have to enable it in the menuconfig using `CONFIG_SPIRAM_BANKSWITCH_ENABLE`, as well as set the amount of banks reserved for this in `CONFIG_SPIRAM_BANKSWITCH_RESERVE`. This decreases the amount of external memory allocated by functions like `malloc()`, but it allows you to use the himem api to map any of the remaining memory into the reserved banks. The himem API is more-or-less an abstraction of the bankswitching scheme: it allows you to claim one or more banks of address space (called ‘regions’ in the API) as well as one or more of banks of memory to map into the ranges.

Example

An example doing a simple memory test of the high memory range is available in esp-idf: `system/himem`

API Reference

Header File

- components/esp_psram/include/esp32/himem.h

Functions

`esp_err_t esp_himem_alloc(size_t size, esp_himem_handle_t *handle_out)`

Allocate a block in high memory.

Parameters

- `size` - Size of the to-be-allocated block, in bytes. Note that this needs to be a multiple of the external RAM mmu block size (32K).
- `handle_out` - [out] Handle to be returned

Returns

- ESP_OK if succesful
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_INVALID_SIZE if size is not a multiple of 32K

`esp_err_t esp_himem_alloc_map_range(size_t size, esp_himem_rangehandle_t *handle_out)`

Allocate a memory region to map blocks into.

This allocates a contiguous CPU memory region that can be used to map blocks of physical memory into.

Parameters

- `size` - Size of the range to be allocated. Note this needs to be a multiple of the external RAM mmu block size (32K).
- `handle_out` - [out] Handle to be returned

Returns

- ESP_OK if succesful
- ESP_ERR_NO_MEM if out of memory or address space
- ESP_ERR_INVALID_SIZE if size is not a multiple of 32K
**esp_err_t esp_himem_map**(esp_himem_handle_t handle, esp_himem_rangehandle_t range, size_t ram_offset, size_t range_offset, size_t len, int flags, void **out_ptr)

Map a block of high memory into the CPUs address space.

This effectively makes the block available for read/write operations.

**Note:** The region to be mapped needs to have offsets and sizes that are aligned to the SPI RAM MMU block size (32K)

**Parameters**
- **handle** – Handle to the block of memory, as given by esp_himem_alloc
- **range** – Range handle to map the memory in
- **ram_offset** – Offset into the block of physical memory of the block to map
- **range_offset** – Offset into the address range where the block will be mapped
- **len** – Length of region to map
- **flags** – One of ESP_HIMEM_MAPFLAG_*
- **out_ptr** – [out] Pointer to variable to store resulting memory pointer in

**Returns**
- ESP_OK if the memory could be mapped
  - ESP_ERR_INVALID_ARG if offset, range or len aren’t MMU-block-aligned (32K)
  - ESP_ERR_INVALID_SIZE if the offsets/lengths don’t fit in the allocated memory or range
  - ESP_ERR_INVALID_STATE if a block in the selected ram offset/length is already mapped, or if a block in the selected range offset/length already has a mapping.

**esp_err_t esp_himem_free**(esp_himem_handle_t handle)

Free a block of physical memory.

This clears out the associated handle making the memory available for re-allocation again. This will only succeed if none of the memory blocks currently have a mapping.

**Parameters**
- **handle** – Handle to the block of memory, as given by esp_himem_alloc

**Returns**
- ESP_OK if the memory is successfully freed
  - ESP_ERR_INVALID_ARG if the handle still is (partially) mapped

**esp_err_t esp_himem_free_map_range**(esp_himem_rangehandle_t handle)

Free a mapping range.

This clears out the associated handle making the range available for re-allocation again. This will only succeed if none of the range blocks currently are used for a mapping.

**Parameters**
- **handle** – Handle to the range block, as given by esp_himem_alloc_map_range

**Returns**
- ESP_OK if the memory is successfully freed
  - ESP_ERR_INVALID_ARG if the handle still is (partially) mapped to

**esp_err_t esp_himem_unmap**(esp_himem_rangehandle_t range, void *ptr, size_t len)

Unmap a region.

**Parameters**
- **range** – Range handle
- **ptr** – Pointer returned by esp_himem_map
- **len** – Length of the block to be unmapped. Must be aligned to the SPI RAM MMU blocksize (32K)

**Returns**
- ESP_OK if the memory is succesfully unmapped,
  - ESP_ERR_INVALID_ARG if ptr or len are invalid.

**size_t esp_himem_get_phys_size**(void)

Get total amount of memory under control of himem API.

**Returns**
Amount of memory, in bytes
size_t esp_himem_get_free_size (void)
  Get free amount of memory under control of himem API.

  Returns Amount of free memory, in bytes

size_t esp_himem_reserved_area_size (void)
  Get amount of SPI memory address space needed for bankswitching.

  Note: This is also weakly defined in esp32/spiram.c and returns 0 there, so if no other function in this file is
  used, no memory is reserved.

  Returns Amount of reserved area, in bytes

Macros

ESP_HIMEM_BLKSZ

ESP_HIMEM_MAPFLAG_RO
  Indicates that a mapping will only be read from. Note that this is unused for now.

Type Definitions

typedef struct esp_himem_ramdatal esp_himem_handle_t

typedef struct esp_himem_rangedatal esp_himem_rangehandle_t

2.10.31 ULP Coprocessor programming

The Ultra Low Power (ULP) coprocessor is a simple finite state machine (FSM) which is designed to perform
measurements using the ADC, temperature sensor, and external I2C sensors, while the main processors are in deep sleep
mode. The ULP coprocessor can access the RTC_SLOW_MEM memory region, and registers in the RTC_CNTL,
RTC_IO, and SARADC peripherals. The ULP coprocessor uses fixed-width 32-bit instructions, 32-bit memory
addressing, and has 4 general-purpose 16-bit registers. This coprocessor is referred to as ULP FSM in ESP-IDF.

Installing the Toolchain

The ULP FSM coprocessor code is written in assembly and compiled using the binutils-esp32ulp toolchain.
If you have already set up ESP-IDF with CMake build system according to the Getting Started Guide, then the ULP
FSM toolchain will already be installed.

Programming ULP FSM

The ULP FSM can be programmed using the supported instruction set. Alternatively, the ULP FSM coprocessor can
also be programmed using C Macros on the main CPU. Theses two methods are described in the following section:

ESP32 ULP coprocessor instruction set This document provides details about the instructions used by ESP32
ULP FSM coprocessor assembler.
ULP FSM coprocessor has 4 16-bit general purpose registers, labeled R0, R1, R2, R3. It also has an 8-bit counter
register (stage_cnt) which can be used to implement loops. Stage count register is accessed using special instructions.
Chapter 2. API Reference

ULP coprocessor can access 8k bytes of RTC_SLOW_MEM memory region. Memory is addressed in 32-bit word units. It can also access peripheral registers in RTC_CNTL, RTC_IO, and SENS peripherals.

All instructions are 32-bit. Jump instructions, ALU instructions, peripheral register and memory access instructions are executed in 1 cycle. Instructions which work with peripherals (TSENS, ADC, I2C) take variable number of cycles, depending on peripheral operation.

The instruction syntax is case insensitive. Upper and lower case letters can be used and intermixed arbitrarily. This is true both for register names and instruction names.

**Note about addressing** ESP32 ULP FSM coprocessor’s JUMP, ST, LD family of instructions expect the address argument to be expressed in the following way depending on the type of address argument used:

- When the address argument is presented as a label then the instruction expects the address to be expressed as 32-bit words.

Consider the following example program:

```
entry:
  NOP
  NOP
  NOP
  NOP

loop:
  MOVE R1, loop
  JUMP R1
```

When this program is assembled and linked, address of label loop will be equal to 16 (expressed in bytes). However JUMP instruction expects the address stored in register R1 to be expressed in 32-bit words. To account for this common use case, the assembler will convert the address of label loop from bytes to words, when generating the MOVE instruction. Hence, the code generated code will be equivalent to:

```
0000  NOP
0004  NOP
0008  NOP
000c  NOP
0010  MOVE R1, 4
0014  JUMP R1
```

- The other case is when the argument of MOVE instruction is not a label but a constant. In this case assembler will use the value as is, without any conversion:

```
.set  val, 0x10
MOVE R1, val
```

In this case, value loaded into R1 will be 0x10.

However, when an immediate value is used as an offset in LD and ST instructions, the assembler considers the address argument in bytes and converts it to 32-bit words before executing the instruction:

```
ST R1, R2, 4 // offset = 4 bytes; Mem[R2 + 4 / 4] = R1
```

In this case, the value in R1 is stored at the memory location pointed by [R2 + offset / 4]

Consider the following code:

```
.global array
array: .long 0
       .long 0
       .long 0
       .long 0

MOVE R1, array
MOVE R2, 0x1234
ST R2, R1, 0 // write value of R2 into the first array element, 
              // i.e. array[0]
```

(continues on next page)
ST R2, R1, 4 // write value of R2 into the second array element
// (4 byte offset), i.e. array[1]
ADD R1, R1, 2 // this increments address by 2 words (8 bytes)
ST R2, R1, 0 // write value of R2 into the third array element,
// i.e. array[2]

Note about instruction execution time  ULP coprocessor is clocked from RTC_FAST_CLK, which is normally
derived from the internal 8MHz oscillator. Applications which need to know exact ULP clock frequency can calibrate
it against the main XTAL clock:

```c
#include "soc/rtc.h"

// calibrate 8M/256 clock against XTAL, get 8M/256 clock period
uint32_t rtc_8md256_period = rtc_clk_cal(RTC_CAL_8MD256, 100);
uint32_t rtc_fast_freq_hz = 1000000ULL * (1 << RTC_CLK_CAL_FRACT) * 256 / rtc_-
->8md256_period;
```

ULP coprocessor needs certain number of clock cycles to fetch each instruction, plus certain number of cycles to
execute it, depending on the instruction. See description of each instruction below for details on the execution time.
Instruction fetch time is:

- 2 clock cycles — for instructions following ALU and branch instructions.
- 4 clock cycles — in other cases.

Note that when accessing RTC memories and RTC registers, ULP coprocessor has lower priority than the main
CPUs. This means that ULP coprocessor execution may be suspended while the main CPUs access same memory
region as the ULP.

The detailed description of all instructions is presented below:

NOP - no operation

Syntax  NOP

Operands  None

Cycles  2 cycle to execute, 4 cycles to fetch next instruction

Description  No operation is performed. Only the PC is incremented.

Example:

```
1: NOP
```

ADD - Add to register

Syntax  ADD Rdst, Rsrc1, Rsrc2

ADD Rdst, Rsrc1, imm

Operands

-  Rdst - Register R[0..3]
-  Rsrc1 - Register R[0..3]
-  Rsrc2 - Register R[0..3]
-  imm - 16-bit signed value

Cycles  2 cycles to execute, 4 cycles to fetch next instruction

Description  The instruction adds source register to another source register or to a 16-bit signed value and stores the
result in the destination register.

Examples:
1: ADD R1, R2, R3 // R1 = R2 + R3
2: Add R1, R2, 0x1234 // R1 = R2 + 0x1234
3: .set value1, 0x03 // constant value1=0x03
   Add R1, R2, value1 // R1 = R2 + value1
4: .global label // declaration of variable label
   add R1, R2, label // R1 = R2 + label
   ...
   label: nop // definition of variable label

SUB - Subtract from register

Syntax SUB Rdst, Rscl, Rsr2
  SUB Rdst, Rscl, imm

Operands
  • Rdst - Register R[0..3]
  • Rscl - Register R[0..3]
  • Rsr2 - Register R[0..3]
  • Imm - 16-bit signed value

Cycles 2 cycles to execute, 4 cycles to fetch next instruction
Description The instruction subtracts the source register from another source register or subtracts a 16-bit signed value from a source register, and stores the result to the destination register.

Examples:
1: SUB R1, R2, R3 // R1 = R2 - R3
2: sub R1, R2, 0x1234 // R1 = R2 - 0x1234
3: .set value1, 0x03 // constant value1=0x03
   SUB R1, R2, value1 // R1 = R2 - value1
4: .global label // declaration of variable label
   SUB R1, R2, label // R1 = R2 - label
   ...
   label: nop // definition of variable label

AND - Bitwise logical AND of two operands

Syntax AND Rdst, Rscl, Rsr2
  AND Rdst, Rscl, imm

Operands
  • Rdst - Register R[0..3]
  • Rscl - Register R[0..3]
  • Rsr2 - Register R[0..3]
  • Imm - 16-bit signed value

Cycles 2 cycles to execute, 4 cycles to fetch next instruction
Description The instruction does a bitwise logical AND of a source register and another source register or a 16-bit signed value and stores the result to the destination register.

Examples:
1: AND R1, R2, R3 // R1 = R2 & R3
2: AND R1, R2, 0x1234 // R1 = R2 & 0x1234
3: .set value1, 0x03 // constant value1=0x03
   AND R1, R2, value1 // R1 = R2 & value1

(continues on next page)
4:  .global label // declaration of variable label
    AND R1, R2, label // R1 - R2 & label
    ...
label:  nop // definition of variable label

OR - Bitwise logical OR of two operands

Syntax  OR Rdst, Rsrl, Rsr2
       OR Rdst, Rsrl, imm

Operands
   • Rdst - Register R[0..3]
   • Rsrl - Register R[0..3]
   • Rsr2 - Register R[0..3]
   • Imm - 16-bit signed value

Cycles  2 cycles to execute, 4 cycles to fetch next instruction

Description  The instruction does a bitwise logical OR of a source register and another source register or a 16-bit signed value and stores the result to the destination register.

Examples:
1:  OR R1, R2, R3 // R1 - R2 || R3
2:  OR R1, R2, 0x1234 // R1 - R2 || 0x1234
3:  .set value1, 0x03 // constant value1=0x03
    OR R1, R2, value1 // R1 - R2 || value1
4:  .global label // declaration of variable label
    OR R1, R2, label // R1 - R2 || label
    ...
label:  nop // definition of variable label

LSH - Logical Shift Left

Syntax  LSH Rdst, Rsrl, Rsr2
       LSH Rdst, Rsrl, imm

Operands
   • Rdst - Register R[0..3]
   • Rsrl - Register R[0..3]
   • Rsr2 - Register R[0..3]
   • Imm - 16-bit signed value

Cycles  2 cycles to execute, 4 cycles to fetch next instruction

Description  The instruction does a logical shift to left of the source register by the number of bits from another source register or a 16-bit signed value and stores the result to the destination register.

Note:  Shift operations which are greater than 15 bits will have an undefined result.

Examples:
1:  LSH R1, R2, R3 // R1 - R2 << R3
2:  LSH R1, R2, 0x03 // R1 - R2 << 0x03
3:  .set value1, 0x03 // constant value1=0x03
    LSH R1, R2, value1 // R1 - R2 << value1

(continues on next page)
RSH - Logical Shift Right

Syntax  
RSH  
\[ Rdst, Rsrc1, Rsrc2 \]

\[ Rdst, Rsrc1, imm \]

Operands  
\( Rdst \) - Register R[0..3]  
\( Rsrc1 \) - Register R[0..3]  
\( Rsrc2 \) - Register R[0..3]  
\( Imm \) - 16-bit signed value

Cycles  
2 cycles to execute, 4 cycles to fetch next instruction

Description  
The instruction does a logical shift to right of a source register by the number of bits from another source register or a 16-bit signed value and stores the result to the destination register.

Note:  
Shift operations which are greater than 15 bits will have an undefined result.

Examples:

1:  
RSH R1, R2, R3  
// R1 = R2 >> R3

2:  
RSH R1, R2, 0x03  
// R1 = R2 >> 0x03

3:  
.set value1, 0x03  
RSH R1, R2, value1  
// R1 = R2 >> value1

4:  
.global label  
// declaration of variable label

label: nop  
// definition of variable label

MOVE – Move to register

Syntax  
MOVE  
\[ Rdst, Rsrc \]

\[ Rdst, imm \]

Operands  
\( Rdst \) – Register R[0..3]  
\( Rsrc \) – Register R[0..3]  
\( Imm \) – 16-bit signed value

Cycles  
2 cycles to execute, 4 cycles to fetch next instruction

Description  
The instruction moves the value from the source register or a 16-bit signed value to the destination register.

Note:  
Note that when a label is used as an immediate, the address of the label will be converted from bytes to words. This is because LD, ST, and JUMP instructions expect the address register value to be expressed in words rather than bytes. See the section Note about addressing for more details.

Examples:

1:  
MOVE R1, R2  
// R1 = R2

2:  
MOVE R1, 0x03  
// R1 = 0x03

3:  
.set value1, 0x03  
MOVE R1, value1  
// R1 = value1

(continues on next page)
4:    .global label // declaration of label
MOVE  R1, label // R1 = address_of(label) / 4
...  
label:  nop // definition of label

ST – Store data to the memory

Syntax  ST Rs, Rd, offset

Operands
- Rs – Register R[0..3], holds the 16-bit value to store
- Rd – Register R[0..3], address of the destination, in 32-bit words
- Offset – 13-bit signed value, offset in bytes

Cycles  4 cycles to execute, 4 cycles to fetch next instruction

Description  The instruction stores the 16-bit value of Rs to the lower half-word of memory with address Rd+offset. The upper half-word is written with the current program counter (PC) (expressed in words, shifted left by 5 bits) OR’ed with Rd (0..3):

\[
\text{MEM[Rd} + \text{offset} / 4][31:0] = \{\text{PC}[10:0], 3'b0, \text{Rd}, \text{Rs}[15:0]\}
\]

The application can use the higher 16 bits to determine which instruction in the ULP program has written any particular word into memory.

Note:  Note that the offset specified in bytes is converted to a 32-bit word offset before execution. See the section Note about addressing for more details.

Examples:

1:  ST  R1, R2, 0x12 // MEM[R2 + 0x12 / 4] = R1

2:  .data  // Data section definition
    Addr1:  .word 123 // Define label Addr1 16 bit
            .set offs, 0x00 // Define constant offs
            .text  // Text section definition
    MOVE  R1, 1 // R1 = 1
    MOVE  R2, Addr1 // R2 = Addr1
    ST  R1, R2, offs // MEM[R2 + 0 / 4] = R1
    // MEM[Addr1 + 0] will be 32'h600001

LD – Load data from the memory

Syntax  LD Rd, Rs, offset

Operands
- Rd – Register R[0..3], destination
- Rs – Register R[0..3], holds address of destination, in 32-bit words
- Offset – 13-bit signed value, offset in bytes

Cycles  4 cycles to execute, 4 cycles to fetch next instruction

Description  The instruction loads the lower 16-bit half-word from memory with address [Rs+offset/4] into the destination register Rd:

\[
\text{Rd}[15:0] = \text{MEM[Rs} + \text{offset} / 4][15:0]
\]

Note:  Note that the offset specified in bytes is converted to a 32-bit word offset before execution. See the section Note about addressing for more details.

Examples:
Chapter 2. API Reference

1:  LD   R1, R2, 0x12  // R1 = MEM[R2 + 0x12 / 4]

2:  .data  // Data section definition
    Addr1: .word 123  // Define label Addr1 16 bit
    .set   offs, 0x00  // Define constant offs
    .text  // Text section definition
    MOVE  R1, 1  // R1 = 1
    MOVE  R2, Addr1  // R2 = Addr1 / 4 (address of label is... converted into words)
    LD   R1, R2, offs  // R1 = MEM[R2 + 0]
                           // R1 will be 123

JUMP – Jump to an absolute address

Syntax  JUMP Rdst
        JUMP ImmAddr
        JUMP Rdst, Condition
        JUMP ImmAddr, Condition

Operands
•  Rdst  – Register R[0..3] containing address to jump to (expressed in 32-bit words)
•  ImmAddr – 13 bits address (expressed in bytes), aligned to 4 bytes
•  Condition:
  –  EQ  – jump if last ALU operation result was zero
  –  OV  – jump if last ALU has set overflow flag

Cycles  2 cycles to execute, 2 cycles to fetch next instruction

Description  The instruction makes jump to the specified address. Jump can be either unconditional or based on an ALU flag.

Examples:

1:  JUMP  R1  // Jump to address in R1 (address in R1 is in... 32-bit words)

2:  JUMP  0x120, EQ  // Jump to address 0x120 (in bytes) if ALU...

(result is zero

3:  JUMP  label  // Jump to label

... label: nop  // Definition of label

4:  .global label  // Declaration of global label
    MOVE  R1, label  // R1 = label (value loaded into R1 is in words)
    JUMP  R1  // Jump to label

... label: nop  // Definition of label

JUMPR – Jump to a relative offset (condition based on R0)

Syntax  JUMPR Step, Threshold, Condition

Operands
•  Step  – relative shift from current position, in bytes
•  Threshold – threshold value for branch condition
•  Condition:
  –  EQ (equal) – jump if value in R0 == threshold
  –  LT (less than) – jump if value in R0 < threshold
  –  LE (less or equal) – jump if value in R0 <= threshold
  –  GT (greater than) – jump if value in R0 > threshold
  –  GE (greater or equal) – jump if value in R0 >= threshold

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Cycles

Conditions $LT$, $GE$, $LE$ and $GT$: 2 cycles to execute, 2 cycles to fetch next instruction

Conditions $LE$ and $GT$ are implemented in the assembler using one JUMPR instruction:

```c
// JUMPR target, threshold, GT is implemented as:
    JUMPR target, threshold+1, GE
// JUMPR target, threshold, LE is implemented as:
    JUMPR target, threshold + 1, LT
```

Conditions $EQ$ is implemented in the assembler using two JUMPR instructions:

```c
// JUMPR target, threshold, EQ is implemented as:
    JUMPR next, threshold + 1, GE
    JUMPR target, threshold, GE
next:
```

Description The instruction makes a jump to a relative address if condition is true. Condition is the result of comparison of R0 register value and the threshold value.

Examples:

1: pos: JUMPR 16, 20, GE // Jump to address (position + 16 bytes) if
    --value in R0 >= 20

2: // Down counting loop using R0 register
    MOVE R0, 16  // load 16 into R0
    label: SUB R0, R0, 1 // R0--
    NOP  // do something
    JUMPR label, 1, GE // jump to label if R0 >= 1

JUMPS – Jump to a relative address (condition based on stage count)

Syntax JUMPS Step, Threshold, Condition

Operands
- **Step** – relative shift from current position, in bytes
- **Threshold** – threshold value for branch condition
- **Condition**:
  - $EQ$ (equal) – jump if value in stage_cnt == threshold
  - $LT$ (less than) – jump if value in stage_cnt < threshold
  - $LE$ (less or equal) – jump if value in stage_cnt <= threshold
  - $GT$ (greater than) – jump if value in stage_cnt > threshold
  - $GE$ (greater or equal) – jump if value in stage_cnt >= threshold

Cycles

Conditions $LE$, $LT$, $GE$: 2 cycles to execute, 2 cycles to fetch next instruction

Conditions $EQ$, $GT$ are implemented in the assembler using two JUMPS instructions:

```c
// JUMPS target, threshold, EQ is implemented as:
    JUMPS next, threshold, LT
    JUMPS target, threshold, LE
next:
// JUMPS target, threshold, GT is implemented as:
```

(continues on next page)
Therefore the execution time will depend on the branches taken: either 2 cycles to execute + 2 cycles to fetch, or 4 cycles to execute + 4 cycles to fetch.

**Description** The instruction makes a jump to a relative address if condition is true. Condition is the result of comparison of count register value and threshold value.

**Examples:**

1: pos: JUMPS 16, 20, EQ // Jump to (position + 16 bytes) if stage_cnt <= 20

2: // Up counting loop using stage count register
   STAGE_RST // set stage_cnt to 0
   label: STAGE_INC 1 // stage_cnt++
   NOP // do something
   JUMPS label, 16, LT // jump to label if stage_cnt < 16

**STAGE_RST** – Reset stage count register

**Syntax** STAGE_RST

**Operands** No operands

**Description** The instruction sets the stage count register to 0

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Examples:**

1: STAGE_RST // Reset stage count register

**STAGE_INC** – Increment stage count register

**Syntax** STAGE_INC Value

**Operands**

- Value – 8 bits value

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction increments the stage count register by the given value.

**Examples:**

1: STAGE_INC 10 // stage_cnt += 10

2: // Up counting loop example:
   STAGE_RST // set stage_cnt to 0
   label: STAGE_INC 1 // stage_cnt++
   NOP // do something
   JUMPS label, 16, LT // jump to label if stage_cnt < 16

**STAGE_DEC** – Decrement stage count register

**Syntax** STAGE_DEC Value

**Operands**

- Value – 8 bits value

**Cycles** 2 cycles to execute, 4 cycles to fetch next instruction

**Description** The instruction decrements the stage count register by the given value.

**Examples:**
Chapter 2. API Reference

1: STAGE_DEC 10 // stage_cnt -- 10;
2: // Down counting loop example
STAGE_RST // set stage_cnt to 0
STAGE_INC 16 // increment stage_cnt to 16
label: STAGE_DEC 1 // stage_cnt--;
NOP // do something
JUMPS label, 0, GT // jump to label if stage_cnt > 0

HALT – End the program

Syntax HALT
Operands No operands
Cycles 2 cycles to execute
Description The instruction halts the ULP coprocessor and restarts the ULP wakeup timer, if it is enabled.

Examples:

1: HALT // Halt the coprocessor

WAKE – Wake up the chip

Syntax WAKE
Operands No operands
Cycles 2 cycles to execute, 4 cycles to fetch next instruction
Description The instruction sends an interrupt from the ULP coprocessor to the RTC controller.
   • If the SoC is in deep sleep mode, and ULP wakeup is enabled, this causes the SoC to wake up.
   • If the SoC is not in deep sleep mode, and ULP interrupt bit (RTC_CNTL_ULP_CP_INT_ENA) is set in RTC_CNTL_INT_ENA_REG register, RTC interrupt will be triggered.

Note: Note that before using WAKE instruction, ULP program may need to wait until RTC controller is ready to wake up the main CPU. This is indicated using RTC_CNTL_RDY_FOR_WAKEUP bit of RTC_CNTL_LOW_POWER_ST_REG register. If WAKE instruction is executed while RTC_CNTL_RDY_FOR_WAKEUP is zero, it has no effect (wake up does not occur). If the WAKE instruction is intended to be used while the main CPU is not in sleep mode then the RTC_CNTL_MAIN_STATE_IN_IDLE (bit 27) of RTC_CNTL_LOW_POWER_ST_REG can be used to check whether main CPU is in normal mode or sleep mode.

Examples:

1: is_rdy_for_wakeup: // Read RTC_CNTL_RDY_FOR_WAKEUP bit
READ_RTC_FIELD(RTC_CNTL_LOW_POWER_ST_REG, RTC_CNTL_RDY_FOR_WAKEUP)
AND r0, r0, 1
JUMP is_rdy_for_wakeup, eq // Retry until the bit is set
WAKE // Trigger wake up
REG_WR 0x006, 24, 24, 0 // Stop ULP timer (clear RTC_CNTL_ULP_CP_
→SLP_TIMER_EN)
HALT // Stop the ULP program
// After these instructions, SoC will wake up,
// and ULP will not run again until started by the main program.
1: check_wakeup: // Read RTC_CNTL_RDY_FOR_WAKEUP and RTC_
→CNTL_MAIN_STATE_IN_IDLE bit
READ_RTC_REG(RTC_CNTL_LOW_POWER_ST_REG, 27, 1)
MOVE r1, r0 // Copy result in to r1
READ_RTC_FIELD(RTC_CNTL_LOW_POWER_ST_REG, RTC_CNTL_RDY_FOR_WAKEUP)
OR r0, r0, r1

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SLEEP – set ULP wakeup timer period

Syntax SLEEP sleep_reg

Operands
- sleep_reg – 0..4, selects one of SENS_ULP_CP_SLEEP_CYCx_REG registers.

Cycles 2 cycles to execute, 4 cycles to fetch next instruction

Description The instruction selects which of the SENS_ULP_CP_SLEEP_CYCx_REG (x = 0..4) register values is to be used by the ULP wakeup timer as wakeup period. By default, the value from SENS_ULP_CP_SLEEP_CYC0_REG is used.

Examples:

1: SLEEP 1 // Use period set in SENS_ULP_CP_SLEEP_CYC1_REG
2: .set sleep_reg, 4 // Set constant
   SLEEP sleep_reg // Use period set in SENS_ULP_CP_SLEEP_CYC4_REG

WAIT – wait some number of cycles

Syntax WAIT Cycles

Operands
- Cycles – number of cycles for wait

Cycles 2 + Cycles cycles to execute, 4 cycles to fetch next instruction

Description The instruction delays for given number of cycles.

Examples:

1: WAIT 10 // Do nothing for 10 cycles
2: .set wait_cnt, 10 // Set a constant
   WAIT wait_cnt // wait for 10 cycles

ADC – do measurement with ADC

Syntax
- ADC Rdst, Sar_sel, Mux
- ADC Rdst, Sar_sel, Mux, 0 — deprecated form

Operands
- Rdst – Destination Register R[0..3], result will be stored to this register
- Sar_sel – Select ADC: 0 = SARADC1, 1 = SARADC2
- Mux – Enable ADC channel. Channel number is [Mux-1]. If the user passes Mux value 1, then ADC channel 0 gets used.

Cycles 23 + max(1, SAR_AMP_WAIT1) + max(1, SAR_AMP_WAIT2) + max(1, SAR_AMP_WAIT3) + SARx_SAMPLE_CYCLE + SARx_SAMPLE_BIT cycles to execute, 4 cycles to fetch next instruction

Description The instruction makes measurements from ADC.

Examples:

.. only:: esp32

1: ADC R1, 0, 1 // Measure value using ADC1 channel 0 and store result into R1
I2C_RD - read single byte from I2C slave

Syntax
• I2C_RD Sub_addr, High, Low, Slave_sel

Operands
• Sub_addr - Address within the I2C slave to read.
• High, Low - Define range of bits to read. Bits outside of [High, Low] range are masked.
• Slave_sel - Index of I2C slave address to use.

Cycles Execution time mostly depends on I2C communication time. 4 cycles to fetch next instruction.

Description I2C_RD instruction reads one byte from I2C slave with index Slave_sel. Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == Slave_sel. 8 bits of read result is stored into R0 register.

Examples:
1: I2C_RD 0x10, 7, 0, 0 // Read byte from sub-address 0x10 of...
→slave with address set in SENS_I2C_SLAVE_ADDR0

I2C_WR - write single byte to I2C slave

Syntax
• I2C_WR Sub_addr, Value, High, Low, Slave_sel

Operands
• Sub_addr - Address within the I2C slave to write.
• Value - 8-bit value to be written.
• High, Low - Define range of bits to write. Bits outside of [High, Low] range are masked.
• Slave_sel - Index of I2C slave address to use.

Cycles Execution time mostly depends on I2C communication time. 4 cycles to fetch next instruction.

Description I2C_WR instruction writes one byte to I2C slave with index Slave_sel. Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == Slave_sel.

Examples:
1: I2C_WR 0x20, 0x33, 7, 0, 1 // Write byte 0x33 to sub-address...
→0x20 of slave with address set in SENS_I2C_SLAVE_ADDR1.

REG_RD – read from peripheral register

Syntax REG_RD Addr, High, Low

Operands
• Addr - Register address, in 32-bit words
• High - Register end bit number
• Low - Register start bit number

Cycles 4 cycles to execute, 4 cycles to fetch next instruction

Description The instruction reads up to 16 bits from a peripheral register into a general purpose register: R0 = REG[Addr][High:Low].

This instruction can access registers in RTC_CNTL, RTC_IO, SENS, and RTC_I2C peripherals. Address of the register, as seen from the ULP, can be calculated from the address of the same register on the DPORT bus as follows:

addr_ulp = (addr_dport - DR_REG_RTC_CNTL_BASE) / 4

Examples:
1: REG_RD 0x120, 7, 4 // load 4 bits: R0 = {12'b0, REG[0x120][7:4]}

REG_WR – write to peripheral register
**Syntax**  
\texttt{REG\_WR \textit{Addr}, High, Low, Data}

**Operands**
- \textit{Addr} – Register address, in 32-bit words.
- \textit{High} – Register end bit number
- \textit{Low} – Register start bit number
- \textit{Data} – Value to write, 8 bits

**Cycles**  
8 cycles to execute, 4 cycles to fetch next instruction

**Description**  
The instruction writes up to 8 bits from an immediate data value into a peripheral register:
\[
\text{REG}[\text{Addr}[\text{High:Low}]} = \text{data}.
\]

This instruction can access registers in RTC\_CNTL, RTC\_IO, SENS, and RTC\_I2C peripherals. Address of the register, as seen from the ULP, can be calculated from the address of the same register on the DPORT bus as follows:

\[
\text{addr\_ulp} = (\text{addr\_dport} - \text{DR\_REG\_RTC\_CNTL\_BASE}) / 4
\]

**Examples:**

1: \text{REG\_WR \ 0x120, 7, 0, 0x10} // set 8 bits: \text{REG[0x120][7:0]} = 0x10

**Convenience macros for peripheral registers access**  
ULP source files are passed through C preprocessor before the assembler. This allows certain macros to be used to facilitate access to peripheral registers.

Some existing macros are defined in \texttt{soc/soc\_ulp.h} header file. These macros allow access to the fields of peripheral registers by their names. Peripheral registers names which can be used with these macros are the ones defined in \texttt{soc/rtc\_cntl\_reg.h}, \texttt{soc/rtc\_io\_reg.h}, \texttt{soc/sens\_reg.h}, and \texttt{soc/rtc\_i2c\_reg.h}.

\texttt{READ\_RTC\_REG(rtc\_reg, low\_bit, bit\_width)}  
Read up to 16 bits from rtc\_reg[low\_bit + bit\_width - 1 : low\_bit] into R0. For example:

```c
#include "soc/soc_ulp.h"
#include "soc/rtc\_cntl\_reg.h"

/* Read 16 lower bits of RTC\_CNTL\_TIME0\_REG into R0 */
READ\_RTC\_REG(RTC\_CNTL\_TIME0\_REG, 0, 16)
```

\texttt{READ\_RTC\_FIELD(rtc\_reg, field)}  
Read from a field in rtc\_reg into R0, up to 16 bits. For example:

```c
#include "soc/soc_ulp.h"
#include "soc/sens\_reg.h"

/* Read 8-bit SENS\_TSENS\_OUT field of SENS\_SAR\_SLAVE\_ADDR3\_REG into R0 */
READ\_RTC\_FIELD(SENS\_SAR\_SLAVE\_ADDR3\_REG, SENS\_TSENS\_OUT)
```

\texttt{WRITE\_RTC\_REG(rtc\_reg, low\_bit, bit\_width, value)}  
Write immediate value into rtc\_reg[low\_bit + bit\_width - 1 : low\_bit], bit\_width <= 8. For example:

```c
#include "soc/soc_ulp.h"
#include "soc/rtc\_io\_reg.h"

/* Set BIT(2) of RTC\_GPIO\_OUT\_DATA\_W1TS field in RTC\_GPIO\_OUT\_W1TS\_REG */
WRITE\_RTC\_REG(RTC\_GPIO\_OUT\_W1TS\_REG, RTC\_GPIO\_OUT\_DATA\_W1TS\_S + 2, 1, 1)
```

\texttt{WRITE\_RTC\_FIELD(rtc\_reg, field, value)}  
Write immediate value into a field in rtc\_reg, up to 8 bits. For example:

```c
#include "soc/soc_ulp.h"
#include "soc/rtc\_cntl\_reg.h"

/* Set RTC\_CNTL\_ULP\_CP\_SLP\_TIMER\_EN field of RTC\_CNTL\_STATE0\_REG to 0 */
WRITE\_RTC\_FIELD(RTC\_CNTL\_STATE0\_REG, RTC\_CNTL\_ULP\_CP\_SLP\_TIMER\_EN, 0)
```
Programming ULP FSM coprocessor using C macros (legacy)  In addition to the existing binutils port for the ESP32 ULP coprocessor, it is possible to generate programs for the ULP FSM coprocessor by embedding assembly-like macros into an ESP32 application. Here is an example how this can be done:

```c
const ulp_insn_t program[] = {
    I_MOVI(R3, 16),      // R3 <- 16
    I_LD(R0, R3, 0),     // R0 <- RTC_SLOW_MEM[R3 + 0]
    I_LD(R1, R3, 1),     // R1 <- RTC_SLOW_MEM[R3 + 1]
    I_ADDR(R2, R0, R1),  // R2 <- R0 + R1
    I_ST(R2, R3, 2),     // R2 -> RTC_SLOW_MEM[R2 + 2]
    I_HALT()
};
size_t load_addr = 0;
size_t size = sizeof(program) / sizeof(ulp_insn_t);
ulp_process_macros_and_load(load_addr, program, &size);
ulp_run(load_addr);
```

The program array is an array of `ulp_insn_t`, i.e. ULP coprocessor instructions. Each `I_XXX` preprocessor define translates into a single 32-bit instruction. Arguments of these preprocessor defines can be register numbers (R0 — R3) and literal constants. See the API reference section at the end of this guide for descriptions of instructions and arguments they take.

**Note:** Because some of the instruction macros expand to inline function calls, defining such array in global scope will cause the compiler to produce an “initializer element is not constant” error. To fix this error, move the definition of instructions array into local scope.

**Note:** Load, store and move instructions use **addresses expressed in 32-bit words**. Address 0 corresponds to the first word of `RTC_SLOW_MEM`. This is different to how address arguments are handled in assembly code of the same instructions. See the section **Note about addressing** for more details for reference.

To generate branch instructions, special `M_` preprocessor defines are used. `M_LABEL` define can be used to define a branch target. Label identifier is a 16-bit integer. `M_Bxxx` defines can be used to generate branch instructions with target set to a particular label.

**Implementation note:** these `M_` preprocessor defines will be translated into two `ulp_insn_t` values: one is a token value which contains label number, and the other is the actual instruction. `ulp_process_macros_and_load` function resolves the label number to the address, modifies the branch instruction to use the correct address, and removes the extra `ulp_insn_t` token which contains the label number.

Here is an example of using labels and branches:

```c
const ulp_insn_t program[] = {
    I_MOVI(R0, 34),      // R0 <- 34
    M_LABEL(),           // label_1
    I_MOVI(R1, 32),      // R1 <- 32
    I_LD(R1, R1, 0),     // R1 <- RTC_SLOW_MEM[R1]
    I_MOVI(R2, 33),      // R2 <- 33
    I_LD(R2, R2, 0),     // R2 <- RTC_SLOW_MEM[R2]
    I_SUBR(R3, R1, R2),  // R3 <- R1 - R2
    I_ST(R3, R0, 0),     // R3 -> RTC_SLOW_MEM[R0 + 0]
    I_ADDI(R0, R0, 1),   // R0++
    M_BL(1, 64),         // if (R0 < 64) goto label_1
    I_HALT(),
};
RTC_SLOW_MEM[32] = 42;
RTC_SLOW_MEM[33] = 18;
size_t load_addr = 0;
size_t size = sizeof(program) / sizeof(ulp_insn_t);
```

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Chapter 2. API Reference

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```c
ulp_process_macros_and_load(load_addr, program, size);
ulp_run(load_addr);
```

API Reference

**Header File**

- components/ulp/ulp_fsm/include/esp32/ulp.h

**Functions**

`static inline uint32_t SOC_REG_TO_ULP_PERIPH_SEL(uint32_t reg)`

Map SoC peripheral register to periph_sel field of RD_REG and WR_REG instructions.

**Parameters**

- `reg` — peripheral register in RTC_CNTL_, RTC_IO_, SENS_, RTC_I2C peripherals.

**Returns**

periph_sel value for the peripheral to which this register belongs.

**Unions**

`union ulp_insn`

```c
#include <ulp.h>
```

Instruction format structure.

All ULP instructions are 32 bit long. This union contains field layouts used by all of the supported instructions. This union also includes a special “macro” instruction layout. This is not a real instruction which can be executed by the CPU. It acts as a token which is removed from the program by the `ulp_process_macros_and_load` function.

These structures are not intended to be used directly. Preprocessor definitions provided below fill the fields of these structure with the right arguments.

**Public Members**

```c
uint32_t cycles
```

Number of cycles to sleep

TBD, cycles used for measurement

```c
uint32_t unused
```

Unused

```c
uint32_t opcode
```

Opcode (OPCODE_DELAY)

Opcode (OPCODE_ST)

Opcode (OPCODE_LD)

Opcode (OPCODE_HALT)

Opcode (OPCODE_BRANCH)

Opcode (OPCODE_ALU)

Opcode (OPCODE_WR_REG)

Opcode (OPCODE_RD_REG)
Opcode (OPCODE_ADC)
Opcode (OPCODE_TSENS)
Opcode (OPCODE_I2C)
Opcode (OPCODE_END)
Opcode (OPCODE_MACRO)

**struct ulp_insn::[anonymous] delay**
Format of DELAY instruction

uint32_t **dreg**
Register which contains data to store
Register where the data should be loaded to
Register which contains target PC, expressed in words (used if .reg == 1)
Destination register
Register where to store ADC result
Register where to store temperature measurement result
Destination register (for SUB_OPCODE_MACRO_LABELPC) >

uint32_t **sreg**
Register which contains address in RTC memory (expressed in words)
Register with operand A

uint32_t **unused1**
Unused

uint32_t **offset**
Offset to add to sreg
Absolute value of target PC offset w.r.t. current PC, expressed in words

uint32_t **unused2**
Unused

uint32_t **sub_opcode**
Sub opcode (SUB_OPCODE_ST)
Sub opcode (SUB_OPCODE_BX)
Sub opcode (SUB_OPCODE_B)
Sub opcode (SUB_OPCODE_BS)
Sub opcode (SUB_OPCODE_ALU_REG)
Sub opcode (SUB_OPCODE_ALU_CNT)
Sub opcode (SUB_OPCODE_ALU_IMM)
Sub opcode (SUB_OPCODE_WAKEUP)
Sub opcode (SUB_OPCODE_SLEEP)

SUB_OPCODE_MACRO_LABEL or SUB_OPCODE_MACRO_LABELPC or SUB_OPCODE_MACRO_BRANCH or
struct ulp_insn::[anonymous] st
  Format of ST instruction

struct ulp_insn::[anonymous] ld
  Format of LD instruction

struct ulp_insn::[anonymous] halt
  Format of HALT instruction

uint32_t addr
  Target PC, expressed in words (used if .reg == 0)
  Address within either RTC_CNTL, RTC_IO, or SARADC

uint32_t reg
  Target PC in register (1) or immediate (0)

uint32_t type
  Jump condition (BX_JUMP_TYPE_xxx)

struct ulp_insn::[anonymous] bx
  Format of BRANCH instruction (absolute address)

uint32_t imm
  Immediate value to compare against
  Immediate value of operand
  Immediate value of operand B

uint32_t cmp
  Comparison to perform: B_CMP_L or B_CMP_GE
  Comparison to perform: JUMPS_LT, JUMPS_GE or JUMPS_LE

uint32_t sign
  Sign of target PC offset: 0: positive, 1: negative

struct ulp_insn::[anonymous] b
  Format of BRANCH instruction (relative address, conditional on R0)

struct ulp_insn::[anonymous] bs
  Format of BRANCH instruction (relative address, conditional on the stage counter)

uint32_t treg
  Register with operand B

uint32_t sel
  Operation to perform, one of ALU_SEL_xxx
  Operation to perform, one of ALU_SEL_Sxxx
struct `ulp_insn`::[anonymous] `alu_reg`
  Format of ALU instruction (both sources are registers)

struct `ulp_insn`::[anonymous] `alu_reg_s`
  Format of ALU instruction (stage counter and an immediate)

struct `ulp_insn`::[anonymous] `alu_imm`
  Format of ALU instruction (one source is an immediate)

`uint32_t` `periph_sel`
  Select peripheral: RTC_CNTL (0), RTC_IO (1), SARADC (2)

`uint32_t` `data`
  8 bits of data to write
  8 bits of data for write operation

`uint32_t` `low`
  Low bit

`uint32_t` `high`
  High bit

struct `ulp_insn`::[anonymous] `wr_reg`
  Format of WR_REG instruction

struct `ulp_insn`::[anonymous] `rd_reg`
  Format of RD_REG instruction

`uint32_t` `mux`
  Select SARADC pad (mux + 1)

`uint32_t` `sar_sel`
  Select SARADC0 (0) or SARADC1 (1)

struct `ulp_insn`::[anonymous] `adc`
  Format of ADC instruction

`uint32_t` `wait_delay`
  Cycles to wait after measurement is done

`uint32_t` `reserved`
  Reserved, set to 0

struct `ulp_insn`::[anonymous] `tsens`
  Format of TSENS instruction

`uint32_t` `i2c_addr`
  I2C slave address
uint32_t low_bits
    low bit of range for write operation (lower bits are masked)

uint32_t high_bits
    high bit of range for write operation (higher bits are masked)

uint32_t i2c_sel
    index of slave address register [7:0]

uint32_t rw
    Write (1) or read (0)

struct ulp_insn::[anonymous] i2c
    Format of I2C instruction

uint32_t wakeup
    Set to 1 to wake up chip

struct ulp_insn::[anonymous] end
    Format of END instruction with wakeup

uint32_t cycle_sel
    Select which one of SARADC_ULP_CP_SLEEP_CYCx_REG to get the sleep duration from

struct ulp_insn::[anonymous] sleep
    Format of END instruction with sleep

uint32_t label
    Label number

struct ulp_insn::[anonymous] macro
    Format of tokens used by MACROs

uint32_t instruction
    Encoded instruction for ULP coprocessor

**Macros**

R0
    general purpose register 0

R1
    general purpose register 1

R2
    general purpose register 2

R3
    general purpose register 3
Chapter 2. API Reference

**OPCODE_WR_REG**
Instruction: write peripheral register (RTC_CNTL/RTC_IO/SARADC)

**OPCODE_RD_REG**
Instruction: read peripheral register (RTC_CNTL/RTC_IO/SARADC)

**RD_REG_PERIPH_RTC_CNTL**
Identifier of RTC_CNTL peripheral for RD_REG and WR_REG instructions

**RD_REG_PERIPH_RTC_IO**
Identifier of RTC_IO peripheral for RD_REG and WR_REG instructions

**RD_REG_PERIPH_SENS**
Identifier of SARADC peripheral for RD_REG and WR_REG instructions

**RD_REG_PERIPH_RTC_I2C**
Identifier of RTC_I2C peripheral for RD_REG and WR_REG instructions

**OPCODE_I2C**
Instruction: read/write I2C

**SUB_OPCODE_I2C_RD**
I2C read

**SUB_OPCODE_I2C_WR**
I2C write

**OPCODE_DELAY**
Instruction: delay (nop) for a given number of cycles

**OPCODE_ADC**
Instruction: SAR ADC measurement

**OPCODE_ST**
Instruction: store indirect to RTC memory

**SUB_OPCODE_ST**
Store 32 bits, 16 MSBs contain PC, 16 LSBs contain value from source register

**OPCODE_ALU**
Arithmetic instructions

**SUB_OPCODE_ALU_REG**
Arithmetic instruction, both source values are in register

**SUB_OPCODE_ALU_IMM**
Arithmetic instruction, one source value is an immediate
Chapter 2. API Reference

**SUB_OPCODE_ALU_CNT**
Arithmetic instruction, stage counter and an immediate

**ALU_SEL_ADD**
Addition

**ALU_SEL_SUB**
Subtraction

**ALU_SEL_AND**
Logical AND

**ALU_SEL_OR**
Logical OR

**ALU_SEL_MOV**
Copy value (immediate to destination register or source register to destination register)

**ALU_SEL_LSH**
Shift left by given number of bits

**ALU_SEL_RSH**
Shift right by given number of bits

**ALU_SEL_SINC**
Increment the stage counter

**ALU_SEL_SDEC**
Decrement the stage counter

**ALU_SEL_SRST**
Reset the stage counter

**OPCODE_BRANCH**
Branch instructions

**SUB_OPCODE_BX**
Branch to absolute PC (immediate or in register)

**SUB_OPCODE_BR**
Branch to relative PC, conditional on R0

**SUB_OPCODE_BS**
Branch to relative PC, conditional on the stage counter

**BX_JUMP_TYPE DIRECT**
Unconditional jump
BX_JUMP_TYPE_ZERO
Branch if last ALU result is zero

BX_JUMP_TYPE_OVF
Branch if last ALU operation caused and overflow

SUB_OPCODE_B
Branch to a relative offset

B_CMP_L
Branch if R0 is less than an immediate

B_CMP_GE
Branch if R0 is greater than or equal to an immediate

JUMPS_LT
Branch if the stage counter <

JUMPS_GE
Branch if the stage counter >=

JUMPS_LE
Branch if the stage counter <=

OPCODE_END
Stop executing the program

SUB_OPCODE_END
Stop executing the program and optionally wake up the chip

SUB_OPCODE_SLEEP
Stop executing the program and run it again after selected interval

OPCODE_TSENS
Instruction: temperature sensor measurement. Poor accuracy, not recommended for most use-cases

OPCODE_HALT
Halt the coprocessor

OPCODE_LD
Indirect load lower 16 bits from RTC memory

OPCODE_MACRO
Not a real opcode. Used to identify labels and branches in the program

SUB_OPCODE_MACRO_LABEL
Label macro
**SUB_OPCODE_MACRO_BRANCH**

Branch macro

**SUB_OPCODE_MACRO_LABELPC**

Label pointer macro

**I_DELAY (cycles)**

Delay (nop) for a given number of cycles

**I_HALT ()**

Halt the coprocessor.

This instruction halts the coprocessor, but keeps ULP timer active. As such, ULP program will be restarted again by timer. To stop the program and prevent the timer from restarting the program, use I_END(0) instruction.

**I_WR_REG (reg, low_bit, high_bit, val)**

Write literal value to a peripheral register

reg[high_bit : low_bit] = val This instruction can access RTC_CNTL_, RTC_IO_, SENS_, and RTC_I2C peripheral registers.

**I_RD_REG (reg, low_bit, high_bit)**

Read from peripheral register into R0

R0 = reg[high_bit : low_bit] This instruction can access RTC_CNTL_, RTC_IO_, SENS_, and RTC_I2C peripheral registers.

**I_WR_REG_BIT (reg, shift, val)**

Set or clear a bit in the peripheral register.

Sets bit (1 << shift) of register reg to value val. This instruction can access RTC_CNTL_, RTC_IO_, SENS_, and RTC_I2C peripheral registers.

**I_WAKE ()**

Wake the SoC from deep sleep.

This instruction initiates wake up from deep sleep. Use esp_deep_sleep_enable_ulp_wakeup to enable deep sleep wakeup triggered by the ULP before going into deep sleep. Note that ULP program will still keep running until the I_HALT instruction, and it will still be restarted by timer at regular intervals, even when the SoC is woken up.

To stop the ULP program, use I_HALT instruction.

To disable the timer which start ULP program, use I_END() instruction. I_END instruction clears the RTC_CNTL_ULP_CP_SLP_TIMER_EN_S bit of RTC_CNTL_STATE0_REG register, which controls the ULP timer.

**I_END ()**

Stop ULP program timer.

This is a convenience macro which disables the ULP program timer. Once this instruction is used, ULP program will not be restarted anymore until ulp_run function is called.

ULP program will continue running after this instruction. To stop the currently running program, use I_HALT().

**I_SLEEP_CYCLE_SEL (timer_idx)**

Select the time interval used to run ULP program.

This instructions selects which of the SENS_SLEEP_CYCLES_Sx registers’ value is used by the ULP program timer. When the ULP program stops at I_HALT instruction, ULP program timer start counting. When
the counter reaches the value of the selected SENS_SLEEP_CYCLES_Sx register, ULP program start running again from the start address (passed to the ulp_run function). There are 5 SENS_SLEEP_CYCLES_Sx registers, so 0 <= timer_idx < 5.

By default, SENS_SLEEP_CYCLES_S0 register is used by the ULP program timer.

**I_TSENS (reg_dest, delay)**

Perform temperature sensor measurement and store it into reg_dest.

Delay can be set between 1 and ((1 << 14) - 1). Higher values give higher measurement resolution.

**I_ADC (reg_dest, adc_idx, pad_idx)**

Perform ADC measurement and store result in reg_dest.

- adc_idx selects ADC (0 or 1).
- pad_idx selects ADC pad (0 - 7).

**I_ST (reg_val, reg_addr, offset_)**

Store value from register reg_val into RTC memory.

The value is written to an offset calculated by adding value of reg_addr register and offset_field (this offset is expressed in 32-bit words). 32 bits written to RTC memory are built as follows:

- bits [31:21] hold the PC of current instruction, expressed in 32-bit words
- bits [20:18] = 3’b0
- bits [17:16] reg_addr (0..3)
- bits [15:0] are assigned the contents of reg_val

RTC_SLOW_MEM[addr + offset_] = { insn_PC[10:0], 3’b0, reg_addr, reg_val[15:0] }

**I_LD (reg_dest, reg_addr, offset_)**

Load value from RTC memory into reg_dest register.

Loads 16 LSBs from RTC memory word given by the sum of value in reg_addr and value of offset_.

**I_BL (pc_offset, imm_value)**

Branch relative if R0 less than immediate value.

pc_offset is expressed in words, and can be from -127 to 127 imm_value is a 16-bit value to compare R0 against

**I_BGE (pc_offset, imm_value)**

Branch relative if R0 greater or equal than immediate value.

pc_offset is expressed in words, and can be from -127 to 127 imm_value is a 16-bit value to compare R0 against

**I_BXR (reg_pc)**

Unconditional branch to absolute PC, address in register.

reg_pc is the register which contains address to jump to. Address is expressed in 32-bit words.

**I_BXI (imm_pc)**

Unconditional branch to absolute PC, immediate address.

Address imm_pc is expressed in 32-bit words.

**I_BXZR (reg_pc)**

Branch to absolute PC if ALU result is zero, address in register.

reg_pc is the register which contains address to jump to. Address is expressed in 32-bit words.

**I_BXZI (imm_pc)**

Branch to absolute PC if ALU result is zero, immediate address.

Address imm_pc is expressed in 32-bit words.
Chapter 2. API Reference

I_BXFR (reg_pc)
Branch to absolute PC if ALU overflow, address in register

reg_pc is the register which contains address to jump to. Address is expressed in 32-bit words.

I_BXFI (imm_pc)
Branch to absolute PC if ALU overflow, immediate address

Address imm_pc is expressed in 32-bit words.

I_ADDR (reg_dest, reg_src1, reg_src2)
Addition: dest = src1 + src2

I_SUBR (reg_dest, reg_src1, reg_src2)
Subtraction: dest = src1 - src2

I_ANDR (reg_dest, reg_src1, reg_src2)
Logical AND: dest = src1 & src2

I_ORR (reg_dest, reg_src1, reg_src2)
Logical OR: dest = src1 | src2

I_MOVR (reg_dest, reg_src)
Copy: dest = src

I_LSHR (reg_dest, reg_src, reg_shift)
Logical shift left: dest = src << shift

I_RSHR (reg_dest, reg_src, reg_shift)
Logical shift right: dest = src >> shift

I_ADDI (reg_dest, reg_src, imm_)
Add register and an immediate value: dest = src1 + imm

I_SUBI (reg_dest, reg_src, imm_)
Subtract register and an immediate value: dest = src - imm

I_ANDI (reg_dest, reg_src, imm_)
Logical AND register and an immediate value: dest = src & imm

I_ORI (reg_dest, reg_src, imm_)
Logical OR register and an immediate value: dest = src | imm

I_MOVI (reg_dest, imm_)
Copy an immediate value into register: dest = imm

I_LSHI (reg_dest, reg_src, imm_)
Logical shift left register value by an immediate: dest = src << imm

I_RSHI (reg_dest, reg_src, imm_)
Logical shift right register value by an immediate: dest = val >> imm

M_LABEL (label_num)
Define a label with number label_num.

This is a macro which doesn’t generate a real instruction. The token generated by this macro is removed by ulp_process_macros_and_load function. Label defined using this macro can be used in branch macros defined below.

M_BRANCH (label_num)
Token macro used by M_B and M_BX macros. Not to be used directly.

M_LABELPC (label_num)
Token macro used by M_MOVL macro. Not to be used directly.
**Chapter 2. API Reference**

**M_MOVL**(reg_dest, label_num)

Macro: Move the program counter at the given label into the register. This address can then be used with I_BXR, I_BXZR, I_BXFR, etc.

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**M_BL**(label_num, imm_value)

Macro: branch to label label_num if R0 is less than immediate value.

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**M_BGE**(label_num, imm_value)

Macro: branch to label label_num if R0 is greater or equal than immediate value

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**M_BX**(label_num)

Macro: unconditional branch to label

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**M_BXZ**(label_num)

Macro: branch to label if ALU result is zero

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**M_BXF**(label_num)

Macro: branch to label if ALU overflow

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**I_STAGE_INC**(imm_)

Increment the stage counter by immediate value

**I_STAGE_DEC**(imm_)

Decrement the stage counter by immediate value

**I_STAGE_RST**( )

Reset the stage counter

**M_BSLT**(label_num, imm_value)

Macro: branch to label if the stage counter is less than immediate value

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

**M_BSGE**(label_num, imm_value)

Macro: branch to label if the stage counter is greater than or equal to immediate value

This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.
Chapter 2. API Reference

M_BSLE (label_num, imm_value)
Macro: branch to label if the stage counter is less than or equal to immediate value
This macro generates two ulp_insn_t values separated by a comma, and should be used when defining contents of ulp_insn_t arrays. First value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

M_BSEQ (label_num, imm_value)
Macro: branch to label if the stage counter is equal to immediate value. Implemented using two JUMPS instructions: JUMPS next, imm_value, LT JUMPS label_num, imm_value, LE
This macro generates three ulp_insn_t values separated by commas, and should be used when defining contents of ulp_insn_t arrays. Second value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

M_BSGT (label_num, imm_value)
Macro: branch to label if the stage counter is greater than immediate value. Implemented using two instructions: JUMPS next, imm_value, LE JUMPS label_num, imm_value, GE
This macro generates three ulp_insn_t values separated by commas, and should be used when defining contents of ulp_insn_t arrays. Second value is not a real instruction; it is a token which is removed by ulp_process_macros_and_load function.

I_JUMPS (pc_offset, imm_value, comp_type)
Branch relative if (stage counter [comp_type] [imm_value]) evaluates to true. pc_offset is expressed in words, and can be from -127 to 127 imm_value is an 8-bit value to compare the stage counter against comp_type is the type of comparison to perform: JUMPS_LT (<), JUMPS_GE (>=) or JUMPS_LE (<=)

I_I2C_RW (sub_addr, val, low_bit, high_bit, slave_sel, rw_bit)
Perform an I2C transaction with a slave device. I_I2C_READ and I_I2C_WRITE are provided for convenience, instead of using this directly.
Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == slave_sel. For read operations, 8 bits of read result is stored into R0 register. For write operations, val will be written to sub_addr at [high_bit:low_bit]. Bits outside of this range are masked.

I_I2C_READ (slave_sel, sub_addr)
Read a byte from the sub address of an I2C slave, and store the result in R0.
Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == slave_sel.

I_I2C_WRITE (slave_sel, sub_addr, val)
Write a byte to the sub address of an I2C slave.
Slave address (in 7-bit format) has to be set in advance into SENS_I2C_SLAVE_ADDRx register field, where x == slave_sel.

Compiling the ULP Code
To compile the ULP FSM code as part of the component, the following steps must be taken:

1. The ULP FSM code, written in assembly, must be added to one or more files with .S extension. These files must be placed into a separate directory inside the component directory, for instance, ulp/.

Note: When registering the component (via idf_component_register), this directory should not be added to the SRC_DIRS argument. The logic behind this is that the ESP-IDF build system will compile files found in SRC_DIRS based on their extensions. For .S files, xtensa-esp32-elf-as assembler is used. This is not desirable for ULP FSM assembly files, so the easiest way to achieve the distinction is by placing ULP FSM assembly
files into a separate directory. The ULP FSM assembly source files should also not be added to SRCS for the same reason. See the step below for how to properly add ULP FSM assembly source files.

2. Call `ulp_embed_binary` from the component CMakeLists.txt after registration. For example:

```cmake
...  idf_component_register()
set(ulp_app_name ulp_${COMPONENT_NAME})
set(ulp_s_sources ulp/ulp_assembly_source_file.S)
set(ulp_exp_dep_srcs "ulp_c_source_file.c")
ulp_embed_binary(${ulp_app_name} "${ulp_s_sources}" "${ulp_exp_dep_srcs}")
```

The first argument to `ulp_embed_binary` specifies the ULP FSM binary name. The name specified here will also be used by other generated artifacts such as the ELF file, map file, header file and linker export file. The second argument specifies the ULP FSM assembly source files. Finally, the third argument specifies the list of component source files which include the header file to be generated. This list is needed to build the dependencies correctly and ensure that the generated header file will be created before any of these files are compiled. See the section below for the concept of generated header files for ULP applications.

3. Build the application as usual (e.g. `idf.py app`).

Inside, the build system will take the following steps to build ULP FSM program:

1. **Run each assembly file (foo.S) through the C preprocessor.** This step generates the preprocessed assembly files (foo.ulp.S) in the component build directory. This step also generates dependency files (foo.ulp.d).

2. **Run preprocessed assembly sources through the assembler.** This produces object (foo.ulp.o) and listing (foo.ulp.lst) files. Listing files are generated for debugging purposes and are not used at later stages of the build process.

3. **Run the linker script template through the C preprocessor.** The template is located in components/ulp/ld directory.

4. **Link the object files into an output ELF file** (`ulp_app_name.elf`). The Map file (`ulp_app_name.map`) generated at this stage may be useful for debugging purposes.

5. **Dump the contents of the ELF file into a binary** (`ulp_app_name.bin`) which can then be embedded into the application.

6. **Generate a list of global symbols** (`ulp_app_name.sym`) in the ELF file using `esp32ulp-elf-nm`.

7. **Create an LD export script and a header file** (`ulp_app_name.ld` and `ulp_app_name.h`) containing the symbols from `ulp_app_name.sym`. This is done using the `esp32ulp_mapgen.py` utility.

8. **Add the generated binary to the list of binary files** to be embedded into the application.

### Accessing the ULP FSM Program Variables

Global symbols defined in the ULP FSM program may be used inside the main program. For example, the ULP FSM program may define a variable `measurement_count` which will define the number of ADC measurements the program needs to make before waking up the chip from deep sleep:

```c
#global measurement_count
measurement_count: .long 0

// later, use measurement_count
move r3, measurement_count
ld r3, r3, 0
```

The main program needs to initialize this variable before the ULP program is started. The build system makes this possible by generating the `$\{ULP\_APP\_NAME\}.h` and `$\{ULP\_APP\_NAME\}.ld` files which define the global symbols present in the ULP program. Each global symbol defined in the ULP program is included in these files and are prefixed with `ulp_`. 

---

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The header file contains the declaration of the symbol:

```c
extern uint32_t ulp_measurement_count;
```

Note that all symbols (variables, arrays, functions) are declared as `uint32_t`. For functions and arrays, take the address of the symbol and cast it to the appropriate type.

The generated linker script file defines the locations of symbols in RTC_SLOW_MEM:

```asm
PROVIDE ( ulp_measurement_count = 0x50000060 );
```

To access the ULP program variables from the main program, the generated header file should be included using an `#include` statement. This will allow the ULP program variables to be accessed as regular variables:

```c
#include "ulp_app_name.h"
```

```c
// later
void init_ulp_vars() {
    ulp_measurement_count = 64;
}
```

Note that the ULP FSM program can only use the lower 16 bits of each 32-bit word in RTC memory, because the registers are 16-bit, and there is no instruction to load from the high part of the word. Likewise, the ULP store instruction writes register values into the lower 16 bits of the 32-bit word in RTC memory. The upper 16 bits are written with a value which depends on the address of the store instruction, thus when reading variables written by the ULP coprocessor, the main application needs to mask the upper 16 bits, e.g.:

```c
printf("Last measurement value: \%d\n", ulp_last_measurement & UINT16_MAX);
```

Starting the ULP FSM Program

To run a ULP FSM program, the main application needs to load the ULP program into RTC memory using the `ulp_load_binary()` function, and then start it using the `ulp_run()` function.

Note that the Enable Ultra Low Power (ULP) Coprocessor option must be enabled in menuconfig to work with ULP. To select the type of ULP to be used, the ULP Co-processor type option must be set. To reserve memory for the ULP, the RTC slow memory reserved for coprocessor option must be set to a value big enough to store ULP code and data. If the application components contain multiple ULP programs, then the size of the RTC memory must be sufficient to hold the largest one.

Each ULP program is embedded into the ESP-IDF application as a binary blob. The application can reference this blob and load it in the following way (suppose ULP_APP_NAME was defined to `ulp_app_name`):

```c
extern const uint8_t bin_start[] asm("_binary_ulp_app_name_bin_start");
extern const uint8_t bin_end[] asm("_binary_ulp_app_name_bin_end");

void start_ulp_program() {
    ESP_ERROR_CHECK( ulp_load_binary(
        0 // load address, set to 0 when using default linker scripts
        bin_start,
        (bin_end - bin_start) / sizeof(uint32_t)) );
}
```

Once the program is loaded into RTC memory, the application can start it by passing the address of the entry point to the `ulp_run` function:

```c
ESP_ERROR_CHECK( ulp_run(&ulp_entry - RTC_SLOW_MEM) );
```

Declaration of the entry point symbol comes from the generated header file mentioned above, `$\{ULP_APP_NAME\}.h`. In the assembly source of the ULP FSM application, this symbol must be marked as `.global`:
ESP32 ULP program flow

ESP32 ULP coprocessor is started by a timer. The timer is started once `ulp_run()` is called. The timer counts a number of RTC_SLOW_CLK ticks (by default, produced by an internal 150 kHz RC oscillator). The number of ticks is set using SENS_ULP_CP_SLEEP_CYCx_REG registers (x = 0..4). When starting the ULP for the first time, SENS_ULP_CP_SLEEP_CYC0_REG will be used to set the number of timer ticks. Later the ULP program can select another SENS_ULP_CP_SLEEP_CYCx_REG register using sleep instruction.

The application can set ULP timer period values (SENS_ULP_CP_SLEEP_CYCx_REG, x = 0..4) using `ulp_set_wakeup_period` function.

Once the timer counts the number of ticks set in the selected SENS_ULP_CP_SLEEP_CYCx_REG register, ULP coprocessor powers up and starts running the program from the entry point set in the call to `ulp_run()`.

The program runs until it encounters a `halt` instruction or an illegal instruction. Once the program halts the ULP coprocessor powers down and the timer is started again.

To disable the timer (effectively preventing the ULP program from running again), clear the RTC_CNTL_ULP_CP_SLP_TIMER_EN bit in the RTC_CNTL_STATE0_REG register. This can be done both from ULP code and from the main program.

Application Examples

- ULP FSM Coprocessor counts pulses on an IO while main CPU is in deep sleep: system/ulp_fsm/ulp
- ULP FSM Coprocessor polls ADC in while main CPU is in deep sleep: system/ulp_fsm/ulp_adc

API Reference

Header File

- components/ulp/ulp_fsm/include/ulp_fsm_common.h

Functions

```c
esp_err_t ulp_isr_register(intr_handler_t fn, void *arg)
```

Register ULP wakeup signal ISR.

**Parameters**

- `fn` - ISR callback function
- `arg` - ISR callback function arguments

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if callback function is NULL
- ESP_ERR_NO_MEM if heap memory cannot be allocated for the interrupt

```c
esp_err_t ulp_isr_deregister(intr_handler_t fn, void *arg)
```

Deregister ULP wakeup signal ISR.

**Parameters**

- `fn` - ISR callback function
- `arg` - ISR callback function arguments

---

**Note:** The ISR routine will only be active if the main CPU is not in deepsleep
Chapter 2. API Reference

Returns

• ESP_OK on success
• ESP_ERR_INVALID_ARG if callback function is NULL
• ESP_ERR_INVALID_STATE if a handler matching both callback function and its arguments isn’t registered

*esp_err_t*  **ulp_process_macros_and_load** (uint32_t load_addr, const ulp_insn_t *program, size_t *psize)

Resolve all macro references in a program and load it into RTC memory.

Parameters

• **load_addr** – address where the program should be loaded, expressed in 32-bit words
• **program** – ulp_insn_t array with the program
• **psize** – size of the program, expressed in 32-bit words

Returns

• ESP_OK on success
• ESP_ERR_NO_MEM if auxiliary temporary structure cannot be allocated
• one of ESP_ERR_ULP_xxx if program is not valid or can not be loaded

*esp_err_t*  **ulp_load_binary** (uint32_t load_addr, const uint8_t* program_binary, size_t program_size)

Load ULP program binary into RTC memory.

ULP program binary should have the following format (all values little-endian):

a. MAGIC, (value 0x00706c75, 4 bytes)
b. TEXT_OFFSET, offset of .text section from binary start (2 bytes)
c. TEXT_SIZE, size of .text section (2 bytes)
d. DATA_SIZE, size of .data section (2 bytes)
e. BSS_SIZE, size of .bss section (2 bytes)
f. (TEXT_OFFSET - 12) bytes of arbitrary data (will not be loaded into RTC memory)
g. .text section
h. .data section

Linker script in components/ulp/ld/esp32.ulp.ld produces ELF files which correspond to this format. This linker script produces binaries with load_addr == 0.

Parameters

• **load_addr** – address where the program should be loaded, expressed in 32-bit words
• **program_binary** – pointer to program binary
• **program_size** – size of the program binary

Returns

• ESP_OK on success
• ESP_ERR_INVALID_ARG if load_addr is out of range
• ESP_ERR_INVALID_SIZE if program_size doesn’t match (TEXT_OFFSET + TEXT_SIZE + DATA_SIZE)
• ESP_ERR_NOT_SUPPORTED if the magic number is incorrect

*esp_err_t*  **ulp_run** (uint32_t entry_point)

Run the program loaded into RTC memory.

Parameters **entry_point** – entry point, expressed in 32-bit words

Returns ESP_OK on success

Macros

**ESP_ERR_ULP_BASE**

Offset for ULP-related error codes

**ESP_ERR_ULP_SIZE_TOO_BIG**

Program doesn’t fit into RTC memory reserved for the ULP
Chapter 2. API Reference

**ESP_ERR_ULP_INVALID_LOAD_ADDR**

Load address is outside of RTC memory reserved for the ULP

**ESP_ERR_ULP_DUPLICATE_LABEL**

More than one label with the same number was defined

**ESP_ERR_ULP_UNDEFINED_LABEL**

Branch instructions references an undefined label

**ESP_ERR_ULP_BRANCH_OUT_OF_RANGE**

Branch target is out of range of B instruction (try replacing with BX)

**Type Definitions**

typedef union _ulp_insn  ulp_insn_t

**Header File**

- components/ulp/ulp_common/include/ulp_common.h

**Functions**

* esp_err_t ulp_set_wakeup_period (size_t period_index, uint32_t period_us)

Set one of ULP wakeup period values.

ULP coprocessor starts running the program when the wakeup timer counts up to a given value (called period). There are 5 period values which can be programmed into SENS_ULP_CP_SLEEP_CYCx_REG registers, x = 0..4 for ESP32, and one period value which can be programmed into RTC_CNTL_ULP_CP_TIMER_1_REG register for ESP32-S2/S3. By default, for ESP32, wakeup timer will use the period set into SENS_ULP_CP_SLEEP_CYC0_REG, i.e. period number 0. ULP program code can use SLEEP instruction to select which of the SENS_ULP_CP_SLEEP_CYCx_REG should be used for subsequent wakeups.

However, please note that SLEEP instruction issued (from ULP program) while the system is in deep sleep mode does not have effect, and sleep cycle count 0 is used.

For ESP32-S2/S3 the SLEEP instruction not exist. Instead a WAKE instruction will be used.

**Note:** The ULP FSM requires two clock cycles to wakeup before being able to run the program. Then additional 16 cycles are reserved after wakeup waiting until the 8M clock is stable. The FSM also requires two more clock cycles to go to sleep after the program execution is halted. The minimum wakeup period that may be set up for the ULP is equal to the total number of cycles spent on the above internal tasks. For a default configuration of the ULP running at 150kHz it makes about 133us.

**Parameters**

- *period_index* – wakeup period setting number (0 - 4)
- *period_us* – wakeup period, us

**Returns**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if period_index is out of range

void ulp_timer_stop (void)

Stop the ULP timer.
Chapter 2. API Reference

Note: This will stop the ULP from waking up if halted, but will not abort any program currently executing on the ULP.

```c
void ulp_timer_resume (void)
ResumetheULPtimer.
```

Note: This will resume an already configured timer, but does no other configuration

Header File

- components/ulp/ulp_common/include/esp32/ulp_common_defs.h

Macros

```c
RTC_SLOW_MEM
RTC slow memory, 8k size
```

### 2.10.32 Watchdogs

#### Overview

The ESP-IDF has support for multiple types of watchdogs, with the two main ones being: The Interrupt Watchdog Timer and the Task Watchdog Timer (TWDT). The Interrupt Watchdog Timer and the TWDT can both be enabled using Project Configuration Menu, however the TWDT can also be enabled during runtime. The Interrupt Watchdog is responsible for detecting instances where FreeRTOS task switching is blocked for a prolonged period of time. The TWDT is responsible for detecting instances of tasks running without yielding for a prolonged period.

ESP-IDF has support for the following types of watchdog timers:

- Interrupt Watchdog Timer (IWDT)
- Task Watchdog Timer (TWDT)

The various watchdog timers can be enabled using the Project Configuration Menu. However, the TWDT can also be enabled during runtime.

#### Interrupt Watchdog Timer (IWDT)

The purpose of the IWDT is to ensure that interrupt service routines (ISRs) are not blocked from running for a prolonged period of time (i.e., the IWDT timeout period). Blocking ISRs from running in a timely manner is undesirable as it can increases ISR latency, and also prevents task switching (as task switching is executed form an ISR). The things that can block ISRs from running include:

- Disabling interrupts
- Critical Sections (also disables interrupts)
- Other same/higher priority ISRs (will block same/lower priority ISRs from running it completes execution)

The IWDT utilizes the watchdog timer in Timer Group 1 as its underlying hardware timer and leverages the FreeRTOS tick interrupt on each CPU to feed the watchdog timer. If the tick interrupt on a particular CPU is not run at within the IWDT timeout period, it is indicative that something is blocking ISRs from being run on that CPU (see the list of reasons above).

When the IWDT times out, the default action is to invoke the panic handler and display the panic reason as Interrupt wdt timeout on CPU0 or Interrupt wdt timeout on CPU1 (as applicable). Depending on the panic handler’s configured behavior (see CONFIG_ESP_SYSTEM_PANIC), users can then debug the source of...
the IWDT timeout (via the backtrace, OpenOCD, gdbstub etc) or simply reset the chip (which may be preferred in a production environment).

If for whatever reason the panic handler is unable to run after an IWDT timeout, the IWDT has a secondary timeout that will hard-reset the chip (i.e., a system reset).

**Configuration**

- The IWDT is enabled by default via the `CONFIG_ESP_INT_WDT` option.
- The IWDT’s timeout is configured by setting the `CONFIG_ESP_INT_WDT_TIMEOUT_MS` option.
  - Note that the default timeout is higher if PSRAM support is enabled, as a critical section or interrupt routine that accesses a large amount of PSRAM will take longer to complete in some circumstances.
  - The timeout should always at least twice longer than the period between FreeRTOS ticks (see `CONFIG_FREERTOS_HZ`).

**Tuning** If you find the IWDT timeout is triggered because an interrupt or critical section is running longer than the timeout period, consider rewriting the code:

- Critical sections should be made as short as possible. Any non-critical code/computation should be placed outside the critical section.
- Interrupt handlers should also perform the minimum possible amount of computation. Users can consider deferring any computation to a task by having the ISR push data to a task using queues.

Neither critical sections or interrupt handlers should ever block waiting for another event to occur. If changing the code to reduce the processing time is not possible or desirable, it’s possible to increase the `CONFIG_ESP_INT_WDT_TIMEOUT_MS` setting instead.

**Task Watchdog Timer (TWDT)**

The Task Watchdog Timer (TWDT) is used to monitor particular tasks, ensuring that they are able to execute within a given timeout period. The TWDT primarily watches the Idle Tasks of each CPU, however any task can subscribe to be watched by the TWDT. By watching the Idle Tasks of each CPU, the TWDT can detect instances of tasks running for a prolonged period of time without yielding. This can be an indicator of poorly written code that spinloops on a peripheral, or a task that is stuck in an infinite loop.

The TWDT is built around the Hardware Watchdog Timer in Timer Group 0. When a timeout occurs, an interrupt is triggered. Users can define the function `esp_task_wdt_isr_user_handler` in the user code, in order to receive the timeout event and extend the default behavior.

**Usage** The following functions can be used to watch tasks using the TWDT:

- `esp_task_wdt_init()` to initialize the TWDT and subscribe the idle tasks.
- `esp_task_wdt_add()` subscribes other tasks to the TWDT.
- Once subscribed, `esp_task_wdt_reset()` should be called from the task to feed the TWDT.
- `esp_task_wdt_delete()` unsubscribes a previously subscribed task
- `esp_task_wdt_deinit()` unsubscribes the idle tasks and deinitializes the TWDT

In the case where applications need to watch at a more granular level (i.e., ensure that a particular functions/stub/code-path is called), the TWDT allows subscription of “users”.

- `esp_task_wdt_add_user()` to subscribe an arbitrary user of the TWDT. This function will return a user handle to the added user.
- `esp_task_wdt_reset_user()` must be called using the user handle in order to prevent a TWDT timeout.
- `esp_task_wdt_delete_user()` unsubscribes an arbitrary user of the TWDT.
Chapter 2. API Reference

Configuration

The default timeout period for the TWDT is set using config item `CONFIG_ESP_TASK_WDT_TIMEOUT_S`. This should be set to at least as long as you expect any single task will need to monopolize the CPU (for example, if you expect the app will do a long intensive calculation and should not yield to other tasks). It is also possible to change this timeout at runtime by calling `esp_task_wdt_init()`.

**Note:** Erasing large flash areas can be time consuming and can cause a task to run continuously, thus triggering a TWDT timeout. The following two methods can be used to avoid this:

- Increase `CONFIG_ESP_TASK_WDT_TIMEOUT_S` in menuconfig for a larger watchdog timeout period.
- You can also call `esp_task_wdt_init()` to increase the watchdog timeout period before erasing a large flash area.

For more information, you can refer to *SPI Flash*.

The following config options control TWDT configuration. They are all enabled by default:

- `CONFIG_ESP_TASK_WDT_EN` - enables TWDT feature. If this option is disabled, TWDT cannot be used, even if initialized at runtime.
- `CONFIG_ESP_TASK_WDT_INIT` - the TWDT is initialized automatically during startup. If this option is disabled, it is still possible to initialize the Task WDT at runtime by calling `esp_task_wdt_init()`.
- `CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU0` - CPU0 Idle task is subscribed to the TWDT during startup. If this option is disabled, it is still possible to subscribe the idle task by calling `esp_task_wdt_init()` again.
- `CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU1` - CPU1 Idle task is subscribed to the TWDT during startup.

**Note:** On a TWDT timeout the default behaviour is to simply print a warning and a backtrace before continuing running the app. If you want a timeout to cause a panic and a system reset then this can be configured through `CONFIG_ESP_TASK_WDT_PANIC`.

JTAG & Watchdogs

While debugging using OpenOCD, the CPUs will be halted every time a breakpoint is reached. However if the watchdog timers continue to run when a breakpoint is encountered, they will eventually trigger a reset making it very difficult to debug code. Therefore OpenOCD will disable the hardware timers of both the interrupt and task watchdogs at every breakpoint. Moreover, OpenOCD will not reenable them upon leaving the breakpoint. This means that interrupt watchdog and task watchdog functionality will essentially be disabled. No warnings or panics from either watchdogs will be generated when the ESP32 is connected to OpenOCD via JTAG.

API Reference

**Task Watchdog**

A full example using the Task Watchdog is available in esp-idf: `system/task_watchdog`

**Header File**

- `components/esp_system/include/esp_task_wdt.h`

**Functions**

`esp_err_t esp_task_wdt_init(const esp_task_wdt_config_t *config)`

Initializes the Task Watchdog Timer (TWDT)

This function configures and initializes the TWDT. This function will subscribe the idle tasks if configured to do so. For other tasks, users can subscribe them using `esp_task_wdt_add()` or `esp_task_wdt_add_user()`. This function won’t start the timer if no task have been registered yet.
Note: esp_task_wdt_init() must only be called after the scheduler is started. Moreover, it must not be called by multiple tasks simultaneously.

Parameters

- config [in] Configuration structure

Returns

- ESP_OK: Initialization was successful
- ESP_ERR_INVALID_STATE: Already initialized
- Other: Failed to initialize TWDT

esp_err_t esp_task_wdt_reconfigure (const esp_task_wdt_config_t *config)
Reconfigure the Task Watchdog Timer (TWDT)

The function reconfigures the running TWDT. It must already be initialized when this function is called.

Note: esp_task_wdt_reconfigure() must not be called by multiple tasks simultaneously.

Parameters

- config [in] Configuration structure

Returns

- ESP_OK: Reconfiguring was successful
- ESP_ERR_INVALID_STATE: TWDT not initialized yet
- Other: Failed to initialize TWDT

esp_err_t esp_task_wdt_deinit (void)
Deinitialize the Task Watchdog Timer (TWDT)

This function will deinitialize the TWDT, and unsubscribe any idle tasks. Calling this function whilst other tasks are still subscribed to the TWDT, or when the TWDT is already deinitialized, will result in an error code being returned.

Note: esp_task_wdt_deinit() must not be called by multiple tasks simultaneously.

Parameters

Returns

- ESP_OK: TWDT successfully deinitialized
- Other: Failed to deinitialize TWDT

esp_err_t esp_task_wdt_add (TaskHandle_t task_handle)
Subscribe a task to the Task Watchdog Timer (TWDT)

This function subscribes a task to the TWDT. Each subscribed task must periodically call esp_task_wdt_reset() to prevent the TWDT from elapsing its timeout period. Failure to do so will result in a TWDT timeout.

Parameters

- task_handle – Handle of the task. Input NULL to subscribe the current running task to the TWDT

Returns

- ESP_OK: Successfully subscribed the task to the TWDT
- Other: Failed to subscribe task

esp_err_t esp_task_wdt_add_user (const char *user_name, esp_task_wdt_user_handle_t *user_handle_ret)
Subscribe a user to the Task Watchdog Timer (TWDT)

This function subscribes a user to the TWDT. A user of the TWDT is usually a function that needs to run periodically. Each subscribed user must periodically call esp_task_wdt_reset_user() to prevent the TWDT from elapsing its timeout period. Failure to do so will result in a TWDT timeout.

Parameters
• **user_name** – [in] String to identify the user
• **user_handle_ret** – [out] Handle of the user

**Returns**
- ESP_OK: Successfully subscribed the user to the TWDT
- Other: Failed to subscribe user

```c
esp_err_t esp_task_wdt_reset (void)
```
Reset the Task Watchdog Timer (TWDT) on behalf of the currently running task.

This function will reset the TWDT on behalf of the currently running task. Each subscribed task must periodically call this function to prevent the TWDT from timing out. If one or more subscribed tasks fail to reset the TWDT on their own behalf, a TWDT timeout will occur.

**Returns**
- ESP_OK: Successfully reset the TWDT on behalf of the currently running task
- Other: Failed to reset

```c
esp_err_t esp_task_wdt_reset_user (esp_task_wdt_user_handle_t user_handle)
```
Reset the Task Watchdog Timer (TWDT) on behalf of a user.

This function will reset the TWDT on behalf of a user. Each subscribed user must periodically call this function to prevent the TWDT from timing out. If one or more subscribed users fail to reset the TWDT on their own behalf, a TWDT timeout will occur.

**Parameters**
- **user_handle** – [in] User handle
  - ESP_OK: Successfully reset the TWDT on behalf of the user
  - Other: Failed to reset

```c
esp_err_t esp_task_wdt_delete (TaskHandle_t task_handle)
```
Unsubscribe a task from the Task Watchdog Timer (TWDT)

This function will unsubscribe a task from the TWDT. After being unsubscribed, the task should no longer call esp_task_wdt_reset().

**Parameters**
- **task_handle** – [in] Handle of the task. Input NULL to unsubscribe the current running task.

**Returns**
- ESP_OK: Successfully unsubscribed the task from the TWDT
- Other: Failed to unsubscribe task

```c
esp_err_t esp_task_wdt_delete_user (esp_task_wdt_user_handle_t user_handle)
```
Unsubscribe a user from the Task Watchdog Timer (TWDT)

This function will unsubscribe a user from the TWDT. After being unsubscribed, the user should no longer call esp_task_wdt_reset_user().

**Parameters**
- **user_handle** – [in] User handle

**Returns**
- ESP_OK: Successfully unsubscribed the user from the TWDT
- Other: Failed to unsubscribe user

```c
esp_err_t esp_task_wdt_status (TaskHandle_t task_handle)
```
Query whether a task is subscribed to the Task Watchdog Timer (TWDT)

This function will query whether a task is currently subscribed to the TWDT, or whether the TWDT is initialized.

**Parameters**
- **task_handle** – [in] Handle of the task. Input NULL to query the current running task.

**Returns**
- ESP_OK: The task is currently subscribed to the TWDT
- ESP_ERR_NOT_FOUND: The task is not subscribed
- ESP_ERR_INVALID_STATE: TWDT was never initialized
void esp_task_wdt_isr_user_handler (void)
User ISR callback placeholder.
This function is called by task_wdt_isr function (ISR for when TWDT times out). It can be defined in user code to handle TWDT events.

Note: It has the same limitations as the interrupt function. Do not use ESP_LOGx functions inside.

Structures

struct esp_task_wdt_config_t
Task Watchdog Timer (TWDT) configuration structure.

Public Members

uint32_t timeout_ms
TWDT timeout duration in milliseconds

uint32_t idle_core_mask
Mask of the cores who’s idle task should be subscribed on initialization

bool trigger_panic
Trigger panic when timeout occurs

Type Definitions

typedef struct esp_task_wdt_user_handle_s *esp_task_wdt_user_handle_t
Task Watchdog Timer (TWDT) user handle.
Code examples for this API section are provided in the system directory of ESP-IDF examples.
Chapter 3

Hardware Reference
Chapter 4

API Guides

4.1 Application Level Tracing library

4.1.1 Overview

ESP-IDF provides a useful feature for program behavior analysis: application level tracing. It is implemented in the corresponding library and can be enabled in menuconfig. This feature allows to transfer arbitrary data between host and ESP32 via JTAG, UART, or USB interfaces with small overhead on program execution. It is possible to use JTAG and UART interfaces simultaneously. The UART interface is mostly used for connection with SEGGER SystemView tool (see SystemView).

Developers can use this library to send application-specific state of execution to the host and receive commands or other types of information from the opposite direction at runtime. The main use cases of this library are:

1. Collecting application-specific data. See Application Specific Tracing.
2. Lightweight logging to the host. See Logging to Host.

Tracing components used when working over JTAG interface are shown in the figure below.

4.1.2 Modes of Operation

The library supports two modes of operation:

Post-mortem mode: This is the default mode. The mode does not need interaction with the host side. In this mode, tracing module does not check whether the host has read all the data from HW UP BUFFER, but directly overwrites old data with the new ones. This mode is useful when only the latest trace data is interesting to the user, e.g., for analyzing program’s behavior just before the crash. The host can read the data later on upon user request, e.g., via special OpenOCD command in case of working via JTAG interface.

Streaming mode: Tracing module enters this mode when the host connects to ESP32. In this mode, before writing new data to HW UP BUFFER, the tracing module checks that whether there is enough space in it and if necessary, waits for the host to read data and free enough memory. Maximum waiting time is controlled via timeout values passed by users to corresponding API routines. So when application tries to write data to the trace buffer using the finite value of the maximum waiting time, it is possible that this data will be dropped. This is especially true for tracing from time critical code (ISR, OS scheduler code, etc.) where infinite timeouts can lead to system malfunction. In order to avoid loss of such critical data, developers can enable additional data buffering via menuconfig option
Fig. 1: Tracing Components Used When Working Over JTAG

`CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX`. This macro specifies the size of data which can be buffered in above conditions. The option can also help to overcome situation when data transfer to the host is temporarily slowed down, e.g., due to USB bus congestions. But it will not help when the average bitrate of the trace data stream exceeds the hardware interface capabilities.

### 4.1.3 Configuration Options and Dependencies

Using of this feature depends on two components:

1. **Host side:** Application tracing is done over JTAG, so it needs OpenOCD to be set up and running on host machine. For instructions on how to set it up, please see [JTAG Debugging](#) for details.

2. **Target side:** Application tracing functionality can be enabled in menuconfig. Please go to `Component config > Application Level Tracing` menu, which allows selecting destination for the trace data (hardware interface for transport: JTAG or/and UART). Choosing any of the destinations automatically enables the `CONFIG_APPTRACE_ENABLE` option. For UART interfaces, users have to define baud rate, TX and RX pins numbers, and additional UART-related parameters.

**Note:** In order to achieve higher data rates and minimize the number of dropped packets, it is recommended to optimize the setting of JTAG clock frequency, so that it is at maximum and still provides stable operation of JTAG. See [Optimize JTAG Speed](#).

There are two additional menuconfig options not mentioned above:

1. **Threshold for flushing last trace data to host on panic** (`CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH`). This option is necessary due to the nature of working over JTAG. In this mode, trace data is exposed to the host in 16 KB blocks. In post-mortem mode, when one block is filled, it is exposed to the host and the previous one becomes unavailable. In other words, the trace data is overwritten in 16 KB granularity. On panic, the latest data from the current input block is exposed to the host and the host can read them for post-analysis. System panic may occur when a very small amount of data are not exposed to the host yet. In this case, the previous 16 KB of collected data will be lost and the host will see the latest, but very small piece of the trace.
It can be insufficient to diagnose the problem. This menuconfig option allows avoiding such situations. It controls the threshold for flushing data in case of panic. For example, users can decide that it needs no less than 512 bytes of the recent trace data, so if there is less then 512 bytes of pending data at the moment of panic, they will not be flushed and will not overwrite the previous 16 KB. The option is only meaningful in post-mortem mode and when working over JTAG.

2. **Timeout for flushing last trace data to host on panic** (*CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO*). The option is only meaningful in streaming mode and it controls the maximum time that the tracing module will wait for the host to read the last data in case of panic.

3. **UART RX/TX ring buffer size** (*CONFIG_APPTRACE_UART_TX_BUFF_SIZE*). The size of the buffer depends on the amount of data transferred through the UART.

4. **UART TX message size** (*CONFIG_APPTRACE_UART_TX_MSG_SIZE*). The maximum size of the single message to transfer.

### 4.1.4 How to Use This Library

This library provides APIs for transferring arbitrary data between the host and ESP32. When enabled in menuconfig, the target application tracing module is initialized automatically at the system startup, so all what the user needs to do is to call corresponding APIs to send, receive or flush the data.

**Application Specific Tracing**

In general, users should decide what type of data should be transferred in every direction and how these data must be interpreted (processed). The following steps must be performed to transfer data between the target and the host:

1. On the target side, users should implement algorithms for writing tracedata to the host. Piece of code below shows an example on how to do this.

```c
#include "esp_app_trace.h"
...
char buf[] = "Hello World!";
esp_err_t res = esp_apptrace_write(ESP_APPTRACE_DEST_TRAX, buf, strlen(buf), ESP_APPTRACE_TMO_INFINITE);  
if (res != ESP_OK) {
    ESP_LOGE(TAG, "Failed to write data to host!");
    return res;
}
```

*esp_apptrace_write()* function uses memcpy to copy user data to the internal buffer. In some cases, it can be more optimal to use *esp_apptrace_buffer_get()* and *esp_apptrace_buffer_put()* functions. They allow developers to allocate buffer and fill it themselves. The following piece of code shows how to do this.

```c
#include "esp_app_trace.h"
...
int number = 10;
char *ptr = (char *)esp_apptrace_buffer_get(ESP_APPTRACE_DEST_TRAX, 32, -100/"tmo in us");
if (ptr == NULL) {
    ESP_LOGE(TAG, "Failed to get buffer!");
    return ESP_FAIL;
}
sprintf(ptr, "Here is the number %d", number);
esp_err_t res = esp_apptrace_buffer_put(ESP_APPTRACE_DEST_TRAX, ptr, -100/"tmo in us");
if (res != ESP_OK) {
    /* in case of error host tracing tool (e.g., OpenOCD) will report...
    incomplete user buffer */
    ESP_LOGE(TAG, "Failed to put buffer!");
    return res;
}
```
Also according to his needs, the user may want to receive data from the host. Piece of code below shows an example on how to do this.

```c
#include "esp_app_trace.h"
...
char buf[32];
char down_buf[32];
size_t sz = sizeof(buf);

/* config down buffer */
esp_apptrace_down_buffer_config(down_buf, sizeof(down_buf));
/* check for incoming data and read them if any */
esp_err_t res = esp_apptrace_read(ESP_APPTRACE_DEST_TRAX, buf, &sz, 0/
  /* do not wait*/);
if (res != ESP_OK) {
    ESP_LOGE(TAG, "Failed to read data from host!");
    return res;
}
if (sz > 0) {
    /* we have data, process them */
    ...
}
```

esp_apptrace_read() function uses memcpy to copy host data to user buffer. In some cases it can be more optimal to use esp_apptrace_down_buffer_get() and esp_apptrace_down_buffer_put() functions. They allow developers to occupy chunk of read buffer and process it in-place. The following piece of code shows how to do this.

```c
#include "esp_app_trace.h"
...
char down_buf[32];
uint32_t *number;
size_t sz = 32;

/* config down buffer */
esp_apptrace_down_buffer_config(down_buf, sizeof(down_buf));
char *ptr = (char *)esp_apptrace_down_buffer_get(ESP_APPTRACE_DEST_TrAX,
  &sz, 100/*tmo in us*/);
if (ptr == NULL) {
    ESP_LOGE(TAG, "Failed to get buffer!");
    return ESP_FAIL;
}
if (sz > 4) {
    number = (uint32_t *)ptr;
    printf("Here is the number %d", *number);
} else {
    printf("No data");
}
esp_err_t res = esp_apptrace_down_buffer_put(ESP_APPTRACE_DEST_TRAX,
  ptr, 100/*tmo in us*/);
if (res != ESP_OK) {
    /* in case of error host tracing tool (e.g., OpenOCD) will report
    incomplete user buffer */
    ESP_LOGE(TAG, "Failed to put buffer!");
    return res;
}
```

2. The next step is to build the program image and download it to the target as described in the Getting Started Guide.
3. Run OpenOCD (see JTAG Debugging).
4. Connect to OpenOCD telnet server. It can be done using the following command in terminal telnet <oocd_host> 4444. If telnet session is opened on the same machine which runs OpenOCD, you can use localhost as <oocd_host> in the command above.
5. Start trace data collection using special OpenOCD command. This command will transfer tracing data and redirect them to the specified file or socket (currently only files are supported as trace data destination). For description of the corresponding commands, see OpenOCD Application Level Tracing Commands.

6. The final step is to process received data. Since the format of data is defined by users, the processing stage is out of the scope of this document. Good starting points for data processor are python scripts in $IDF_PATH/tools/esp_app_trace: apptrace_proc.py (used for feature tests) and logtrace_proc.py (see more details in section Logging to Host).

OpenOCD Application Level Tracing Commands

HW UP BUFFER is shared between user data blocks and the filling of the allocated memory is performed on behalf of the API caller (in task or ISR context). In multithreading environment, it can happen that the task/ISR which fills the buffer is preempted by another high priority task/ISR. So it is possible that the user data preparation process is not completed at the moment when that chunk is read by the host. To handle such conditions, the tracing module prepends all user data chunks with header which contains the allocated user buffer size (2 bytes) and the length of the actually written data (2 bytes). So the total length of the header is 4 bytes. OpenOCD command which reads trace data reports error when it reads incomplete user data chunk, but in any case, it puts the contents of the whole user chunk (including unfilled area) to the output file.

Below is the description of available OpenOCD application tracing commands.

Note: Currently, OpenOCD does not provide commands to send arbitrary user data to the target.

Command usage:

```
esp aptrace [start <options>] | [stop] | [status] | [dump <cores_num> <outfile>]
```

Sub-commands:

- **start** Start tracing (continuous streaming).
- **stop** Stop tracing.
- **status** Get tracing status.
- **dump** Dump all data from (post-mortem dump).

Start command syntax:

```
start <outfile> [poll_period [trace_size [stop_tmo [wait4halt [skip_size]]]]]
```

- **outfile** Path to file to save data from both CPUs. This argument should have the following format: file://path/to/file.
- **poll_period** Data polling period (in ms) for available trace data. If greater than 0, then command runs in non-blocking mode. By default, 1 ms.
- **trace_size** Maximum size of data to collect (in bytes). Tracing is stopped after specified amount of data is received. By default, -1 (trace size stop trigger is disabled).
- **stop_tmo** Idle timeout (in sec). Tracing is stopped if there is no data for specified period of time. By default, -1 (disable this stop trigger). Optionally set it to value longer than longest pause between tracing commands from target.
- **wait4halt** If 0, start tracing immediately, otherwise command waits for the target to be halted (after reset, by breakpoint etc.) and then automatically resumes it and starts tracing. By default, 0.
- **skip_size** Number of bytes to skip at the start. By default, 0.

Note: If poll_period is 0, OpenOCD telnet command line will not be available until tracing is stopped. You must stop it manually by resetting the board or pressing Ctrl+C in OpenOCD window (not one with the telnet session). Another option is to set trace_size and wait until this size of data is collected. At this point, tracing stops automatically.

Command usage examples:
1. Collect 2048 bytes of tracing data to the file `trace.log`. The file will be saved in the `openocd-esp32` directory.

```bash
 esp aptrace start file://trace.log 1 2048 5 0 0
```

The tracing data will be retrieved and saved in non-blocking mode. This process will stop automatically after 2048 bytes are collected, or if no data are available for more than 5 seconds.

**Note:** Tracing data is buffered before it is made available to OpenOCD. If you see “Data timeout!” message, then it is likely that the target is not sending enough data to empty the buffer to OpenOCD before the timeout. Either increase the timeout or use the function `esp_aptrace_flush()` to flush the data on specific intervals.

2. Retrieve tracing data indefinitely in non-blocking mode.

```bash
 esp aptrace start file://trace.log 1 -1 -1 0 0
```

There is no limitation on the size of collected data and there is no data timeout set. This process may be stopped by issuing `esp aptrace stop` command on OpenOCD telnet prompt, or by pressing Ctrl+C in OpenOCD window.

3. Retrieve tracing data and save them indefinitely.

```bash
 esp aptrace start file://trace.log 0 -1 -1 0 0
```

OpenOCD telnet command line prompt will not be available until tracing is stopped. To stop tracing, press Ctrl+C in the OpenOCD window.

4. Wait for the target to be halted. Then resume the target’s operation and start data retrieval. Stop after collecting 2048 bytes of data:

```bash
 esp aptrace start file://trace.log 0 2048 -1 1 0
```

To configure tracing immediately after reset, use the OpenOCD `reset halt` command.

### Logging to Host

ESP-IDF implements a useful feature: logging to the host via application level tracing library. This is a kind of semihosting when all `ESP_LOGx` calls send strings to be printed to the host instead of UART. This can be useful because “printing to host” eliminates some steps performed when logging to UART. Most part of the work is done on the host.

By default, ESP-IDF’s logging library uses vprintf-like function to write formatted output to dedicated UART. In general, it involves the following steps:

1. Format string is parsed to obtain type of each argument.
2. According to its type, every argument is converted to string representation.
3. Format string combined with converted arguments is sent to UART.

Though the implementation of the vprintf-like function can be optimized to a certain level, all steps above have to be performed in any case and every step takes some time (especially item 3). So it frequently occurs that with additional log added to the program to identify the problem, the program behavior is changed and the problem cannot be reproduced. And in the worst cases, the program cannot work normally at all and ends up with an error or even hangs.

Possible ways to overcome this problem are to use higher UART bitrates (or another faster interface) and/or to move string formatting procedure to the host.

The application level tracing feature can be used to transfer log information to the host using `esp_aptrace_vprintf` function. This function does not perform full parsing of the format string and arguments. Instead, it just calculates the number of arguments passed and sends them along with the format string address to the host. On the host, log data is processed and printed out by a special Python script.

### Limitations

Current implementation of logging over JTAG has some limitations:
1. No support for tracing from ESP_EARLY_LOGx macros.
2. No support for printf arguments whose size exceeds 4 bytes (e.g., double and uint64_t).
3. Only strings from the .rodata section are supported as format strings and arguments.
4. The maximum number of printf arguments is 256.

**How To Use It** In order to use logging via trace module, users need to perform the following steps:

1. On the target side, the special vprintf-like function esp_apptrace_vprintf() needs to be installed. It sends log data to the host. An example is esp_log_set_vprintf(esp_apptrace_vprintf); To send log data to UART again, use esp_log_set_vprintf(vprintf);
2. Follow instructions in items 2-5 in Application Specific Tracing.
3. To print out collected log records, run the following command in terminal: $IDF_PATH/tools/esp_app_trace/logtrace_proc.py /path/to/trace/file /path/to/program/elf/file.

**Log Trace Processor Command Options** Command usage:

logtrace_proc.py [-h] [--no-errors] <trace_file> <elf_file>

Positional arguments:
- **trace_file** Path to log trace file.
- **elf_file** Path to program ELF file.

Optional arguments:
- **-h, --help** Show this help message and exit.
- **--no-errors, -n** Do not print errors.

**System Behavior Analysis with SEGGER SystemView**

Another useful ESP-IDF feature built on top of application tracing library is the system level tracing which produces traces compatible with SEGGER SystemView tool (see SystemView). SEGGER SystemView is a real-time recording and visualization tool that allows to analyze runtime behavior of an application. It is possible to view events in real-time through the UART interface.

**How To Use It** Support for this feature is enabled by Component config > Application Level Tracing > FreeRTOS SystemView Tracing (CONFIG_APPTRACE_SV_ENABLE) menuconfig option. There are several other options enabled under the same menu:

1. SystemView destination. Select the destination interface: JTAG or UART. In case of UART, it will be possible to connect SystemView application to the ESP32 directly and receive data in real-time.
2. ESP32 timer to use as SystemView timestamp source: (CONFIG_APPTRACE_SV_TS_SOURCE) selects the source of timestamps for SystemView events. In the single core mode, timestamps are generated using ESP32 internal cycle counter running at maximum 240 Mhz (~4 ns granularity). In the dual-core mode, external timer working at 40 Mhz is used, so the timestamp granularity is 25 ns.
3. Individually enabled or disabled collection of SystemView events (CONFIG_APPTRACE_SV_EVT_XXX):
   - Trace Buffer Overflow Event
   - ISR Enter Event
   - ISR Exit Event
   - ISR Exit to Scheduler Event
   - Task Start Execution Event
   - Task Stop Execution Event
   - Task Start Ready State Event
   - Task Stop Ready State Event
   - Task Create Event
   - Task Terminate Event
   - System Idle Event
   - Timer Enter Event
Chapter 4. API Guides

- Timer Exit Event

ESP-IDF has all the code required to produce SystemView compatible traces, so users can just configure necessary project options (see above), build, download the image to target, and use OpenOCD to collect data as described in the previous sections.

4. Select Pro or App CPU in menuconfig options Component config > Application Level Tracing > FreeRTOS SystemView Tracing to trace over the UART interface in real-time.

OpenOCD SystemView Tracing Command Options

Command usage:

```
esp sysview [start <options>] | [stop] | [status]
```

Sub-commands:

- **start**: Start tracing (continuous streaming).
- **stop**: Stop tracing.
- **status**: Get tracing status.

Start command syntax:

```
start <outfile1> [outfile2] [poll_period [trace_size [stop_tmo]]]
```

- **outfile1**: Path to file to save data from PRO CPU. This argument should have the following format: `file://path/to/file`.
- **outfile2**: Path to file to save data from APP CPU. This argument should have the following format: `file://path/to/file`.
- **poll_period**: Data polling period (in ms) for available trace data. If greater than 0, then command runs in non-blocking mode. By default, 1 ms.
- **trace_size**: Maximum size of data to collect (in bytes). Tracing is stopped after specified amount of data is received. By default, -1 (trace size stop trigger is disabled).
- **stop_tmo**: Idle timeout (in sec). Tracing is stopped if there is no data for specified period of time. By default, -1 (disable this stop trigger).

**Note:** If `poll_period` is 0, OpenOCD telnet command line will not be available until tracing is stopped. You must stop it manually by resetting the board or pressing Ctrl+C in the OpenOCD window (not the one with the telnet session). Another option is to set `trace_size` and wait until this size of data is collected. At this point, tracing stops automatically.

Command usage examples:

1. Collect SystemView tracing data to files `pro-cpu.SVDat` and `app-cpu.SVDat`. The files will be saved in `openocd-esp32` directory.

   ```
   esp sysview start file://pro-cpu.SVDat file://app-cpu.SVDat
   ```

   The tracing data will be retrieved and saved in non-blocking mode. To stop this process, enter `esp sysview stop` command on OpenOCD telnet prompt, optionally pressing Ctrl+C in the OpenOCD window.

2. Retrieve tracing data and save them indefinitely.

   ```
   esp sysview start file://pro-cpu.SVDat file://app-cpu.SVDat 0 -1 -1
   ```

   OpenOCD telnet command line prompt will not be available until tracing is stopped. To stop tracing, press Ctrl+C in the OpenOCD window.

Data Visualization

After trace data are collected, users can use a special tool to visualize the results and inspect behavior of the program.

Unfortunately, SystemView does not support tracing from multiple cores. So when tracing from ESP32 with JTAG interfaces in the dual-core mode, two files are generated: one for PRO CPU and another for APP CPU. Users can load each file into separate instances of the tool. For tracing over UART, users can select Component config
Chapter 4. API Guides

> Application Level Tracing > FreeRTOS SystemView Tracing in menuconfig Pro or App to choose which CPU has to be traced.

It is uneasy and awkward to analyze data for every core in separate instance of the tool. Fortunately, there is an Eclipse plugin called Impulse which can load several trace files, thus making it possible to inspect events from both cores in one view. Also, this plugin has no limitation of 1,000,000 events as compared to the free version of SystemView. Good instructions on how to install, configure, and visualize data in Impulse from one core can be found here.

Note: ESP-IDF uses its own mapping for SystemView FreeRTOS events IDs, so users need to replace the original file mapping $SYSVIEW_INSTALL_DIR/Description/SYSVIEW_FreeRTOS.txt with $IDF_PATH/tools/esp_app_trace/SYSVIEW_FreeRTOS.txt. Also, contents of that IDF-specific file should be used when configuring SystemView serializer using the above link.

Configure Impulse for Dual Core Traces  After installing Impulse and ensuring that it can successfully load trace files for each core in separate tabs, users can add special Multi Adapter port and load both files into one view. To do this, users need to do the following steps in Eclipse:

1. Open the Signal Ports view. Go to Windows > Show View > Other menu. Find the Signal Ports view in Impulse folder and double-click it.
2. In the Signal Ports view, right-click Ports and select Add > New Multi Adapter Port.
3. In the open dialog box, click Add and select New Pipe/File.
4. In the open dialog box, select SystemView Serializer as Serializer and set path to PRO CPU trace file. Click OK.
5. Repeat the steps 3-4 for APP CPU trace file.
6. Double-click the created port. View for this port should open.
7. Click the Start/Stop Streaming button. Data should be loaded.
8. Use the Zoom Out, Zoom In and Zoom Fit buttons to inspect data.
9. For settings measurement cursors and other features, please see Impulse documentation.

Note: If you have problems with visualization (no data is shown or strange behaviors of zoom action are observed), you can try to delete current signal hierarchy and double-click on the necessary file or port. Eclipse will ask you to create a new signal hierarchy.

Gcov (Source Code Coverage)

Basics of Gcov and Gcovr  Source code coverage is data indicating the count and frequency of every program execution path that has been taken within a program’s runtime. Gcov is a GCC tool that, when used in concert with the compiler, can generate log files indicating the execution count of each line of a source file. The Gcovr tool is a utility for managing Gcov and generating summarized code coverage results.

Generally, using Gcov to compile and run programs on the host will undergo these steps:

1. Compile the source code using GCC with the --coverage option enabled. This will cause the compiler to generate a .gcno notes files during compilation. The notes files contain information to reconstruct execution path block graphs and map each block to source code line numbers. Each source file compiled with the --coverage option should have their own .gcno file of the same name (e.g., a main.c will generate a main.gcno when compiled).
2. Execute the program. During execution, the program should generate .gcda data files. These data files contain the counts of the number of times an execution path was taken. The program will generate a .gcda file for each source file compiled with the --coverage option (e.g., main.c will generate a main.gcda).
3. Gcov or Gcovr can be used to generate a code coverage report that produces a .gcno, .gcda, and source files. Gcov will generate a text-based coverage report for each source file in the form of a .gcov file, whilst Gcovr will generate a coverage report in HTML format.
**Gcov and Gcovr in ESP-IDF** Using Gcov in ESP-IDF is complicated due to the fact that the program is running remotely from the host (i.e., on the target). The code coverage data (i.e., the .gcda files) is initially stored on the target itself. OpenOCD is then used to dump the code coverage data from the target to the host via JTAG during runtime. Using Gcov in ESP-IDF can be split into the following steps.

1. **Setting Up a Project for Gcov**
2. **Dumping Code Coverage Data**
3. **Generating Coverage Report**

### Setting Up a Project for Gcov

**Compiler Option** In order to obtain code coverage data in a project, one or more source files within the project must be compiled with the --coverage option. In ESP-IDF, this can be achieved at the component level or the individual source file level:

- To cause all source files in a component to be compiled with the --coverage option, you can add `target_compile_options(${COMPONENT_LIB} PRIVATE --coverage)` to the CMakeLists.txt file of the component.
- To cause a select number of source files (e.g., source1.c and source2.c) in the same component to be compiled with the --coverage option, you can add `set_source_files_properties(source1.c source2.c PROPERTIES COMPIL_FLAGS --coverage)` to the CMakeLists.txt file of the component.

When a source file is compiled with the --coverage option (e.g., gcov_example.c), the compiler will generate the gcov_example.gcno file in the project’s build directory. For example, if gcov_example_main.c of the main component is compiled with the --coverage option, then dumping the code coverage data would generate a gcov_example_main.gcda in build/esp-idf/main/CMakeFiles/__idf_main.dir/gcov_example_main.c.gcda. Note that the .gcno files produced during compilation are also placed in the same directory.

### Project Configuration
Before building a project with source code coverage, make sure that the following project configuration options are enabled by running `idf.py menuconfig`.

- Enable the application tracing module by selecting Trace Memory for the `CONFIG_APPTRACE_DESTINATION1` option.
- Enable Gcov to the host via the `CONFIG_APPTRACE_GCOV_ENABLE`.

### Dumping Code Coverage Data
Once a project has been compiled with the --coverage option and flashed onto the target, code coverage data will be stored internally on the target (i.e., in trace memory) whilst the application runs. The process of transferring code coverage data from the target to the host is known as dumping.

The dumping of code coverage data is done via OpenOCD (see JTAG Debugging on how to setup and run OpenOCD). A dump is triggered by issuing commands to OpenOCD, therefore a telnet session to OpenOCD must be opened to issue such commands (run `telnet localhost 4444`). Note that GDB could be used instead of telnet to issue commands to OpenOCD, however all commands issued from GDB will need to be prefixed as `mon <oocd_command>`.

When the target dumps code coverage data, the .gcda files are stored in the project’s build directory. For example, if gcov_example_main.c of the main component is compiled with the --coverage option, then dumping the code coverage data would generate a gcov_example_main.gcda in build/esp-idf/main/CMakeFiles/__idf_main.dir/gcov_example_main.c.gcda. Note that the .gcno files produced during compilation are also placed in the same directory.

The dumping of code coverage data can be done multiple times throughout an application’s lifetime. Each dump will simply update the .gcda file with the newest code coverage information. Code coverage data is accumulative, thus the newest data will contain the total execution count of each code path over the application’s entire lifetime.

ESP-IDF supports two methods of dumping code coverage data form the target to the host:

- Instant Run-Time Dumpgit
- Hard-coded Dump
**Instant Run-Time Dump**  An Instant Run-Time Dump is triggered by calling the **ESP32 gcov OpenOCD** command (via a telnet session). Once called, OpenOCD will immediately preempt the ESP32’s current state and execute a built-in ESP-IDF Gcov debug stub function. The debug stub function will handle the dumping of data to the host. Upon completion, the ESP32 will resume its current state.

**Hard-coded Dump**  A Hard-coded Dump is triggered by the application itself by calling **esp_gcov_dump()** from somewhere within the application. When called, the application will halt and wait for OpenOCD to connect and retrieve the code coverage data. Once **esp_gcov_dump()** is called, the host must execute the **esp gcov dump OpenOCD command** (via a telnet session). The **esp gcov dump** command will cause OpenOCD to connect to the ESP32, retrieve the code coverage data, then disconnect from the ESP32, thus allowing the application to resume. Hard-coded Dumps can also be triggered multiple times throughout an application’s lifetime.

Hard-coded dumps are useful if code coverage data is required at certain points of an application’s lifetime by placing **esp_gcov_dump()** where necessary (e.g., after application initialization, during each iteration of an application’s main loop).

GDB can be used to set a breakpoint on **esp_gcov_dump()**, then call **mon esp gcov dump automatically via the use a gdbinit script** (see Using GDB from Command Line).

The following GDB script will add a breakpoint at **esp_gcov_dump()**, then call the **mon esp gcov dump** OpenOCD command.

```
b esp_gcov_dump
commands
mon esp gcov dump
end
```

**Note:** Note that all OpenOCD commands should be invoked in GDB as: **mon <oocd_command>**.

**Generating Coverage Report**  Once the code coverage data has been dumped, the `.gcno`, `.gcda` and the source files can be used to generate a code coverage report. A code coverage report is simply a report indicating the number of times each line in a source file has been executed.

Both Gcov and Gcovr can be used to generate code coverage reports. Gcov is provided along with the Xtensa toolchain, whilst Gcovr may need to be installed separately. For details on how to use Gcov or Gcovr, refer to Gcov documentation and Gcovr documentation.

**Adding Gcovr Build Target to Project**  To make report generation more convenient, users can define additional build targets in their projects such that the report generation can be done with a single build command.

Add the following lines to the `CMakeLists.txt` file of your project.

```
include($ENV{IDF_PATH}/tools/cmake/gcov.cmake)
idf_create_coverage_report(${CMAKE_CURRENT_BINARY_DIR}/coverage_report)
idf_clean_coverage_report(${CMAKE_CURRENT_BINARY_DIR}/coverage_report)
```

The following commands can now be used:

- **cmake --build build/ --target gcovr-report** will generate an HTML coverage report in `$BUILD_DIR_BASE)/coverage_report/html` directory.
- **cmake --build build/ --target cov-data-clean** will remove all coverage data files.

### 4.2 Application Startup Flow

This note explains various steps which happen before **app_main** function of an ESP-IDF application is called.
Chapter 4. API Guides

The high level view of startup process is as follows:

1. **First stage bootloader** in ROM loads second-stage bootloader image to RAM (IRAM & DRAM) from flash offset 0x1000.
2. **Second stage bootloader** loads partition table and main app image from flash. Main app incorporates both RAM segments and read-only segments mapped via flash cache.
3. **Application startup** executes. At this point the second CPU and RTOS scheduler are started.

This process is explained in detail in the following sections.

### 4.2.1 First stage bootloader

After SoC reset, PRO CPU will start running immediately, executing reset vector code, while APP CPU will be held in reset. During startup process, PRO CPU does all the initialization. APP CPU reset is de-asserted in the `call_start_cpu0` function of application startup code. Reset vector code is located in the mask ROM of the ESP32 chip and cannot be modified.

Startup code called from the reset vector determines the boot mode by checking `GPIO_STRAP_REG` register for bootstrap pin states. Depending on the reset reason, the following takes place:

1. Reset from deep sleep: if the value in `RTC_CNTL_STORE6_REG` is non-zero, and CRC value of RTC memory in `RTC_CNTL_STORE7_REG` is valid, use `RTC_CNTL_STORE6_REG` as an entry point address and jump immediately to it. If `RTC_CNTL_STORE6_REG` is zero, or `RTC_CNTL_STORE7_REG` contains invalid CRC, or once the code called via `RTC_CNTL_STORE6_REG` returns, proceed with boot as if it was a power-on reset. **Note:** to run customized code at this point, a deep sleep stub mechanism is provided. Please see deep sleep documentation for this.

2. For power-on reset, software SoC reset, and watchdog SoC reset: check the `GPIO_STRAP_REG` register if a custom boot mode (such as UART Download Mode) is requested. If this is the case, this custom loader mode is executed from ROM. Otherwise, proceed with boot as if it was due to software CPU reset. Consult ESP32 datasheet for a description of SoC boot modes and how to execute them.

3. For software CPU reset and watchdog CPU reset: configure SPI flash based on EFUSE values, and attempt to load the code from flash. This step is described in more detail in the next paragraphs.

**Note:** During normal boot modes the RTC watchdog is enabled when this happens, so if the process is interrupted or stalled then the watchdog will reset the SOC automatically and repeat the boot process. This may cause the SoC to strap into a new boot mode, if the strapping GPIOs have changed.

Second stage bootloader binary image is loaded from flash starting at address 0x1000. If **Secure Boot** is in use then the first 4 kB sector of flash is used to store secure boot IV and digest of the bootloader image. Otherwise, this sector is unused.

### 4.2.2 Second stage bootloader

In ESP-IDF, the binary image which resides at offset 0x1000 in flash is the second stage bootloader. Second stage bootloader source code is available in `components/bootloader` directory of ESP-IDF. Second stage bootloader is used in ESP-IDF to add flexibility to flash layout (using partition tables), and allow for various flows associated with flash encryption, secure boot, and over-the-air updates (OTA) to take place.

When the first stage bootloader is finished checking and loading the second stage bootloader, it jumps to the second stage bootloader entry point found in the binary image header.

Second stage bootloader reads the partition table found by default at offset 0x8000. **Configurable value.** See **partition tables** documentation for more information. The bootloader finds factory and OTA app partitions. If OTA app partitions are found in the partition table, the bootloader consults the `otadata` partition to determine which one should be booted. See **Over The Air Updates (OTA)** for more information.

For a full description of the configuration options available for the ESP-IDF bootloader, see **Bootloader**.
Chapter 4. API Guides

For the selected partition, second stage bootloader reads the binary image from flash one segment at a time:

- For segments with load addresses in internal IRAM (Instruction RAM) or DRAM (Data RAM), the contents are copied from flash to the load address.
- For segments which have load addresses in DROM (data stored in flash) or IROM (code executed from flash) regions, the flash MMU is configured to provide the correct mapping from the flash to the load address.

Note that the second stage bootloader configures flash MMU for both PRO and APP CPUs, but it only enables flash MMU for PRO CPU. Reason for this is that second stage bootloader code is loaded into the memory region used by APP CPU cache. The duty of enabling cache for APP CPU is passed on to the application.

Once all segments are processed - meaning code is loaded and flash MMU is set up, second stage bootloader verifies the integrity of the application and then jumps to the application entry point found in the binary image header.

4.2.3 Application startup

Application startup covers everything that happens after the app starts executing and before the app_main function starts running inside the main task. This is split into three stages:

- Port initialization of hardware and basic C runtime environment.
- System initialization of software services and FreeRTOS.
- Running the main task and calling app_main.

Note: Understanding all stages of ESP-IDF app initialization is often not necessary. To understand initialization from the application developer’s perspective only, skip forward to Running the main task.

Port Initialization

ESP-IDF application entry point is call_start_cpu0 function found in components/esp_system/port/cpu_start.c. This function is executed by the second stage bootloader, and never returns.

This port-layer initialization function initializes the basic C Runtime Environment (“CRT”) and performs initial configuration of the SoC’s internal hardware:

- Reconfigure CPU exceptions for the app (allowing app interrupt handlers to run, and causing Fatal Errors to be handled using the options configured for the app rather than the simpler error handler provided by ROM).
- If the option CONFIG_BOOTLOADER_WDT_ENABLE is not set then the RTC watchdog timer is disabled.
- Initialize internal memory (data & bss).
- Finish configuring the MMU cache.
- Enable PSRAM if configured.
- Set the CPU clocks to the frequencies configured for the project.
- Reconfigure the main SPI flash based on the app header settings (necessary for compatibility with bootloader versions before ESP-IDF V4.0, see Bootloader Compatibility).
- If the app is configured to run on multiple cores, start the other core and wait for it to initialize as well (inside the similar “port layer” initialization function call_start_cpu1).

Once call_start_cpu0 completes running, it calls the “system layer” initialization function start_cpu0 found in components/esp_system/startup.c. Other cores will also complete port-layer initialization and call start_other_cores found in the same file.

System Initialization

The main system initialization function is start_cpu0. By default, this function is weak-linked to the function start_cpu0_default. This means that it’s possible to override this function to add some additional initialization steps.

The primary system initialization stage includes:
• Log information about this application (project name, *App Version*, etc.) if default log level enables this.
• Initialize the heap allocator (before this point all allocations must be static or on the stack).
• Initialize newlib component syscalls and time functions.
• Configure the brownout detector.
• Setup libc stdin, stdout, and stderr according to the serial console configuration.
• Perform any security-related checks, including burning efuses that should be burned for this configuration (including disabling ROM download mode on ESP32 V3, *CONFIG_ESP32_DISABLE_BASIC_ROM_CONSOLE*).
• Initialize SPI flash API support.
• Call global C++ constructors and any C functions marked with `__attribute__((constructor))`.

Secondary system initialization allows individual components to be initialized. If a component has an initialization function annotated with the *ESP_SYSTEM_INIT_FN* macro, it will be called as part of secondary initialization. Component initialization functions have priorities assigned to them to ensure the desired initialization order. The priorities are documented in *esp_system/system_init_fn.txt* and *ESP_SYSTEM_INIT_FN* definition in source code are checked against this file.

**Running the main task**

After all other components are initialized, the main task is created and the FreeRTOS scheduler starts running.

After doing some more initialization tasks (that require the scheduler to have started), the main task runs the application-provided function *app_main* in the firmware.

The main task that runs *app_main* has a fixed RTOS priority (one higher than the minimum) and a *configurable stack size*.

The main task core affinity is also configurable: *CONFIG_ESP_MAIN_TASK_AFFINITY*.

Unlike normal FreeRTOS tasks (or embedded C *main* functions), the *app_main* task is allowed to return. If this happens, The task is cleaned up and the system will continue running with other RTOS tasks scheduled normally.

Therefore, it is possible to implement *app_main* as either a function that creates other application tasks and then returns, or as a main application task itself.

**Second core startup**

A similar but simpler startup process happens on the APP CPU:

When running system initialization, the code on PRO CPU sets the entry point for APP CPU, de-asserts APP CPU reset, and waits for a global flag to be set by the code running on APP CPU, indicating that it has started. Once this is done, APP CPU jumps to call _start_cpu*1 function in *components/esp_system/port/cpu_start.c*.

While PRO CPU does initialization in _start_cpu0* function, APP CPU runs _start_cpu_other_cores* function. Similar to _start_cpu0*, this function is weak-linked and defaults to the _start_cpu_other_cores_default* function but can be replaced with a different function by the application.

The _start_cpu_other_cores_default* function does some core-specific system initialization and then waits for the PRO CPU to start the FreeRTOS scheduler, at which point it executes _esp_startup_start_app_other_cores* which is another weak-linked function defaulting to _esp_startup_start_app_other_cores_default*.

By default _esp_startup_start_app_other_cores_default* does nothing but spin in a busy-waiting loop until the scheduler of the PRO CPU triggers an interrupt to start the RTOS scheduler on the APP CPU.

### 4.3 BluFi
4.3.1 Overview

The BluFi for ESP32 is a Wi-Fi network configuration function via Bluetooth channel. It provides a secure protocol to pass Wi-Fi configuration and credentials to ESP32. Using this information, ESP32 can then connect to an AP or establish a SoftAP.

Fragmenting, data encryption, and checksum verification in the BluFi layer are the key elements of this process. You can customize symmetric encryption, asymmetric encryption, and checksum support customization. Here we use the DH algorithm for key negotiation, 128-AES algorithm for data encryption, and CRC16 algorithm for checksum verification.

4.3.2 The BluFi Flow

The BluFi networking flow includes the configuration of the SoftAP and Station.

The following uses Station as an example to illustrate the core parts of the procedure, including broadcast, connection, service discovery, negotiation of the shared key, data transmission, and connection status backhaul.

1. Set the ESP32 into GATT Server mode and then it will send broadcasts with specific advertising data. You can customize this broadcast as needed, which is not a part of the BluFi Profile.
2. Use the App installed on the mobile phone to search for this particular broadcast. The mobile phone will connect to ESP32 as the GATT Client once the broadcast is confirmed. The App used during this part is up to you.
3. After the GATT connection is successfully established, the mobile phone will send a data frame for key negotiation to ESP32 (see the section The Frame Formats Defined in BluFi for details).
4. After ESP32 receives the data frame of key negotiation, it will parse the content according to the user-defined negotiation method.
5. The mobile phone works with ESP32 for key negotiation using the encryption algorithms, such as DH, RSA, or ECC.
6. After the negotiation process is completed, the mobile phone will send a control frame for security-mode setup to ESP32.
7. When receiving this control frame, ESP32 will be able to encrypt and decrypt the communication data using the shared key and the security configuration.
8. The mobile phone sends the data frame defined in the section of The Frame Formats Defined in BluFi, with the Wi-Fi configuration information to ESP32, including SSID, password, etc.
9. The mobile phone sends a control frame of Wi-Fi connection request to ESP32. When receiving this control frame, ESP32 will regard the communication of essential information as done and get ready to connect to the Wi-Fi.
10. After connecting to the Wi-Fi, ESP32 will send a control frame of Wi-Fi connection status report to the mobile phone. At this point, the networking procedure is completed.

Note:

1. After ESP32 receives the control frame of security-mode configuration, it will execute the operations in accordance with the defined security mode.
2. The data lengths before and after symmetric encryption/decryption must stay the same. It also supports in-place encryption and decryption.

4.3.3 The Flow Chart of BluFi

4.3.4 The Frame Formats Defined in BluFi

The frame formats for the communication between the mobile phone App and ESP32 are defined as follows:

The frame format with no fragment:
Create GATT connection
Negotiate key procedure
CTRL: Set ESP32 to Phone Security mode
DATA: SSID
DATA: Password
DATA: Other information, such as CA certification
CTRL: Connect to AP
DATA: Connection State Report

Fig. 2: BluFi Flow Chart
If the frag frame bit in the **Frame Control** field is enabled, there would be a 2-byte **Total Content Length** field in the **Data** field. This **Total Content Length** field indicates the length of the remaining part of the frame and also tells the remote how much memory needs to be allocated.

The frame format with fragments:

<table>
<thead>
<tr>
<th>Field</th>
<th>Value (Byte)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (Least Significant Bit)</td>
<td>1</td>
</tr>
<tr>
<td>Frame Control</td>
<td>1</td>
</tr>
<tr>
<td>Sequence Number</td>
<td>1</td>
</tr>
<tr>
<td>Data Length</td>
<td>1</td>
</tr>
<tr>
<td>Data</td>
<td>$\text{Data Length}$</td>
</tr>
<tr>
<td>CheckSum (Most Significant Bit)</td>
<td>2</td>
</tr>
</tbody>
</table>

Normally, the control frame does not contain data bits, except for ACK Frame.

The format of ACK Frame:

<table>
<thead>
<tr>
<th>Field</th>
<th>Value (Byte)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type - ACK (Least Significant Bit)</td>
<td>1</td>
</tr>
<tr>
<td>Frame Control</td>
<td>1</td>
</tr>
<tr>
<td>Sequence Number</td>
<td>1</td>
</tr>
<tr>
<td>Data Length</td>
<td>1</td>
</tr>
<tr>
<td>Data</td>
<td>Acked Sequence Number: 2</td>
</tr>
<tr>
<td>CheckSum (Most Significant Bit)</td>
<td>2</td>
</tr>
</tbody>
</table>

1. **Type** field takes 1 byte and is divided into **Type** and **Subtype**. **Type** uses the lower two bits, indicating whether the frame is a data frame or a control frame. **Subtype** uses the upper six bits, indicating the specific meaning of this data frame or control frame.

   • The control frame is not encrypted for the time being and supports to be verified.
   • The data frame supports to be encrypted and verified.

1.1 Control Frame (Binary: 0x0 b’ 00)
<table>
<thead>
<tr>
<th>Control Frame</th>
<th>Implication</th>
<th>Explanation</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0 (b’ 000000)</td>
<td>ACK</td>
<td>The data field of the ACK frame uses the same sequence value of the frame to reply to.</td>
<td>The data field consumes a byte and its value is the same as the sequence field of the frame to reply to.</td>
</tr>
<tr>
<td>0x1 (b’ 000001)</td>
<td>Set the ESP device to the security mode.</td>
<td>To inform the ESP device of the security mode to use when sending data, which is allowed to be reset multiple times during the process. Each setting affects the subsequent security mode used. If it is not set, the ESP device will send the control frame and data frame with no checksum and encryption by default. The data transmission from the mobile phone to the ESP device is controlled by this control frame.</td>
<td>The data field consumes a byte. The higher four bits are for the security mode setting of the control frame, and the lower four bits are for the security mode setting of the data frame.</td>
</tr>
<tr>
<td>0x2 (b’ 000010)</td>
<td>Set the opmode of Wi-Fi.</td>
<td>The frame contains opmode settings for configuring the Wi-Fi mode of the ESP device.</td>
<td>data[0] is for opmode settings, including:</td>
</tr>
<tr>
<td>0x3 (b’ 000011)</td>
<td>Connect the ESP device to the AP.</td>
<td>To notify the ESP device that the essential information has been sent and it is allowed to connect to the AP.</td>
<td>No data field is contained.</td>
</tr>
<tr>
<td>0x4 (b’ 000100)</td>
<td>Disconnect the ESP device from the AP.</td>
<td>No data field is contained.</td>
<td></td>
</tr>
<tr>
<td>0x5 (b’ 000101)</td>
<td>To get the information of the ESP device’s Wi-Fi mode and it’s status.</td>
<td>• No data field is contained. When receiving this control frame, the ESP device will send back a follow-up frame of Wi-Fi connection state report to the mobile phone with the information of the current opmode, connection status, SSID, and so on.</td>
<td></td>
</tr>
<tr>
<td>0x6 (b’ 000110)</td>
<td>Disconnect the STA device from the SoftAP (in SoftAP mode).</td>
<td>Data[0-5] is taken as the MAC address for the STA device. If there is a second STA device, then it uses data[6-11] and the rest can be done in the same manner.</td>
<td></td>
</tr>
<tr>
<td>0x7 (b’ 001011)</td>
<td>Get the version information.</td>
<td>The ESP device will disconnect the BLE GATT link after receives this command.</td>
<td></td>
</tr>
<tr>
<td>0x8 (b’ 010100)</td>
<td>Disconnect the BLE GATT link.</td>
<td>To get the ESP device to scan the Wi-Fi access points around.</td>
<td>No data field is contained. When receiving this control frame, the ESP device will send back a follow-up frame of Wi-Fi list report to the mobile phone.</td>
</tr>
<tr>
<td>0x9 (b’ 011000)</td>
<td>Get the Wi-Fi list.</td>
<td>Systems</td>
<td></td>
</tr>
</tbody>
</table>
1.2 Data Frame (Binary: 0x1b’01)
<table>
<thead>
<tr>
<th>Data Frame</th>
<th>Implication</th>
<th>Explanation</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x0 (b'000000)</td>
<td>Send the negotiation data.</td>
<td>The negotiation data will be sent to the callback function registered in the application layer.</td>
<td>The length of the data depends on the length field.</td>
</tr>
<tr>
<td>0x1 (b'000001)</td>
<td>Send the SSID for STA mode.</td>
<td>To send the BSSID of the AP for the STA device to connect under the condition that the SSID is hidden.</td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x2 (b'000100)</td>
<td>Send the SSID for STA mode.</td>
<td>To send the SSID of the AP for the STA device to connect.</td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x3 (b'000101)</td>
<td>Send the password for STA mode.</td>
<td>To send the password of the AP for the STA device to connect.</td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x4 (b'000110)</td>
<td>Send the SSID for SoftAP mode.</td>
<td></td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x5 (b'001001)</td>
<td>Send the password for SoftAP mode.</td>
<td></td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x6 (b'001110)</td>
<td>Set the maximum connection number for SoftAP mode.</td>
<td>data[0] represents the value of the connection number, ranging from 1 to 4. When the transmission direction is ESP device to the mobile phone, it means to provide the mobile phone with the needed information.</td>
<td></td>
</tr>
<tr>
<td>0x7 (b'001111)</td>
<td>Set the authentication mode for SoftAP mode.</td>
<td>data[0]: • 0x00: OPEN • 0x01: WEP • 0x02: WPA_PSK • 0x03: WPA2_PSK • 0x04: WPA_WPA2_PSK When the transmission direction is from the ESP device to the mobile phone, it means to provide the mobile phone with the needed information.</td>
<td></td>
</tr>
<tr>
<td>0x8 (b'010000)</td>
<td>Set the number of channels for SoftAP mode.</td>
<td>data[0] represents the quantity of the supported channels, ranging from 1 to 14. When the transmission direction is from the ESP device to the mobile phone, it means to provide the mobile phone with the needed information.</td>
<td></td>
</tr>
<tr>
<td>0x9 (b'010010)</td>
<td>Username</td>
<td>It provides the username of the GATT client when using encryption of enterprise level.</td>
<td>The length of the data depends on the length field.</td>
</tr>
<tr>
<td>0xa (b'010100)</td>
<td>CA Certification</td>
<td>It provides the CA Certification when using encryption of enterprise level.</td>
<td>Please refer to Note 2 below.</td>
</tr>
<tr>
<td>0xb (b'010110)</td>
<td>Client Certification</td>
<td>It provides the client certification when using encryption of enterprise level. Whether the private key is contained or not depends on the content of the certification.</td>
<td>Please refer to Note 2 below.</td>
</tr>
<tr>
<td>0xc (b'011000)</td>
<td>Server Certification</td>
<td>It provides the server certification when using encryption of enterprise level. Whether the private key is contained or not depends on the content of the certification.</td>
<td>Please refer to Note 2 below.</td>
</tr>
<tr>
<td>Espressif Systems</td>
<td></td>
<td></td>
<td>Release v5.1.2</td>
</tr>
<tr>
<td>0xd (b'011010)</td>
<td>Client Private Key</td>
<td>It provides the private key of the client when using encryption of enterprise level.</td>
<td>Please refer to Note 2 below.</td>
</tr>
</tbody>
</table>
Chapter 4. API Guides

Note:

• Note 1: The length of the data depends on the data length field. When the transmission direction is from the ESP device to the mobile phone, it means to provide the mobile phone with the needed information.
• Note 2: The length of the data depends on the data length field. The frame supports to be fragmented if the data length is not long enough.

2. Frame Control

   The Frame Control field takes one byte and each bit has a different meaning.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Meaning</th>
</tr>
</thead>
</table>
   | 0x01 | Indicates whether the frame is encrypted.  
   |      | • 1 means encrypted.  
   |      | • 0 means unencrypted.  
   |      | The encrypted part of the frame includes the full clear data before the DATA field is encrypted (no checksum). Control frame is not encrypted, so this bit is 0.  
   | 0x02 | Indicates whether a frame contains a checksum (such as SHA1, MD5, CRC) for the end of the frame. Data field includes sequence, data length, and clear text. Both the control frame and the data frame can choose whether to contain a check bit or not.  
   | 0x04 | Indicates the data direction.  
   |      | • 0 means from the mobile phone to the ESP device.  
   |      | • 1 means from the ESP device to the mobile phone.  
   | 0x08 | Indicates whether the other person is required to reply to an ACK.  
   |      | • 0 indicates not required to reply to an ACK.  
   |      | • 1 indicates required to reply to an ACK.  
   | 0x10 | Indicates whether there are subsequent data fragments.  
   |      | • 0 indicates that there is no subsequent data fragment for this frame.  
   |      | • 1 indicates that there are subsequent data fragments which used to transmit longer data.  
   |      | In the case of a frag frame, the total length of the current content section + subsequent content section is given in the first two bytes of the data field (that is, the content data of the maximum support 64 K).  
   | 0x10-0x80 | Reserved |

3. Sequence Number

   The Sequence Number field is the field for sequence control. When a frame is sent, the value of this field is automatically incremented by 1 regardless of the type of frame, which prevents Replay Attack. The sequence would be cleared after each reconnection.

4. Data Length

   The Data Length field indicates the length of the data field, which does not include CheckSum.

5. Data

   Content of the Data field can be different according to various values of Type or Subtype. Please refer to the table above.

6. CheckSum

   The CheckSum field takes two bytes, which is used to check “sequence + data length + clear text data”.

4.3.5 The Security Implementation of ESP32

1. Securing Data

   To ensure that the transmission of the Wi-Fi SSID and password is secure, the message needs to be encrypted using symmetric encryption algorithms, such as AES, DES, and so on. Before using symmetric encryption algorithms, the devices are required to negotiate (or generate) a shared key using an asymmetric encryption algorithm (DH, RSA, ECC, etc).

2. Ensuring Data Integrity
To ensure data integrity, you need to add a checksum algorithm, such as SHA1, MD5, CRC, etc.

3. Securing Identity (Signature)
Algorithm like RSA can be used to secure identity. But for DH, it needs other algorithms as an companion for signature.

4. Replay Attack Prevention
It is added to the Sequence Number field and used during the checksum verification.
For the coding of ESP32, you can determine and develop the security processing, such as key negotiation. The mobile application sends the negotiation data to ESP32, and then the data will be sent to the application layer for processing. If the application layer does not process it, you can use the DH encryption algorithm provided by BluFi to negotiate the key.

The application layer needs to register several security-related functions to BluFi:

```c
typedef void (*esp_blufi_negotiate_data_handler_t)(uint8_t *data, int len, uint8_t *output_data, int *output_len, bool *need_free)
```

This function is for ESP32 to receive normal data during negotiation. After processing is completed, the data will be transmitted using Output_data and Output_len.

BluFi will send output_data from Negotiate_data_handler after Negotiate_data_handler is called.

Here are two “_**”, which means the length of the data to be emitted is unknown. Therefore, it requires the function to allocate itself (malloc) or point to the global variable to inform whether the memory needs to be freed by NEED_FREE.

```c
typedef int (*esp_blufi_encrypt_func_t)(uint8_t iv8, uint8_t *crypt_data, int *crypt_len)
```

The data to be encrypted and decrypted must be in the same length. The IV8 is an 8-bit sequence value of frames, which can be used as a 8-bit of IV.

```c
typedef int (*esp_blufi_decrypt_func_t)(uint8_t iv8, uint8_t *crypt_data, int *crypt_len)
```

The data to be encrypted and decrypted must be in the same length. The IV8 is an 8-bit sequence value of frames, which can be used as an 8-bit of IV.

```c
typedef uint16_t (*esp_blufi_checksum_func_t)(uint8_t iv8, uint8_t *data, int len)
```

This function is used to compute CheckSum and return a value of CheckSum. BluFi uses the returned value to compare the CheckSum of the frame.

### 4.3.6 GATT Related Instructions

#### UUID

BluFi Service UUID: 0xFFFF, 16 bit
BluFi (the mobile -> ESP32): 0xFF01, writable
Blufi (ESP32 -> the mobile phone): 0xFF02, readable and callable

### 4.4 Bootloader

The ESP-IDF Software Bootloader performs the following functions:

1. Minimal initial configuration of internal modules;
2. Initialize Flash Encryption and/or Secure features, if configured;
3. Select the application partition to boot, based on the partition table and ota_data (if any);
4. Load this image to RAM (IRAM & DRAM) and transfer management to the image that was just loaded. Bootloader is located at the address 0x1000 in the flash.

For a full description of the startup process including the ESP-IDF bootloader, see Application Startup Flow.

### 4.4.1 Bootloader Compatibility

It is recommended to update to newer versions of ESP-IDF; when they are released. The OTA (over the air) update process can flash new apps in the field but cannot flash a new bootloader. For this reason, the bootloader supports booting apps built from newer versions of ESP-IDF.

The bootloader does not support booting apps from older versions of ESP-IDF. When updating ESP-IDF manually on an existing product that might need to downgrade the app to an older version, keep using the older ESP-IDF bootloader binary as well.

**Note:** If testing an OTA update for an existing product in production, always test it using the same ESP-IDF bootloader binary that is deployed in production.

#### Before ESP-IDF V2.1

Bootloaders built from very old versions of ESP-IDF (before ESP-IDF V2.1) perform less hardware configuration than newer versions. When using a bootloader from these early ESP-IDF versions and building a new app, enable the config option `CONFIG_APP_COMPATIBLE_PRE_V2_1_BOOTLOADERS`.

#### Before ESP-IDF V3.1

Bootloaders built from versions of ESP-IDF before V3.1 do not support MD5 checksums in the partition table binary. When using a bootloader from these ESP-IDF versions and building a new app, enable the config option `CONFIG_APP_COMPATIBLE_PRE_V3_1_BOOTLOADERS`.

#### Before ESP-IDF V5.1

Bootloaders built from versions of ESP-IDF prior to V5.1 do not support `CONFIG_ESP_SYSTEM_ESP32_SRAM1_REGION_AS_IRAM`. When using a bootloader from these ESP-IDF versions and building a new app you should not use this option.

#### SPI Flash Configuration

Each ESP-IDF application or bootloader .bin file contains a header with `CONFIG_ESPTOOLPY_FLASHMODE`, `CONFIG_ESPTOOLPY_FLASHFREQ`, `CONFIG_ESPTOOLPY_FLASHSIZE` embedded in it. These are used to configure the SPI flash during boot.

The First stage bootloader in ROM reads the Second stage bootloader header information from flash and uses this information to load the rest of the Second stage bootloader from flash. However, at this time the system clock speed is lower than configured and not all flash modes are supported. When the Second stage bootloader then runs, it will reconfigure the flash using values read from the currently selected app binary’s header (and NOT from the Second stage bootloader header). This allows an OTA update to change the SPI flash settings in use.

Bootloaders prior to ESP-IDF V4.0 used the bootloader’s own header to configure the SPI flash, meaning these values could not be changed in an update. To maintain compatibility with older bootloaders, the app re-initializes the flash settings during app startup using the configuration found in the app header.
4.4.2 Log Level

The default bootloader log level is “Info”. By setting the `CONFIG_BOOTLOADER_LOG_LEVEL` option, it’s possible to increase or decrease this level. This log level is separate from the log level used in the app (see Logging library).

Reducing bootloader log verbosity can improve the overall project boot time by a small amount.

4.4.3 Factory Reset

Sometimes it is desirable to have a way for the device to fall back to a known-good state, in case of some problem with an update.

To roll back to the original “factory” device configuration and clear any user settings, configure the config item `CONFIG_BOOTLOADER_FACTORY_RESET` in the bootloader.

The factory reset mechanism allows the device to be factory reset in two ways:

- Clear one or more data partitions. The `CONFIG_BOOTLOADER_DATA_FACTORY_RESET` option allows users to specify which data partitions will be erased when the factory reset is executed.
  
  Users can specify the names of partitions as a comma-delimited list with optional spaces for readability. (Like this: `nvs, phy_init, nvs_custom`).
  
  Make sure that the names of partitions specified in the option are the same as those found in the partition table.
  
  Partitions of type “app” cannot be specified here.

- Boot from “factory” app partition. Enabling the `CONFIG_BOOTLOADER_OTA_DATA_ERASE` option will cause the device to boot from the default “factory” app partition after a factory reset (or if there is no factory app partition in the partition table then the default ota app partition is selected instead). This reset process involves erasing the OTA data partition which holds the currently selected OTA partition slot. The “factory” app partition slot (if it exists) is never updated via OTA, so resetting to this allows reverting to a “known good” firmware application.

Either or both of these configuration options can be enabled independently.

In addition, the following configuration options control the reset condition:

- `CONFIG_BOOTLOADER_NUM_PIN_FACTORY_RESET` - The input GPIO number used to trigger a factory reset. This GPIO must be pulled low or high (configurable) on reset to trigger this.

- `CONFIG_BOOTLOADER_HOLD_TIME_GPIO` - This is hold time of GPIO for reset/test mode (by default 5 seconds). The GPIO must be held continuously for this period of time after reset before a factory reset or test partition boot (as applicable) is performed.

- `CONFIG_BOOTLOADER_FACTORY_RESET_PIN_LEVEL` - Configure whether a factory reset should trigger on a high or low level of the GPIO. If the GPIO has an internal pullup then this is enabled before the pin is sampled, consult the ESP32 datasheet for details on pin internal pullups.

If an application needs to know if the factory reset has occurred, users can call the function `bootloader_common_get_rtc_retain_mem_factory_reset_state()`. If the status is read as true, the function will return the status, indicating that the factory reset has occurred. The function then resets the status to false for subsequent factory reset judgement.

If the status is read as false, the function will return the status, indicating that the factory reset has not occurred, or the memory where this status is stored is invalid.

Note that this feature reserves some RTC FAST memory (the same size as the `CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP` feature).

4.4.4 Boot from Test Firmware

It’s possible to write a special firmware app for testing in production, and boot this firmware when needed. The project partition table will need a dedicated app partition entry for this testing app, type `app` and subtype `test` (see Partition Tables).
Implementing a dedicated test app firmware requires creating a totally separate ESP-IDF project for the test app (each project in ESP-IDF only builds one app). The test app can be developed and tested independently of the main project, and then integrated at production testing time as a pre-compiled .bin file which is flashed to the address of the main project’s test app partition.

To support this functionality in the main project’s bootloader, set the configuration item `CONFIG_BOOTLOADER_APP_TEST` and configure the following two items:

- `CONFIG_BOOTLOADER_NUM_PIN_APP_TEST` - GPIO number to boot TEST partition. The selected GPIO will be configured as an input with internal pull-up enabled. To trigger a test app, this GPIO must be pulled low on reset. Once the GPIO input is released (allowing it to be pulled up) and the device has been reboot, the normally configured application will boot (factory or any OTA app partition slot).
- `CONFIG_BOOTLOADER_HOLD_TIME_GPIO` - this is hold time of GPIO for reset/test mode (by default 5 seconds). The GPIO must be held low continuously for this period of time after reset before a factory reset or test partition boot (as applicable) is performed.

### 4.4.5 Rollback

Rollback and anti-rollback features must be configured in the bootloader as well.

Consult the *App rollback* and *Anti-rollback* sections in the *OTA API reference document*.

### 4.4.6 Watchdog

By default, the hardware RTC Watchdog timer remains running while the bootloader is running and will automatically reset the chip if no app has successfully started after 9 seconds.

- The timeout period can be adjusted by setting `CONFIG_BOOTLOADER_WDT_TIME_MS` and recompiling the bootloader.
- The app’s behaviour can be adjusted so the RTC Watchdog remains enabled after app startup. The Watchdog would need to be explicitly reset (i.e., fed) by the app to avoid a reset. To do this, set the `CONFIG_BOOTLOADER_WDT_DISABLE_IN_USER_CODE` option, modify the app as needed, and then recompile the app.
- The RTC Watchdog can be disabled in the bootloader by disabling the `CONFIG_BOOTLOADER_WDT_ENABLE` setting and recompiling the bootloader. This is not recommended.

### 4.4.7 Bootloader Size

When enabling additional bootloader functions, including Flash Encryption or Secure Boot, and especially if setting a high `CONFIG_BOOTLOADER_LOG_LEVEL` level, then it is important to monitor the bootloader .bin file’s size.

When using the default `CONFIG_PARTITION_TABLE_OFFSET` value 0x8000, the size limit is 0x8000 bytes.

If the bootloader binary is too large, then the bootloader build will fail with an error “Bootloader binary size [...] is too large for partition table offset”. If the bootloader binary is flashed anyhow then the ESP32 will fail to boot - errors will be logged about either invalid partition table or invalid bootloader checksum.

Options to work around this are:

- Set *bootloader compiler optimization* back to “Size” if it has been changed from this default value.
- Reduce *bootloader log level*. Setting log level to Warning, Error or None all significantly reduce the final binary size (but may make it harder to debug).
- Set `CONFIG_PARTITION_TABLE_OFFSET` to a higher value than 0x8000, to place the partition table later in the flash. This increases the space available for the bootloader. If the partition table CSV file contains explicit partition offsets, they will need changing so no partition has an offset lower than `CONFIG_PARTITION_TABLE_OFFSET + 0x1000`. (This includes the default partition CSV files supplied with ESP-IDF.)
When Secure Boot V2 is enabled, there is also an absolute binary size limit of 48 KB (0xC000 bytes) (excluding the 4 KB signature), because the bootloader is first loaded into a fixed size buffer for verification.

4.4.8 Fast Boot from Deep-Sleep

The bootloader has the `CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP` option which allows the wake-up time from Deep-sleep to be reduced (useful for reducing power consumption). This option is available when `CONFIG_SECURE_BOOT` option is disabled. Reduction of time is achieved due to the lack of image verification. During the first boot, the bootloader stores the address of the application being launched in the RTC FAST memory. And during the awakening, this address is used for booting without any checks, thus fast loading is achieved.

4.4.9 Custom Bootloader

The current bootloader implementation allows a project to extend it or modify it. There are two ways of doing it: by implementing hooks or by overriding it. Both ways are presented in `custom_bootloader` folder in ESP-IDF examples:

- `bootloader_hooks` which presents how to connect some hooks to the bootloader initialization
- `bootloader_override` which presents how to override the bootloader implementation

In the bootloader space, you cannot use the drivers and functions from other components. If necessary, then the required functionality should be placed in the project’s `bootloader_components` directory (note that this will increase its size).

If the bootloader grows too large then it can collide with the partition table, which is flashed at offset 0x8000 by default. Increase the `partition table offset` value to place the partition table later in the flash. This increases the space available for the bootloader.

4.5 Build System

This document explains the implementation of the ESP-IDF build system and the concept of “components”. Read this document if you want to know how to organize and build a new ESP-IDF project or component.

4.5.1 Overview

An ESP-IDF project can be seen as an amalgamation of a number of components. For example, for a web server that shows the current humidity, there could be:

- The ESP-IDF base libraries (libc, ROM bindings, etc)
- The Wi-Fi drivers
- A TCP/IP stack
- The FreeRTOS operating system
- A web server
- A driver for the humidity sensor
- Main code tying it all together

ESP-IDF makes these components explicit and configurable. To do that, when a project is compiled, the build system will look up all the components in the ESP-IDF directories, the project directories and (optionally) in additional custom component directories. It then allows the user to configure the ESP-IDF project using a text-based menu system to customize each component. After the components in the project are configured, the build system will compile the project.
Chapter 4. API Guides

Concepts

- A “project” is a directory that contains all the files and configuration to build a single “app” (executable), as well as additional supporting elements such as a partition table, data/filesystem partitions, and a bootloader.
- “Project configuration” is held in a single file called `sdkconfig` in the root directory of the project. This configuration file is modified via `idf.py menuconfig` to customize the configuration of the project. A single project contains exactly one project configuration.
- An “app” is an executable that is built by ESP-IDF. A single project will usually build two apps - a “project app” (the main executable, i.e., your custom firmware) and a “bootloader app” (the initial bootloader program which launches the project app).
- “Components” are modular pieces of standalone code that are compiled into static libraries (.a files) and linked to an app. Some are provided by ESP-IDF itself, others may be sourced from other places.
- “Target” is the hardware for which an application is built. A full list of supported targets in your version of ESP-IDF can be seen by running `idf.py –list-targets`.

Some things are not part of the project:

- “ESP-IDF” is not part of the project. Instead, it is standalone, and linked to the project via the `IDF_PATH` environment variable which holds the path of the `esp-idf` directory. This allows the IDF framework to be decoupled from your project.
- The toolchain for compilation is not part of the project. The toolchain should be installed in the system command line PATH.

4.5.2 Using the Build System

idf.py

The `idf.py` command-line tool provides a front-end for easily managing your project builds. It manages the following tools:

- **CMake**, which configures the project to be built
- **Ninja** which builds the project
- `esptool.py` for flashing the target.

You can read more about configuring the build system using `idf.py` [here](#).

Using CMake Directly

`idf.py` is a wrapper around **CMake** for convenience. However, you can also invoke CMake directly if you prefer.

When `idf.py` does something, it prints each command that it runs for easy reference. For example, the `idf.py build` command is the same as running these commands in a bash shell (or similar commands for Windows Command Prompt):

```
mkdir -p build
cd build
cmake .. -G Ninja  # or 'Unix Makefiles'
ninja
```

In the above list, the `cmake` command configures the project and generates build files for use with the final build tool. In this case, the final build tool is `Ninja`: running `ninja` actually builds the project.

It’s not necessary to run `cmake` more than once. After the first build, you only need to run `ninja` each time. `ninja` will automatically re-invokes `cmake` if the project needs reconfiguration.

If using CMake with `ninja` or `make`, there are also targets for more of the `idf.py` sub-commands. For example, running `make menuconfig` or `ninja menuconfig` in the build directory will work the same as `idf.py menuconfig`.
Chapter 4. API Guides

**Note:** If you’re already familiar with CMake, you may find the ESP-IDF CMake-based build system unusual because it wraps a lot of CMake’s functionality to reduce boilerplate. See [writing pure CMake components](#) for some information about writing more “CMake style” components.

**Flashling with Ninja or Make** It’s possible to build and flash directly from ninja or make by running a target like:

```
ninja flash
```

Or:

```
make app-flash
```

Available targets are: flash, app-flash (app only), bootloader-flash (bootloader only).

When flashing this way, optionally set the ESPPORT and ESPBAUD environment variables to specify the serial port and baud rate. You can set environment variables in your operating system or IDE project. Alternatively, set them directly on the command line:

```
ESPPORT=/dev/ttyUSB0 ninja flash
```

**Note:** Providing environment variables at the start of the command like this is Bash shell Syntax. It will work on Linux and macOS. It won’t work when using Windows Command Prompt, but it will work when using Bash-like shells on Windows.

Or:

```
make -j3 app-flash ESPPORT=COM4 ESPBAUD=2000000
```

**Note:** Providing variables at the end of the command line is make syntax, and works for make on all platforms.

**Using CMake in an IDE**

You can also use an IDE with CMake integration. The IDE will want to know the path to the project’s CMakeLists.txt file. IDEs with CMake integration often provide their own build tools (CMake calls these “generators”) to build the source files as part of the IDE.

When adding custom non-build steps like “flash” to the IDE, it is recommended to execute idf.py for these “special” commands.

For more detailed information about integrating ESP-IDF with CMake into an IDE, see [Build System Metadata](#).

**Setting up the Python Interpreter**

ESP-IDF works well with Python version 3.7+.

idf.py and other Python scripts will run with the default Python interpreter, i.e. python. You can switch to a different one like python3 $IDF_PATH/tools/idf.py ... or you can set up a shell alias or another script to simplify the command.

If using CMake directly, running cmake -D PYTHON=python3 ... will cause CMake to override the default Python interpreter.

If using an IDE with CMake, setting the PYTHON value as a CMake cache override in the IDE UI will override the default Python interpreter.
To manage the Python version more generally via the command line, check out the tools pyenv or virtualenv. These let you change the default Python version.

### 4.5.3 Example Project

An example project directory tree might look like this:

```
- myProject/
  - CMakeLists.txt
  - sdkconfig
    - components/ - component1/ - CMakeLists.txt
    - Kconfig
    - src1.c
    - component2/ - CMakeLists.txt
    - Kconfig
    - src1.c
    - include/ - component2.h
  - main/ - CMakeLists.txt
    - src1.c
    - src2.c
  - build/
```

This example “myProject” contains the following elements:

- A top-level project CMakeLists.txt file. This is the primary file which CMake uses to learn how to build the project; and may set project-wide CMake variables. It includes the file /tools/cmake/project.cmake which implements the rest of the build system. Finally, it sets the project name and defines the project.
- “sdkconfig” project configuration file. This file is created/updated when idf.py menuconfig runs, and holds the configuration for all of the components in the project (including ESP-IDF itself). The “sdkconfig” file may or may not be added to the source control system of the project.
- Optional “components” directory contains components that are part of the project. A project does not have to contain custom components of this kind, but it can be useful for structuring reusable code or including third-party components that aren’t part of ESP-IDF. Alternatively, EXTRA_COMPONENT_DIRS can be set in the top-level CMakeLists.txt to look for components in other places.
- “main” directory is a special component that contains source code for the project itself. “main” is a default name, the CMake variable COMPONENT_DIRS includes this component but you can modify this variable. See the renaming main section for more info. If you have a lot of source files in your project, we recommend grouping most into components instead of putting them all in “main”.
- “build” directory is where the build output is created. This directory is created by idf.py if it doesn’t already exist. CMake configures the project and generates interim build files in this directory. Then, after the main build process is run, this directory will also contain interim object files and libraries as well as final binary output files. This directory is usually not added to source control or distributed with the project source code.

Component directories each contain a component CMakeLists.txt file. This file contains variable definitions to control the build process of the component, and its integration into the overall project. See Component CMakeLists Files for more details.

Each component may also include a Kconfig file defining the component configuration options that can be set via menuconfig. Some components may also include Kconfig.projbuild and project_include.cmake files, which are special files for overriding parts of the project.

### 4.5.4 Project CMakeLists File

Each project has a single top-level CMakeLists.txt file that contains build settings for the entire project. By default, the project CMakeLists can be quite minimal.
Minimal Example CMakeLists

Minimal project:

```cmake
cmake_minimum_required(VERSION 3.16)
include($ENV{IDF_PATH}/tools/cmake/project.cmake)
project(myProject)
```

**Mandatory Parts**

The inclusion of these three lines, in the order shown above, is necessary for every project:

- `cmake_minimum_required(VERSION 3.16)` tells CMake the minimum version that is required to build the project. ESP-IDF is designed to work with CMake 3.16 or newer. This line must be the first line in the CMakeLists.txt file.
- `include($ENV{IDF_PATH}/tools/cmake/project.cmake)` pulls in the rest of the CMake functionality to configure the project, discover all the components, etc.
- `project(myProject)` creates the project itself, and specifies the project name. The project name is used for the final binary output files of the app - i.e myProject.elf, myProject.bin. Only one project can be defined per CMakeLists file.

**Optional Project Variables**

These variables all have default values that can be overridden for custom behavior. Look in `/tools/cmake/project.cmake` for all of the implementation details.

- `COMPONENT_DIRS`: Directories to search for components. Defaults to IDF_PATH/components, PROJECT_DIR/components, and EXTRA_COMPONENT_DIRS. Override this variable if you don’t want to search for components in these places.
- `EXTRA_COMPONENT_DIRS`: Optional list of additional directories to search for components. Paths can be relative to the project directory, or absolute.
- `COMPONENTS`: A list of component names to build into the project. Defaults to all components found in the COMPONENT_DIRS directories. Use this variable to “trim down” the project for faster build times. Note that any component which “requires” another component via the REQUIRES or PRIV_REQUIRES arguments on component registration will automatically have it added to this list, so the COMPONENTS list can be very short.

Any paths in these variables can be absolute paths, or set relative to the project directory.

To set these variables, use the `cmake set command` i.e `set(VARIABLE "VALUE")`. The `set()` commands should be placed after the `cmake_minimum(...) line but before the include(...) line.

**Renaming main Component**

The build system provides special treatment to the main component. It is a component that gets automatically added to the build provided that it is in the expected location, PROJECT_DIR/main. All other components in the build are also added as its dependencies, saving the user from hunting down dependencies and providing a build that works right out of the box. Renaming the main component causes the loss of these behind-the-scenes heavy lifting, requiring the user to specify the location of the newly renamed component and manually specify its dependencies. Specifically, the steps to renaming main are as follows:

1. Rename main directory.
2. Set `EXTRA_COMPONENT_DIRS` in the project CMakeLists.txt to include the renamed main directory.
3. Specify the dependencies in the renamed component’s CMakeLists.txt file via REQUIRES or PRIV_REQUIRES arguments on component registration.
Overriding Default Build Specifications

The build sets some global build specifications (compile flags, definitions, etc.) that get used in compiling all sources from all components.

For example, one of the default build specifications set is the compile option `-Wextra`. Suppose a user wants to use override this with `-Wno-extra`, it should be done after `project()`:

```cmake
cmake_minimum_required(VERSION 3.16)
include(${ENV{IDF_PATH}}/tools/cmake/project.cmake)
project(myProject)

idf_build_set_property(COMPILE_OPTIONS "-Wno-error" APPEND)
```

This ensures that the compile options set by the user won’t be overridden by the default build specifications, since the latter are set inside `project()`.

4.5.5 Component CMakeLists Files

Each project contains one or more components. Components can be part of ESP-IDF, part of the project’s own components directory, or added from custom component directories (see above).

A component is any directory in the `COMPONENT_DIRS` list which contains a `CMakeLists.txt` file.

Searching for Components

The list of directories in `COMPONENT_DIRS` is searched for the project’s components. Directories in this list can either be components themselves (ie they contain a `CMakeLists.txt` file), or they can be top-level directories whose sub-directories are components.

When CMake runs to configure the project, it logs the components included in the build. This list can be useful for debugging the inclusion/exclusion of certain components.

Multiple Components with the Same Name

When ESP-IDF is collecting all the components to compile, it will do this in the order specified by `COMPONENT_DIRS`; by default, this means ESP-IDF’s internal components first (`IDF_PATH/components`), then any components in directories specified in `EXTRA_COMPONENT_DIRS`, and finally the project’s components (`PROJECT_DIR/components`). If two or more of these directories contain component sub-directories with the same name, the component in the last place searched is used. This allows, for example, overriding ESP-IDF components with a modified version by copying that component from the ESP-IDF components directory to the project components directory and then modifying it there. If used in this way, the ESP-IDF directory itself can remain untouched.

Note: If a component is overridden in an existing project by moving it to a new location, the project will not automatically see the new component path. Run `idf.py reconfigure` (or delete the project build folder) and then build again.

Minimal Component CMakeLists

The minimal component `CMakeLists.txt` file simply registers the component to the build system using `idf_component_register`:

```cmake
idf_component_register(SRCS "foo.c" "bar.c"
                      INCLUDE_DIRS "include"
                      REQUIRES mbedtls)
```
SRCS is a list of source files (*.c, *.cpp, *.cc, *.S). These source files will be compiled into the component library.

INCLUDE_DIRS is a list of directories to add to the global include search path for any component which requires this component, and also the main source files.

REQUIRES is not actually required, but it is very often required to declare what other components this component will use. See component requirements.

A library with the name of the component will be built and linked to the final app.

Directories are usually specified relative to the CMakeLists.txt file itself, although they can be absolute.

There are other arguments that can be passed to idf_component_register. These arguments are discussed here.

See example component requirements and example component CMakeLists for more complete component CMakeLists.txt examples.

**Preset Component Variables**

The following component-specific variables are available for use inside component CMakeLists, but should not be modified:

- COMPONENT_DIR: The component directory. Evaluates to the absolute path of the directory containing CMakeLists.txt. The component path cannot contain spaces. This is the same as the CMAKE_CURRENT_SOURCE_DIR variable.
- COMPONENT_NAME: Name of the component. Same as the name of the component directory.
- COMPONENT_ALIAS: Alias of the library created internally by the build system for the component.
- COMPONENT_LIB: Name of the library created internally by the build system for the component.

The following variables are set at the project level, but available for use in component CMakeLists:

- CONFIG_*: Each value in the project configuration has a corresponding variable available in cmake. All names begin with CONFIG_. More information here.
- ESP_PLATFORM: Set to 1 when the CMake file is processed within the ESP-IDF build system.

**Build/Project Variables**

The following are some project/build variables that are available as build properties and whose values can be queried using idf_build_get_property from the component CMakeLists.txt:

- PROJECT_NAME: Name of the project, as set in project CMakeLists.txt file.
- PROJECT_DIR: Absolute path of the project directory containing the project CMakeLists. Same as the CMAKE_CURRENT_SOURCE_DIR variable.
- COMPONENTS: Names of all components that are included in this build, formatted as a semicolon-delimited CMake list.
- IDF_VER: Git version of ESP-IDF (produced by git describe)
- IDF_VERSION_MAJOR, IDF_VERSION_MINOR, IDF_VERSION_PATCH: Components of ESP-IDF version, to be used in conditional expressions. Note that this information is less precise than that provided by IDF_VER variable. v4.0-dev-*, v4.0-beta1, v4.0-rc1 and v4.0 will all have the same values of IDF_VERSION_* variables, but different IDF_VER values.
- IDF_TARGET: Name of the target for which the project is being built.
- PROJECT_VER: Project version.
  - If CONFIG_APP_PROJECT_VER_FROM_CONFIG option is set, the value of CONFIG_APP_PROJECT_VER will be used.
  - Else, if PROJECT_VER variable is set in project CMakeLists.txt file, its value will be used.
  - Else, if the PROJECT_DIR/version.txt exists, its contents will be used as PROJECT_VER.
  - Else, if the project is located inside a Git repository, the output of git description will be used.
  - Otherwise, PROJECT_VER will be “1”.
- EXTRA_PARTITION_SUBTYPES: CMake list of extra partition subtypes. Each subtype description is a comma-separated string with type_name, subtype_name, numeric_value format. Components may add new subtypes by appending them to this list.
Other build properties are listed here.

**Controlling Component Compilation**

To pass compiler options when compiling source files belonging to a particular component, use the `target_compile_options` function:

```cmake
target_compile_options(${COMPONENT_LIB} PRIVATE -Wno-unused-variable)
```

To apply the compilation flags to a single source file, use the CMake `set_source_files_properties` command:

```cmake
set_source_files_properties(mysrc.c
    PROPERTIES COMPILE_FLAGS -Wno-unused-variable
)
```

This can be useful if there is upstream code that emits warnings.

When using these commands, place them after the call to `idf_component_register` in the component CMakeLists file.

### 4.5.6 Component Configuration

Each component can also have a Kconfig file, alongside CMakeLists.txt. This contains configuration settings to add to the configuration menu for this component.

These settings are found under the “Component Settings” menu when menuconfig is run.

To create a component Kconfig file, it is easiest to start with one of the Kconfig files distributed with ESP-IDF.

For an example, see Adding conditional configuration.

### 4.5.7 Preprocessor Definitions

The ESP-IDF build system adds the following C preprocessor definitions on the command line:

- **ESP_PLATFORM**: Can be used to detect that build happens within ESP-IDF.
- **IDF_VER**: Defined to a git version string. E.g. v2.0 for a tagged release or v1.0-275-g0efaa4f for an arbitrary commit.

### 4.5.8 Component Requirements

When compiling each component, the ESP-IDF build system recursively evaluates its dependencies. This means each component needs to declare the components that it depends on ("requires").

**When Writing a Component**

```cmake
idf_component_register(...
    REQUIRES mbedtls
    PRIV_REQUIRES console spiffs)
```

- **REQUIRES** should be set to all components whose header files are #included from the public header files of this component.
- **PRIV_REQUIRES** should be set to all components whose header files are #included from any source files in this component, unless already listed in `REQUIRES`. Also, any component which is required to be linked in order for this component to function correctly.
• The values of REQUIRE and PRIV_REQUIRES should not depend on any configuration choices (CONFIG_XXX macros). This is because requirements are expanded before the configuration is loaded. Other component variables (like include paths or source files) can depend on configuration choices.
• Not setting either or both REQUIRE variables is fine. If the component has no requirements except for the Common component requirements needed for RTOS, libc, etc.

If a component only supports some target chips (values of IDF_TARGET) then it can specify REQUIRED_IDF_TARGETS in the idf_component_register call to express these requirements. In this case, the build system will generate an error if the component is included in the build, but does not support the selected target.

**Note:** In CMake terms, REQUIRE & PRIV_REQUIRES are approximate wrappers around the CMake functions target_link_libraries(... PUBLIC ...) and target_link_libraries(... PRIVATE ...)

---

**Example of Component Requirements**

Imagine there is a car component, which uses the engine component, which uses the spark_plug component:

```
- autoProject/
  - CMakeLists.txt
- components/ - car/ - CMakeLists.txt
  - car.c
  - car.h
- engine/ - CMakeLists.txt
  - engine.c
  - include/ - engine.h
- spark_plug/ - CMakeLists.txt
  - spark_plug.c
  - spark_plug.h
```

**Car Component** The car.h header file is the public interface for the car component. This header includes engine.h directly because it uses some declarations from this header:

```c
/* car.h */
#include "engine.h"

#ifdef ENGINE_IS_HYBRID
#define CAR_MODEL "Hybrid"
#endif
```

And car.c includes car.h as well:

```c
/* car.c */
#include "car.h"
```

This means the car/CMakeLists.txt file needs to declare that car requires engine:

```c
idf_component_register(SRCS "car.c"
  INCLUDE_DIRS "."
  REQUIRES engine)
```

• SRCS gives the list of source files in the car component.
• INCLUDE_DIRS gives the list of public include directories for this component. Because the public interface is car.h, the directory containing car.h is listed here.
• REQUIRES gives the list of components required by the public interface of this component. Because car.h is a public header and includes a header from engine, we include engine here. This makes sure that any other component which includes car.h will be able to recursively include the required engine.h also.
Engine Component  The engine component also has a public header file include/engine.h, but this header is simpler:

```c
/* engine.h */
#define ENGINE_IS_HYBRID

void engine_start(void);
```

The implementation is in engine.c:

```c
/* engine.c */
#include "engine.h"
#include "spark_plug.h"
...
```

In this component, engine depends on spark_plug but this is a private dependency. spark_plug.h is needed to compile engine.c, but not needed to include engine.h.

This means that the engine/CMakeLists.txt file can use PRIV_REQUIRES:

```c
idf_component_register(SRCS "engine.c" 
  INCLUDE_DIRS "include" 
  PRIV_REQUIRES "spark_plug")
```

As a result, source files in the car component don’t need the spark_plug include directories added to their compiler search path. This can speed up compilation, and stops compiler command lines from becoming longer than necessary.

Spark Plug Component  The spark_plug component doesn’t depend on anything else. It has a public header file spark_plug.h, but this doesn’t include headers from any other components.

This means that the spark_plug/CMakeLists.txt file doesn’t need any REQUIRES or PRIV_REQUIRES clauses:

```c
idf_component_register(SRCS "spark_plug.c" 
  INCLUDE_DIRS ".")
```

Source File Include Directories

Each component’s source file is compiled with these include path directories, as specified in the passed arguments to idf_component_register:

```c
idf_component_register(...) 
  INCLUDE_DIRS "include" 
  PRIV_INCLUDE_DIRS "other"
```

- The current component’s INCLUDE_DIRS and PRIV_INCLUDE_DIRS.
- The INCLUDE_DIRS belonging to all other components listed in the REQUIRES and PRIV_REQUIRES parameters (ie all the current component’s public and private dependencies).
- Recursively, all of the INCLUDE_DIRS of those components REQUIRES lists (ie all public dependencies of this component’s dependencies, recursively expanded).

Main Component Requirements

The component named main is special because it automatically requires all other components in the build. So it’s not necessary to pass REQUIRES or PRIV_REQUIRES to this component. See renaming main for a description of what needs to be changed if no longer using the main component.
Common Component Requirements

To avoid duplication, every component automatically requires some “common” IDF components even if they are not mentioned explicitly. Headers from these components can always be included.

The list of common components is: cxx, newlib, freertos, esp_hw_support, heap, log, soc, hal, esp_rom, esp_common, esp_system, xtensa/riscv.

Including Components in the Build

- By default, every component is included in the build.
- If you set the COMPONENTS variable to a minimal list of components used directly by your project, then the build will expand to also include required components. The full list of components will be:
  - Components mentioned explicitly in COMPONENTS.
  - Those components’ requirements (evaluated recursively).
  - The “common” components that every component depends on.
- Setting COMPONENTS to the minimal list of required components can significantly reduce compile times.

Circular Dependencies

It’s possible for a project to contain Component A that requires (REQUIRES or PRIV_REQUIRES) Component B, and Component B that requires Component A. This is known as a dependency cycle or a circular dependency.

CMake will usually handle circular dependencies automatically by repeating the component library names twice on the linker command line. However, this strategy does’t always work, and the build may fail with a linker error about “Undefined reference to …”, referencing a symbol defined by one of the components inside the circular dependency. This is particularly likely if there is a large circular dependency, i.e. A->B->C->D->A.

The best solution is to restructure the components to remove the circular dependency. In most cases, a software architecture without circular dependencies has desirable properties of modularity and clean layering and will be more maintainable in the long term. However, removing circular dependencies is not always possible.

To bypass a linker error caused by a circular dependency, the simplest workaround is to increase the CMake LINK_INTERFACE_MULTIPLICITY property of one of the component libraries. This causes CMake to repeat this library and its dependencies more than two times on the linker command line.

For example:

```makefile
set_property(TARGET ${COMPONENT_LIB} APPEND PROPERTY LINK_INTERFACE_MULTIPLICITY 3)
```

- This line should be placed after idf_component_register in the component CMakeLists.txt file.
- If possible, place this line in the component that creates the circular dependency by depending on a lot of other components. However, the line can be placed inside any component that is part of the cycle. Choosing the component that owns the source file shown in the linker error message, or the component that defines the symbol(s) mentioned in the linker error message, is a good place to start.
- Usually increasing the value to 3 (default is 2) is enough, but if this doesn’t work then try increasing the number further.
- Adding this option will make the linker command line longer, and the linking stage slower.

Advanced Workaround: Undefined Symbols

If only one or two symbols are causing a circular dependency, and all other dependencies are linear, then there is an alternative method to avoid linker errors: Specify the specific symbols required for the “reverse” dependency as undefined symbols at link time.

For example, if component A depends on component B but component B also needs to reference reverse_ops from component A (but nothing else), then you can add a line like the following to the component B CMakeLists.txt to resolve the cycle at link time:

```makefile
# This symbol is provided by 'Component A' at link time
target_link_libraries(${COMPONENT_LIB} INTERFACE "-u reverse_ops")
```


• The \(-u\) argument means that the linker will always include this symbol in the link, regardless of dependency ordering.

• This line should be placed after idf_component_register in the component CMakelists.txt file.

• If ‘Component B’ doesn’t need to access any headers of ‘Component A’, only link to a few symbol(s), then this line can be used instead of any REQUIRES from B to A. This further simplifies the component structure in the build system.

See the target_link_libraries documentation for more information about this CMake function.

Requirements in the Build System Implementation

• Very early in the CMake configuration process, the script expand_requirements.cmake is run. This script does a partial evaluation of all component CMakelists.txt files and builds a graph of component requirements (this graph may have cycles). The graph is used to generate a file component_depends.cmake in the build directory.

• The main CMake process then includes this file and uses it to determine the list of components to include in the build (internal BUILD_COMPONENTS variable). The BUILD_COMPONENTS variable is sorted so dependencies are listed first, however, as the component dependency graph has cycles this cannot be guaranteed for all components. The order should be deterministic given the same set of components and component dependencies.

• The value of BUILD_COMPONENTS is logged by CMake as “Component names: “

• Configuration is then evaluated for the components included in the build.

• Each component is included in the build normally and the CMakelists.txt file is evaluated again to add the component libraries to the build.

Component Dependency Order The order of components in the BUILD_COMPONENTS variable determines other orderings during the build:

• Order that project_include.cmake files are included in the project.

• Order that the list of header paths is generated for compilation (via \(-I\) argument). (Note that for a given component’s source files, only that component’s dependency’s header paths are passed to the compiler.)

Adding Link-Time Dependencies The ESP-IDF CMake helper function idf_component_add_link_dependency adds a link-only dependency between one component and another. In almost all cases, it is better to use the PRIV_REQUIRES feature in idf_component_register to create a dependency. However, in some cases, it’s necessary to add the link-time dependency of another component to this component, i.e., the reverse order to PRIV_REQUIRES (for example: Overriding Default Chip Drivers).

To make another component depend on this component at link time:

```make
idf_component_add_link_dependency(FROM other_component)
```

Place this line after the line with idf_component_register.

It’s also possible to specify both components by name:

```make
idf_component_add_link_dependency(FROM other_component TO that_component)
```

4.5.9 Overriding Parts of the Project

project_include.cmake

For components that have build requirements that must be evaluated before any component CMakelists files are evaluated, you can create a file called project_include.cmake in the component directory. This CMake file is included when project.cmake is evaluating the entire project.

project_include.cmake files are used inside ESP-IDF, for defining project-wide build features such as esptool.py command line arguments and the bootloader “special app”.

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Unlike component CMakeLists.txt files, when including a project_include.cmake file the current source directory (CMAKE_CURRENT_SOURCE_DIR and working directory) is the project directory. Use the variable COMPONENT_DIR for the absolute directory of the component.

Note that project_include.cmake isn’t necessary for the most common component uses, such as adding include directories to the project, or LDFLAGS to the final linking step. These values can be customized via the CMakeLists.txt file itself. See Optional Project Variables for details.

Note that project_include.cmake isn’t necessary for the most common component uses, such as adding include directories to the project, or LDFLAGS to the final linking step. These values can be customized via the CMakeLists.txt file itself. See Optional Project Variables for details.

project_include.cmake files are included in the order given in BUILD_COMPONENTS variable (as logged by CMake). This means that a component’s project_include.cmake file will be included after it’s all dependencies’ project_include.cmake files, unless both components are part of a dependency cycle. This is important if a project_include.cmake file relies on variables set by another component. See also above.

Take great care when setting variables or targets in a project_include.cmake file. As the values are included in the top-level project CMake pass, they can influence or break functionality across all components!

KConfig.projbuild

This is an equivalent to project_include.cmake for Component Configuration KConfig files. If you want to include configuration options at the top level of menuconfig, rather than inside the “Component Configuration” sub-menu, then these can be defined in the KConfig.projbuild file alongside the CMakeLists.txt file.

Take care when adding configuration values in this file, as they will be included across the entire project configuration. Where possible, it’s generally better to create a KConfig file for Component Configuration.

project_include.cmake files are used inside ESP-IDF, for defining project-wide build features such as esptool.py command line arguments and the bootloader “special app”.

Wrappers to Redefine or Extend Existing Functions

Thanks to the linker’s wrap feature, it is possible to redefine or extend the behavior of an existing ESP-IDF function. To do so, you will need to provide the following CMake declaration in your project’s CMakeLists.txt file:

```cmake
target_link_libraries(${COMPONENT_LIB} INTERFACE "-Wl,--wrap=function_to_redefine")
```

Where function_to_redefine is the name of the function to redefine or extend. This option will let the linker replace all the calls to function_to_redefine functions in the binary libraries with calls to __wrap_function_to_redefine function. Thus, you must define this new symbol in your application.

The linker will provide a new symbol named __real_function_to_redefine which points to the former implementation of the function to redefine. It can be called from the new implementation, making it an extension of the former one.

This mechanism is shown in the example build_system/wrappers. Check examples/build_system/wrappers/README.md for more details.

4.5.10 Configuration-Only Components

Special components which contain no source files, only Kconfig.projbuild and KConfig, can have a one-line CMakeLists.txt file which calls the function idf_component_register() with no arguments specified. This function will include the component in the project build, but no library will be built and no header files will be added to any included paths.

4.5.11 Debugging CMake

For full details about CMake and CMake commands, see the CMake v3.16 documentation.

Some tips for debugging the ESP-IDF CMake-based build system:
• When CMake runs, it prints quite a lot of diagnostic information including lists of components and component paths.
• Running `cmake -DDEBUG=1` will produce more verbose diagnostic output from the IDF build system.
• Running `cmake` with the `--trace` or `--trace-expand` options will give a lot of information about control flow. See the `cmake` command line documentation.

When included from a project CMakeLists file, the `project.cmake` file defines some utility modules and global variables and then sets `IDF_PATH` if it was not set in the system environment.

It also defines an overridden custom version of the built-in `CMake` project function. This function is overridden to add all of the ESP-IDF specific project functionality.

**Warning On Undefined Variables**

By default, the function of warnings on undefined variables is disabled.

To enable this function, we can pass the `--warn-uninitialized` flag to `CMake` or pass the `--cmake-warn-uninitialized` flag to `idf.py` so it will print a warning if an undefined variable is referenced in the build. This can be very useful to find buggy CMake files.

Browse the `/tools/cmake/project.cmake` file and supporting functions in `/tools/cmake/` for more details.

### 4.5.12 Example Component CMakeLists

Because the build environment tries to set reasonable defaults that will work most of the time, component `CMakeLists.txt` can be very small or even empty (see *Minimal Component CMakeLists*). However, overriding `preset_component_variables` is usually required for some functionality.

Here are some more advanced examples of component CMakeLists files.

**Adding Conditional Configuration**

The configuration system can be used to conditionally compile some files depending on the options selected in the project configuration.

Kconfig:

```plaintext
config FOO_ENABLE_BAR
  bool "Enable the BAR feature."
  help
    This enables the BAR feature of the FOO component.
```

CMakeLists.txt:

```plaintext
set(srcs "foo.c" "more_foo.c")

if(CONFIG_FOO_ENABLE_BAR)
  list(APPEND srcs "bar.c")
endif()

idf_component_register(SRCS "${srcs}"
  ...
)
```

This example makes use of the CMake `if` function and `list APPEND` function.

This can also be used to select or stub out an implementation, as such:

Kconfig:
Chapter 4. API Guides

config ENABLE_LCD_OUTPUT
  bool "Enable LCD output."
  help
    Select this if your board has an LCD.
config ENABLE_LCD_CONSOLE
  bool "Output console text to LCD"
  depends on ENABLE_LCD_OUTPUT
  help
    Select this to output debugging output to the LCD
config ENABLE_LCD_PLOT
  bool "Output temperature plots to LCD"
  depends on ENABLE_LCD_OUTPUT
  help
    Select this to output temperature plots

CMakeLists.txt:

```cmake
if(
  CONFIG_ENABLE_LCD_OUTPUT) 
  set(srcs lcd-real.c lcd-spi.c)
else() 
  set(srcs lcd-dummy.c)
endif()

# We need font if either console or plot is enabled 
if( CONFIG_ENABLE_LCD_CONSOLE OR CONFIG_ENABLE_LCD_PLOT )
  list(APPEND srcs "font.c")
endif()

idf_component_register(SRCS "${srcs}"
                       ...
```
This answer is adapted from the CMake FAQ entry, which contains some other examples that will also work with ESP-IDF builds.

In this example, logo.h will be generated in the current directory (the build directory) while logo.bmp comes with the component and resides under the component path. Because logo.h is a generated file, it should be cleaned when the project is cleaned. For this reason, it is added to the ADDITIONAL_CLEAN_FILES property.

**Note:** If generating files as part of the project CMakeLists.txt file, not a component CMakeLists.txt, then use build property PROJECT_DIR instead of ${COMPONENT_DIR} and ${PROJECT_NAME}.elf instead of ${COMPONENT_LIB}.

If a source file from another component included logo.h, then add_dependencies would need to be called to add a dependency between the two components, to ensure that the component source files were always compiled in the correct order.

### Embedding Binary Data

Sometimes you have a file with some binary or text data that you’d like to make available to your component, but you don’t want to reformat the file as a C source.

You can specify argument EMBED_FILES in the component registration, giving space-delimited names of the files to embed:

```
idf_component_register(...
    EMBED_FILES server_root_cert.der)
```

Or if the file is a string, you can use the variable EMBED_TXTFILES. This will embed the contents of the text file as a null-terminated string:

```
idf_component_register(...
    EMBED_TXTFILES server_root_cert.pem)
```

The file’s contents will be added to the .rodata section in flash, and are available via symbol names as follows:

```c
extern const uint8_t server_root_cert_pem_start[] asm("_binary_server_root_cert_pem_start");
extern const uint8_t server_root_cert_pem_end[] asm("_binary_server_root_cert_pem_end");
```

The names are generated from the full name of the file, as given in EMBED_FILES. Characters ., .. etc. are replaced with underscores. The _binary prefix in the symbol name is added by objcopy and is the same for both text and binary files.

To embed a file into a project, rather than a component, you can call the function target_add_binary_data like this:

```
target_add_binary_data(myproject.elf "main/data.bin" TEXT)
```

Place this line after the project() line in your project CMakeLists.txt file. Replace myproject.elf with your project name. The final argument can be TEXT to embed a null-terminated string, or BINARY to embed the content as-is.

For an example of using this technique, see the “main” component of the file_serving example protocols/http_server/file_serving/main/CMakeLists.txt - two files are loaded at build time and linked into the firmware.

It is also possible to embed a generated file:

```
add_custom_command(OUTPUT my_processed_file.bin
    COMMAND my_process_file_cmd my_unprocessed_file.bin)
target_add_binary_data(my_target "my_processed_file.bin" BINARY)
```
In the example above, *my_processed_file.bin* is generated from *my_unprocessed_file.bin* through some command *my_process_file_cmd*, then embedded into the target.

To specify a dependence on a target, use the **DEPENDS** argument:

```cmake
add_custom_target(my_process COMMAND ...) target_add_binary_data(my_target "my_embed_file.bin" BINARY DEPENDS my_process)
```

The **DEPENDS** argument to `target_add_binary_data` ensures that the target executes first.

**Code and Data Placements**

ESP-IDF has a feature called linkerscript generation that enables components to define where its code and data will be placed in memory through linker fragment files. These files are processed by the build system, and is used to augment the linker script used for linking app binary. See *Linker Script Generation* for a quick start guide as well as a detailed discussion of the mechanism.

**Fully Overriding the Component Build Process**

Obviously, there are cases where all these recipes are insufficient for a certain component, for example when the component is basically a wrapper around another third-party component not originally intended to be compiled under this build system. In that case, it’s possible to forego the ESP-IDF build system entirely by using a CMake feature called *ExternalProject*. Example component CMakeLists:

```cmake
# External build process for quirc, runs in source dir and # produces libquirc.a
externalproject_add(quirc_build
    PREFIX ${COMPONENT_DIR}
    SOURCE_DIR ${COMPONENT_DIR}/quirc
    CONFIGURE_COMMAND ""
    BUILD_IN_SOURCE 1
    BUILD_COMMAND make CC=${CMAKE_C_COMPILER} libquirc.a
    INSTALL_COMMAND ""
)

# Add libquirc.a to the build process
add_library(quirc STATIC IMPORTED GLOBAL)
add_dependencies(quirc quirc_build)

set_target_properties(quirc PROPERTIES IMPORTED_LOCATION
    ${COMPONENT_DIR}/quirc/libquirc.a)
set_target_properties(quirc PROPERTIES INTERFACE_INCLUDE_DIRECTORIES
    ${COMPONENT_DIR}/quirc/lib)
set_directory_properties( PROPERTIES ADDITIONAL_CLEAN_FILES
    "${COMPONENT_DIR}/quirc/libquirc.a")
```

(The above CMakeLists.txt can be used to create a component named *quirc* that builds the *quirc* project using its own Makefile.)

- **externalproject_add** defines an external build system.
  - **SOURCE_DIR**, **CONFIGURE_COMMAND**, **BUILD_COMMAND** and **INSTALL_COMMAND** should always be set. **CONFIGURE_COMMAND** can be set to an empty string if the build system has no “configure” step. **INSTALL_COMMAND** will generally be empty for ESP-IDF builds.
  - Setting **BUILD_IN_SOURCE** means the build directory is the same as the source directory. Otherwise, you can set **BUILD_DIR**.
  - Consult the *ExternalProject* documentation for more details about **externalproject_add()**.

- The second set of commands adds a library target, which points to the “imported” library file built by the external system. Some properties need to be set in order to add include directories and tell CMake where this file is.
Finally, the generated library is added to `ADDITIONAL_CLEAN_FILES`. This means `make clean` will delete this library. (Note that the other object files from the build won’t be deleted.)

**Note:** When using an external build process with PSRAM, remember to add `-mfix-esp32-psram-cache-issue` to the C compiler arguments. See `CONFIG_SPIRAM_CACHE_WORKAROUND` for details of this flag.

### ExternalProject Dependencies and Clean Builds

CMake has some unusual behavior around external project builds:

- `ADDITIONAL_CLEAN_FILES` only works when “make” or “ninja” is used as the build system. If an IDE build system is used, it won’t delete these files when cleaning.
- However, the `ExternalProject configure & build` commands will always be re-run after a clean is run.
- Therefore, there are two alternative recommended ways to configure the external build command:
  1. Have the external `BUILD_COMMAND` run a full clean compile of all sources. The build command will be run if any of the dependencies passed to `externalproject_add` with `DEPENDS` have changed, or if this is a clean build (ie any of `idf.py clean`, `ninja clean`, or `make clean` was run.)
  2. Have the external `BUILD_COMMAND` be an incremental build command. Pass the parameter `BUILD_ALWAYS 1` to `externalproject_add`. This means the external project will be built each time a build is run, regardless of dependencies. This is only recommended if the external project has correct incremental build behavior, and doesn’t take too long to run.

The best of these approaches for building an external project will depend on the project itself, its build system, and whether you anticipate needing to frequently recompile the project.

### 4.5.13 Custom Sdkconfig Defaults

For example projects or other projects where you don’t want to specify a full sdkconfig configuration, but you do want to override some key values from the ESP-IDF defaults, it is possible to create a file `sdkconfig.defaults` in the project directory. This file will be used when creating a new config from scratch, or when any new config value hasn’t yet been set in the `sdkconfig` file.

To override the name of this file or to specify multiple files, set the `SDKCONFIG_DEFAULTS` environment variable or set `SDKCONFIG_DEFAULTS` in top-level `CMakeLists.txt`. File names that are not specified as full paths are resolved relative to current project’s directory.

When specifying multiple files, use a semicolon as the list separator. Files listed first will be applied first. If a particular key is defined in multiple files, the definition in the latter file will override definitions from former files.

Some of the IDF examples include a `sdkconfig.ci` file. This is part of the continuous integration (CI) test framework and is ignored by the normal build process.

### Target-dependent Sdkconfig Defaults

In addition to `sdkconfig.defaults` file, build system will also load defaults from `sdkconfig.defaults.TARGET_NAME` file, where `TARGET_NAME` is the value of `IDF_TARGET`. For example, for `esp32` target, default settings will be taken from `sdkconfig.defaults` first, and then from `sdkconfig.defaults.esp32`.

If `SDKCONFIG_DEFAULTS` is used to override the name of defaults file/files, the name of target-specific defaults file will be derived from `SDKCONFIG_DEFAULTS` value/values using the rule above. When there are multiple files in `SDKCONFIG_DEFAULTS`, target-specific file will be applied right after the file bringing it in, before all latter files in `SDKCONFIG_DEFAULTS`.

For example, if `SDKCONFIG_DEFAULTS="sdkconfig.defaults;sdkconfig_devkit1"`, and there is a file `sdkconfig.defaults.esp32` in the same folder, then the files will be applied in the following order: (1) `sdkconfig.defaults` (2) `sdkconfig.defaults.esp32` (3) `sdkconfig_devkit1`.
## 4.5.14 Flash Arguments

There are some scenarios that we want to flash the target board without IDF. For this case we want to save the built binaries, esptool.py and esptool write flash arguments. It’s simple to write a script to save binaries and esptool.py.

After running a project build, the build directory contains binary output files (.bin files) for the project and also the following flashing data files:

- `flash_project_args` contains arguments to flash the entire project (app, bootloader, partition table, PHY data if this is configured).
- `flash_app_args` contains arguments to flash only the app.
- `flash_bootloader_args` contains arguments to flash only the bootloader.

You can pass any of these flasher argument files to `esptool.py` as follows:

```python
python esptool.py --chip esp32 write_flash @build/flash_project_args
```

Alternatively, it is possible to manually copy the parameters from the argument file and pass them on the command line.

The build directory also contains a generated file `flasher_args.json` which contains project flash information, in JSON format. This file is used by `idf.py` and can also be used by other tools which need information about the project build.

## 4.5.15 Building the Bootloader

The bootloader is a special “subproject” inside `/components/bootloader/subproject`. It has its own project CMakeLists.txt file and builds separate .ELF and .BIN files to the main project. However, it shares its configuration and build directory with the main project.

The subproject is inserted as an external project from the top-level project, by the file `/components/bootloader/project_include.cmake`. The main build process runs CMake for the subproject, which includes discovering components (a subset of the main components) and generating a bootloader-specific config (derived from the main `sdkconfig`).

## 4.5.16 Writing Pure CMake Components

The ESP-IDF build system “wraps” CMake with the concept of “components”, and helper functions to automatically integrate these components into a project build.

However, underneath the concept of “components” is a full CMake build system. It is also possible to make a component which is pure CMake.

Here is an example minimal “pure CMake” component CMakeLists file for a component named `json`:

```cmake
add_library(json STATIC
  cJSON/cJSON.c
  cJSON/cJSON_Utils.c)
target_include_directories(json PUBLIC cJSON)
```

- This is actually an equivalent declaration to the IDF `json` component `/components/json/CMakeLists.txt`.
- This file is quite simple as there are not a lot of source files. For components with a large number of files, the globbing behavior of ESP-IDF’s component logic can make the component CMakeLists style simpler.
- Any time a component adds a library target with the component name, the ESP-IDF build system will automatically add this to the build, expose public include directories, etc. If a component wants to add a library target with a different name, dependencies will need to be added manually via CMake commands.
4.5.17 Using Third-Party CMake Projects with Components

CMake is used for a lot of open-source C and C++ projects — code that users can tap into for their applications. One of the benefits of having a CMake build system is the ability to import these third-party projects, sometimes even without modification! This allows for users to be able to get functionality that may not yet be provided by a component, or use another library for the same functionality.

Importing a library might look like this for a hypothetical library `foo` to be used in the `main` component:

```cmake
idf_component_register(...)

set(FOO_BUILD_STATIC OFF)
set(FOO_BUILD_TESTS OFF)

add_subdirectory(foo)

target_link_libraries(main PUBLIC foo)
```

For an actual example, take a look at `build_system/cmake/import_lib`. Take note that what needs to be done in order to import the library may vary. It is recommended to read up on the library’s documentation for instructions on how to import it from other projects. Studying the library’s CMakeLists.txt and build structure can also be helpful.

It is also possible to wrap a third-party library to be used as a component in this manner. For example, the `mbedtls` component is a wrapper for Espressif’s fork of `mbedtls`. See its component `CMakeLists.txt`.

The CMake variable `ESP_PLATFORM` is set to 1 whenever the ESP-IDF build system is being used. Tests such as

```cmake
if (ESP_PLATFORM)
    target_link_libraries(foo PRIVATE idf::spi_flash)
endif()
```

4.5.18 Using Prebuilt Libraries with Components

Another possibility is that you have a prebuilt static library (`.a` file), built by some other build process. The ESP-IDF build system provides a utility function `add_prebuilt_library` for users to be able to easily import and use prebuilt libraries:

```cmake
add_prebuilt_library(target_name lib_path [REQUIRES req1 req2 ...] [PRIV_REQUIRES _req1 req2 ...])
```

where:

- `target_name`- name that can be used to reference the imported library, such as when linking to other targets
Chapter 4. API Guides

- **lib_path** - path to prebuilt library; may be an absolute or relative path to the component directory

Optional arguments **REQUIRES** and **PRIV_REQUIRES** specify dependency on other components. These have the same meaning as the arguments for **idf_component_register**.

Take note that the prebuilt library must have been compiled for the same target as the consuming project. Configuration relevant to the prebuilt library must also match. If not paid attention to, these two factors may contribute to subtle bugs in the app.

For an example, take a look at `build_system/cmake/import_prebuilt`.

### 4.5.19 Using ESP-IDF in Custom CMake Projects

ESP-IDF provides a template CMake project for easily creating an application. However, in some instances the user might already have an existing CMake project or may want to create a custom one. In these cases it is desirable to be able to consume IDF components as libraries to be linked to the user’s targets (libraries/executables).

It is possible to do so by using the **build system APIs provided** by **tools/cmake/idf.cmake**. For example:

```cmake
cmake_minimum_required(VERSION 3.16)
project(my_custom_app C)

# Include CMake file that provides ESP-IDF CMake build system APIs.
include($ENV{IDF_PATH}/tools/cmake/idf.cmake)

# Include ESP-IDF components in the build, may be thought as an equivalent of
# add_subdirectory() but with some additional processing and magic for ESP-IDF
# build processes.
idf_build_process(esp32)

# Create the project executable and plainly link the newlib component to it using
# its alias, idf::newlib.
add_executable(${CMAKE_PROJECT_NAME}.elf main.c)
target_link_libraries(${CMAKE_PROJECT_NAME}.elf idf::newlib)

# Let the build system know what the project executable is to attach more targets,
# dependencies, etc.
idf_build_executable(${CMAKE_PROJECT_NAME}.elf)
```

The example in `build_system/cmake/idf_as_lib` demonstrates the creation of an application equivalent to `hello world application` using a custom CMake project.

**Note:** The IDF build system can only set compiler flags for source files that it builds. When an external CMakeLists.txt file is used and PSRAM is enabled, remember to add `-mfix-esp32-psram-cache-issue` to the C compiler arguments. See `CONFIG_SPIRAM_CACHE_WORKAROUND` for details of this flag.

### 4.5.20 ESP-IDF CMake Build System API

**idf-build-commands**

```cmake
idf_build_get_property(var property [GENERATOR_EXPRESSION])
```

Retrieve a **build property** `property` and store it in `var` accessible from the current scope. Specifying **GENERATOR_EXPRESSION** will retrieve the generator expression string for that property, instead of the actual value, which can be used with CMake commands that support generator expressions.
idf_build_set_property(property val [APPEND])

Set a build property property with value val. Specifying APPEND will append the specified value to the current value of the property. If the property does not previously exist or it is currently empty, the specified value becomes the first element/member instead.

idf_build_component(component_dir)

Present a directory component_dir that contains a component to the build system. Relative paths are converted to absolute paths with respect to current directory. All calls to this command must be performed before idf_build_process.

This command does not guarantee that the component will be processed during build (see the COMPONENTS argument description for idf_build_process)

idf_build_process(target
    [PROJECT_DIR project_dir]
    [PROJECT_VER project_ver]
    [PROJECT_NAME project_name]
    [SDKCONFIG sdkconfig]
    [SDKCONFIG_DEFAULTS sdkconfig_defaults]
    [BUILD_DIR build_dir]
    [COMPONENTS component1 component2 ...])

Performs the bulk of the behind-the-scenes magic for including ESP-IDF components such as component configuration, libraries creation, dependency expansion and resolution. Among these functions, perhaps the most important from a user’s perspective is the libraries creation by calling each component’s idf_component_register. This command creates the libraries for each component, which are accessible using aliases in the form idf::component_name. These aliases can be used to link the components to the user’s own targets, either libraries or executables.

The call requires the target chip to be specified with target argument. Optional arguments for the call include:

- PROJECT_DIR - directory of the project; defaults to CMAKE_SOURCE_DIR
- PROJECT_NAME - name of the project; defaults to CMAKE_PROJECT_NAME
- PROJECT_VER - version/revision of the project; defaults to “1”
- SDKCONFIG - output path of generated sdkconfig file; defaults to PROJECT_DIR/sdkconfig or CMAKE_SOURCE_DIR/sdkconfig depending if PROJECT_DIR is set
- SDKCONFIG_DEFAULTS - list of files containing default config to use in the build (list must contain full paths); defaults to empty. For each value filename in the list, the config from file filename.target, if it exists, is also loaded.
- BUILD_DIR - directory to place ESP-IDF build-related artifacts, such as generated binaries, text files, components; defaults to CMAKE_BINARY_DIR
- COMPONENTS - select components to process among the components known by the build system (added via idf_build_component). This argument is used to trim the build. Other components are automatically added if they are required in the dependency chain, i.e. the public and private requirements of the components in this list are automatically added, and in turn the public and private requirements of those requirements, so on and so forth. If not specified, all components known to the build system are processed.

idf_build_executable(executable)

Specify the executable executable for ESP-IDF build. This attaches additional targets such as dependencies related to flashing, generating additional binary files, etc. Should be called after idf_build_process.

idf_build_get_config(var config [GENERATOR_EXPRESSION])

Get the value of the specified config. Much like build properties, specifying GENERATOR_EXPRESSION will retrieve the generator expression string for that config, instead of the actual value, which can be used with CMake commands that support generator expressions. Actual config values are only known after call to idf_build_process, however.
**idf-build-properties**

These are properties that describe the build. Values of build properties can be retrieved by using the build command `idf_build_get_property`. For example, to get the Python interpreter used for the build:

```c
idf_build_get_property(python PYTHON)
message(STATUS "The Python interpreter is: ${python}")
```

- **BUILD_DIR** - build directory; set from `idf_build_process` `BUILD_DIR` argument
- **BUILD_COMPONENTS** - list of components included in the build; set by `idf_build_process`
- **BUILD_COMPONENT_ALIASES** - list of library alias of components included in the build; set by `idf_build_process`
- **C_COMPILE_OPTIONS** - compile options applied to all components’ C source files
- **COMPILE_OPTIONS** - compile options applied to all components’ source files, regardless of it being C or C++
- **COMPILE_DEFINITIONS** - compile definitions applied to all component source files
- **DEPENDENCIES_LOCK** - lock file path used in component manager. The default value is `dependencies.lock` under the project path.
- **EXECUTABLE** - project executable; set by call to `idf_build_executable`
- **EXECUTABLE_NAME** - name of project executable without extension; set by call to `idf_build_executable`
- **EXECUTABLE_DIR** - path containing the output executable
- **IDF_COMPONENT_MANAGER** - the component manager is enabled by default, but if this property is set to 0 it was disabled by the `IDF_COMPONENT_MANAGER` environment variable
- **IDF_PATH** - ESP-IDF path; set from `IDF_PATH` environment variable, if not, inferred from the location of `idf.cmake`
- **IDF_TARGET** - target chip for the build; set from the required target argument for `idf_build_process` `IDF_TARGET` argument
- **IDF_VER** - ESP-IDF version; set from either a version file or the Git revision of the `IDF_PATH` repository
- **INCLUDE_DIRECTORIES** - include directories for all component source files
- **KCONFIGS** - list of Kconfig files found in components in build; set by `idf_build_process`
- **KCONFIG_PROJBUILDS** - list of Kconfig.projbuild files found in components in build; set by `idf_build_process`
- **PROJECT_NAME** - name of the project; set from `idf_build_process` `PROJECT_NAME` argument
- **PROJECT_DIR** - directory of the project; set from `idf_build_process` `PROJECT_DIR` argument
- **PROJECT_VER** - version of the project; set from `idf_build_process` `PROJECT_VER` argument
- **PYTHON** - Python interpreter used for the build; set from `PYTHON` environment variable if available, if not “python” is used
- **SDKCONFIG** - full path to output config file; set from `idf_build_process` `SDKCONFIG` argument
- **SDKCONFIG_DEFAULTS** - list of files containing default config to use in the build; set from `idf_build_process` `SDKCONFIG_DEFAULTS` argument
- **SDKCONFIG_HEADER** - full path to C/C++ header file containing component configuration; set by `idf_build_process`
- **SDKCONFIG_CMAKE** - full path to CMake file containing component configuration; set by `idf_build_process`
- **SDKCONFIG_JSON** - full path to JSON file containing component configuration; set by `idf_build_process`
- **SDKCONFIG_JSON_MENUS** - full path to JSON file containing config menus; set by `idf_build_process`

**idf-component-commands**

```c
idf_component_get_property(var component property [GENERATOR_EXPRESSION])
```

Retrieve a specified component’s `component property`, `property` and store it in `var` accessible from the current scope. Specifying `GENERATOR_EXPRESSION` will retrieve the generator expression string for that property, instead of the actual value, which can be used with CMake commands that support generator expressions.
**Chapter 4. API Guides**

### idf_component_set_property(component property val [APPEND])

Set a specified component’s component property, property with value val. Specifying APPEND will append the specified value to the current value of the property. If the property does not previously exist or is currently empty, the specified value becomes the first element/member instead.

**Code Block**

```
idf_component_set_property(component property val [APPEND])
```

### idf_component_register([[[SRCS src1 src2 ...] | [SRC_DIRS dir1 dir2 ...]) [EXCLUDE_-
SRCS src1 src2 ...]])

```
[INCLUDE_DIRS dir1 dir2 ...]
[PRIV_INCLUDE_DIRS dir1 dir2 ...]
[REQUIRES component1 component2 ...]
[PRIV_REQUIRES component1 component2 ...]
[LDFRAGMENTS ldfragment1 ldfragment2 ...]
[REQUIRED_IDF_TARGETS target1 target2 ...]
[EMBED_FILES file1 file2 ...]
[EMBED_TXTFILES file1 file2 ...]
[KCONFIG kconfig]
[KCONFIG_PROJBUILD kconfig_projbuild]
[WHOLE_ARCHIVE])
```

Register a component to the build system. Much like the `project()` CMake command, this should be called from the component’s CMakeLists.txt directly (not through a function or macro) and is recommended to be called before any other command. Here are some guidelines on what commands can not be called before `idf_component_register`:

- commands that are not valid in CMake script mode
- custom commands defined in `project_include.cmake`
- build system API commands except `idf_build_get_property`; although consider whether the property may not have been set yet

Commands that set and operate on variables are generally okay to call before `idf_component_register`.

The arguments for `idf_component_register` include:

- **SRCS** - component source files used for creating a static library for the component; if not specified, component is a treated as a config-only component and an interface library is created instead.
- **SRC_DIRS, EXCLUDE_SRCS** - used to glob source files (.c, .cpp, .S) by specifying directories, instead of specifying source files manually via SRCS. Note that this is subject to the limitations of globbing in CMake. Source files specified in EXCLUDE_SRCS are removed from the globbed files.
- **INCLUDE_DIRS** - paths, relative to the component directory, which will be added to the include search path for all other components which require the current component
- **PRIV_INCLUDE_DIRS** - directory paths, must be relative to the component directory, which will be added to the include search path for this component’s source files only
- **REQUIRES** - public component requirements for the component
- **PRIV_REQUIRES** - private component requirements for the component; ignored on config-only components
- **LDFRAGMENTS** - component linker fragment files
- **REQUIRED_IDF_TARGETS** - specify the only target the component supports
- **KCONFIG** - override the default Kconfig file
- **KCONFIG_PROJBUILD** - override the default Kconfig projbuild file
- **WHOLE_ARCHIVE** - if specified, the component library is surrounded by `-Wl,--whole-archive`, `-Wl,--no-whole-archive when linked`. This has the same effect as setting WHOLE_ARCHIVE component property.

The following are used for embedding data into the component, and is considered as source files when determining if a component is config-only. This means that even if the component does not specify source files, a static library is still created internally for the component if it specifies either:

- **EMBED_FILES** - binary files to be embedded in the component
- **EMBED_TXTFILES** - text files to be embedded in the component
**idf-component-properties**

These are properties that describe a component. Values of component properties can be retrieved by using the build command `idf_component_get_property`. For example, to get the directory of the freertos component:

```c
idf_component_get_property(dir freertos COMPONENT_DIR)
message(STATUS "The 'freertos' component directory is: %{dir}")
```

- **COMPONENT_ALIAS** - alias for COMPONENT_LIB used for linking the component to external targets; set by `idf_build_component` and alias library itself is created by `idf_component_register`
- **COMPONENT_DIR** - component directory; set by `idf_build_component`
- **COMPONENT_OVERRIDEN_DIR** - contains the directory of the original component if this component overrides another component
- **COMPONENT_LIB** - name for created component static/interface library; set by `idf_build_component` and library itself is created by `idf_component_register`
- **COMPONENT_NAME** - name of the component; set by `idf_build_component` based on the component directory name
- **COMPONENT_TYPE** - type of the component, whether LIBRARY or CONFIG_ONLY. A component is of type LIBRARY if it specifies source files or embeds a file
- **EMBED_FILES** - list of files to embed in component; set from `idf_component_register` EMBED_FILES argument
- **EMBED_TXTFILES** - list of text files to embed in component; set from `idf_component_register` EMBED_TXTFILES argument
- **INCLUDE_DIRS** - list of component include directories; set from `idf_component_register` INCLUDE_DIRS argument
- **KCONFIG** - component Kconfig file; set by `idf_build_component`
- **KCONFIG_PROJBUILD** - component Kconfig.projbUILD; set by `idf_build_component`
- **LDFFRAGMENTS** - list of component linker fragment files; set from `idf_component_register` LDFFRAGMENTS argument
- **MANAGED_PRIV_REQUIRES** - list of private component dependencies added by the IDF component manager from dependencies in `idf_component.yml` manifest file
- **MANAGEDQUIRES** - list of public component dependencies added by the IDF component manager from dependencies in `idf_component.yml` manifest file
- **PRIV_INCLUDE_DIRS** - list of component private include directories; set from `idf_component_register` PRIV_INCLUDE_DIRS on components of type LIBRARY
- **PRIVQUIRES** - list of private component dependencies; set from value of `idf_component_register` PRIVQUIRES argument and dependencies in `idf_component.yml` manifest file
- **REQUIRED_IDF_TARGETS** - list of targets the component supports; set from `idf_component_register` REQUIRED_IDF_TARGETS argument
- **REQUIRES** - list of public component dependencies; set from value of `idf_component_register` REQUIRES argument and dependencies in `idf_component.yml` manifest file
- **SRCS** - list of component source files; set from SRCS or SRC_DIRS/EXCLUDE_SRCS argument of `idf_component_register`
- **WHOLE_ARCHIVE** - if this property is set to TRUE (or any boolean “true” CMake value: 1, ON, YES, Y), the component library is surrounded by `-Wl,--whole-archive,-Wl,--no-whole-archive` when linked. This can be used to force the linker to include every object file into the executable, even if the object file doesn’t resolve any references from the rest of the application. This is commonly used when a component contains plugins or modules which rely on link-time registration. This property is FALSE by default. It can be set to TRUE from the component CMakeLists.txt file.

### 4.5.21 File Globbing & Incremental Builds

The preferred way to include source files in an ESP-IDF component is to list them manually via SRCS argument to `idf_component_register`: 
This preference reflects the CMake best practice of manually listing source files. This could, however, be inconvenient when there are lots of source files to add to the build. The ESP-IDF build system provides an alternative way for specifying source files using SRC_DIRS:

```
idf_component_register(SRC_DIRS library platform ...
```

This uses globbing behind the scenes to find source files in the specified directories. Be aware, however, that if a new source file is added and this method is used, then CMake won’t know to automatically re-run and this file won’t be added to the build.

The trade-off is acceptable when you’re adding the file yourself, because you can trigger a clean build or run `idf.py` `reconfigure` to manually re-run CMake. However, the problem gets harder when you share your project with others who may check out a new version using a source control tool like Git...

For components which are part of ESP-IDF, we use a third party Git CMake integration module (`/tools/cmake/third_party/GetGitRevisionDescription.cmake`) which automatically re-runs CMake any time the repository commit changes. This means if you check out a new ESP-IDF version, CMake will automatically re-run.

For project components (not part of ESP-IDF), there are a few different options:

- If keeping your project file in Git, ESP-IDF will automatically track the Git revision and re-run CMake if the revision changes.
- If some components are kept in a third git repository (not the project repository or ESP-IDF repository), you can add a call to the `git_describe` function in a component CMakeLists file in order to automatically trigger re-runs of CMake when the Git revision changes.
- If not using Git, remember to manually run `idf.py` `reconfigure` whenever a source file may change.
- To avoid this problem entirely, use SRC_DIRS argument to `idf_component_register` to list all source files in project components.

The best option will depend on your particular project and its users.

### 4.5.22 Build System Metadata

For integration into IDEs and other build systems, when CMake runs the build process generates a number of metadata files in the `build/` directory. To regenerate these files, run `cmake` or `idf.py` `reconfigure` (or any other `idf.py` build command).

- `compile_commands.json` is a standard format JSON file which describes every source file which is compiled in the project. A CMake feature generates this file, and many IDEs know how to parse it.
- `project_description.json` contains some general information about the ESP-IDF project, configured paths, etc.
- `flasher_args.json` contains `esptool.py` arguments to flash the project’s binary files. There are also `flash_*_args` files which can be used directly with `esptool.py`. See `Flash arguments`.
- `CMakeCache.txt` is the CMake cache file which contains other information about the CMake process, toolchain, etc.
- `config/sdkconfig.json` is a JSON-formatted version of the project configuration values.
- `config/kconfig_menus.json` is a JSON-formatted version of the menus shown in menuconfig, for use in external IDE UIs.

### JSON Configuration Server

A tool called kconfserver is provided to allow IDEs to easily integrate with the configuration system logic. kconfserver is designed to run in the background and interact with a calling process by reading and writing JSON over process stdin & stdout.
You can run `kconfserver` from a project via `idf.py confserver` or `ninja kconfserver`, or a similar target triggered from a different build generator.

For more information about `kconfserver`, see the [esp-idf-kconfig documentation](#).

### 4.5.23 Build System Internals

#### Build Scripts

The list files for the ESP-IDF build system reside in `/tools/cmake`. The modules which implement core build system functionality are as follows:

- **build.cmake** - Build related commands i.e. build initialization, retrieving/setting build properties, build processing.
- **component.cmake** - Component related commands i.e. adding components, retrieving/setting component properties, registering components.
- **kconfig.cmake** - Generation of configuration files (sdkconfig, sdkconfig.h, sdkconfig.cmake, etc.) from Kconfig files.
- **ldgen.cmake** - Generation of final linker script from linker fragment files.
- **target.cmake** - Setting build target and toolchain file.
- **utilities.cmake** - Miscellaneous helper commands.

Aside from these files, there are two other important CMake scripts in `/tools/cmake`:

- **idf.cmake** - Sets up the build and includes the core modules listed above. Included in CMake projects in order to access ESP-IDF build system functionality.
- **project.cmake** - Includes `idf.cmake` and provides a custom `project()` command that takes care of all the heavy lifting of building an executable. Included in the top-level CMakelists.txt of standard ESP-IDF projects.

The rest of the files in `/tools/cmake` are support or third-party scripts used in the build process.

#### Build Process

This section describes the standard ESP-IDF application build process. The build process can be broken down roughly into four phases:

![Fig. 3: ESP-IDF Build System Process](image)

**Initialization**  This phase sets up necessary parameters for the build.

- **Upon inclusion of `idf.cmake` in `project.cmake`, the following steps are performed:**
  - Set `IDF_PATH` from environment variable or inferred from path to `project.cmake` included in the top-level CMakelists.txt.
  - Add `/tools/cmake` to `CMAKE_MODULE_PATH` and include core modules plus the various helper/third-party scripts.
  - Set build tools/executables such as default Python interpreter.
  - Get ESP-IDF git revision and store as `IDF_VER`.
  - Set global build specifications i.e. compile options, compile definitions, include directories for all components in the build.
  - Add components in `components` to the build.

- **The initial part of the custom `project()` command performs the following steps:**
- Set IDF_TARGET from environment variable or CMake cache and the corresponding CMAKE_TOOLCHAIN_FILE to be used.
- Add components in EXTRA_COMPONENT_DIRS to the build.
- Prepare arguments for calling command idf_build_process() from variables such as COMPONENTS/EXCLUDE_COMPONENTS, SDKCONFIG, SDKCONFIG_DEFAULTS.

The call to idf_build_process() command marks the end of this phase.

Enumeration

This phase builds a final list of components to be processed in the build, and is performed in the first half of idf_build_process().

- Retrieve each component’s public and private requirements. A child process is created which executes each component’s CMakeLists.txt in script mode. The values of idf_component_register REQUIRES and PRIV_REQUIRES argument is returned to the parent build process. This is called early expansion. The variable CMAKE_BUILD_EARLY_EXPANSION is defined during this step.
- Recursively include components based on public and private requirements.

Processing

This phase processes the components in the build, and is the second half of idf_build_process().

- Load project configuration from sdkconfig file and generate an sdkconfig.cmake and sdkconfig.h header. These define configuration variables/macros that are accessible from the build scripts and C/C++ source/header files, respectively.
- Include each component’s project_include.cmake.
- Add each component as a subdirectory, processing its CMakeLists.txt. The component CMakeLists.txt calls the registration command, idf_component_register which adds source files, include directories, creates component library, links dependencies, etc.

Finalization

This phase is everything after idf_build_process().

- Create executable and link the component libraries to it.
- Generate project metadata files such as project_description.json and display relevant information about the project built.

Browse /tools/cmake/project.cmake for more details.

4.5.24 Migrating from ESP-IDF GNU Make System

Some aspects of the CMake-based ESP-IDF build system are very similar to the older GNU Make-based system. The developer needs to provide values the include directories, source files etc. There is a syntactical difference, however, as the developer needs to pass these as arguments to the registration command, idf_component_register.

Automatic Conversion Tool

An automatic project conversion tool is available in tools/cmake/convert_to_cmake.py in ESP-IDF v4.x releases. The script was removed in v5.0 because of its make build system dependency.
Chapter 4. API Guides

No Longer Available in CMake

Some features are significantly different or removed in the CMake-based system. The following variables no longer exist in the CMake-based build system:

- **COMPONENT_BUILD_DIR**: Use `CMAKE_CURRENT_BINARY_DIR` instead.
- **COMPONENT_LIBRARY**: Defaulted to `{COMPONENT_NAME}.a`, but the library name could be overridden by the component. The name of the component library can no longer be overridden by the component.
- **CC, LD, AR, OBJCOPY**: Full paths to each tool from the gcc xtensa cross-toolchain. Use `CMAKE_C_COMPILER`, `CMAKE_C_LINK_EXECUTABLE`, `CMAKE_OBJCOPY`, etc instead. [Full list here.](#)
- **HOSTCC, HOSTLD, HOSTAR**: Full names of each tool from the host native toolchain. These are no longer provided, external projects should detect any required host toolchain manually.
- **COMPONENT_ADD_IDFLAGS**: Used to override linker flags. Use the CMake `target_link_libraries` command instead.
- **COMPONENT_ADD_LINKER_DEPS**: List of files that linking should depend on. `target_link_libraries` will usually infer these dependencies automatically. For linker scripts, use the provided custom CMake function `target_linker_scripts`.
- **COMPONENT_SUBMODULES**: No longer used, the build system will automatically enumerate all submodules in the ESP-IDF repository.
- **COMPONENT_EXTRA_INCLUDES**: Used to be an alternative to `COMPONENT_PRIV_INCLUDEDIRS` for absolute paths. Use `PRIV_INCLUDE_DIRS` argument to `idf_component_register` for all cases now (can be relative or absolute).
- **COMPONENT_OBJS**: Previously, component sources could be specified as a list of object files. Now they can be specified as a list of source files via `SRCS` argument to `idf_component_register`.
- **COMPONENT_OBJEXCLUDE**: Has been replaced with `EXCLUDE_SRCS` argument to `idf_component_register`. Specify source files (as absolute paths or relative to component directory), instead.
- **COMPONENT_EXTRA_CLEAN**: Set property `ADDITIONAL_CLEAN_FILES` instead but note [CMake has some restrictions around this functionality.](#)
- **COMPONENT_OWNBUILDTARGET & COMPONENT_OWNCLEANTARGET**: Use CMake `ExternalProject` instead. See [Fully Overriding the Component Build Process](#) for full details.
- **COMPONENT_CONFIG_ONLY**: Call `idf_component_register` without any arguments instead. See [Configuration-Only Components](#).
- **CFLAGS, CPPFLAGS, CXXFLAGS**: Use equivalent CMake commands instead. See [Controlling Component Compilation](#).

No Default Values

Unlike in the legacy Make-based build system, the following have no default values:

- Source directories (`COMPONENT_SRCDIRS` variable in Make, `SRC_DIRS` argument to `idf_component_register` in CMake)
- Include directories (`COMPONENT_ADD_INCLUDEDIRS` variable in Make, `INCLUDE_DIRS` argument to `idf_component_register` in CMake)

No Longer Necessary

- In the legacy Make-based build system, it is required to also set `COMPONENT_SRCDIRS` if `COMPONENT_SRCS` is set. In CMake, the equivalent is not necessary i.e. specifying `SRC_DIRS` to `idf_component_register` if `SRCS` is also specified (in fact, `SRCS` is ignored if `SRC_DIRS` is specified).

Flashing from Make

`make flash` and similar targets still work to build and flash. However, project `sdkconfig` no longer specifies serial port and baud rate. Environment variables can be used to override these. See [Flashing with Ninja or Make](#) for more details.
4.6 RF Coexistence

4.6.1 Overview

ESP32 has only one 2.4 GHz ISM band RF module, which is shared by Bluetooth (BT & BLE) and Wi-Fi, so Bluetooth can’t receive or transmit data while Wi-Fi is receiving or transmitting data and vice versa. Under such circumstances, ESP32 uses the time-division multiplexing method to receive and transmit packets.

4.6.2 Supported Coexistence Scenario for ESP32

Table 1: Supported Features of Wi-Fi and BLE Coexistence

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Table 2: Supported Features of Wi-Fi and Classic Bluetooth (BT) Coexistence

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</table>

Note: Y: supported and performance is stable C1: supported but the performance is unstable X: not supported S: supported and performance is stable in STA mode, otherwise not supported.

4.6.3 Coexistence Mechanism and Policy

Coexistence Mechanism

The RF resource allocation mechanism is based on priority. As shown below, both Bluetooth module and Wi-Fi module request RF resources from the coexistence module, and the coexistence module decides who will use the RF resource based on their priority.
Coexistence Policy

Coexistence Period and Time Slice Wi-Fi, BT, and BLE have their fixed time slice to use the RF. A coexistence period is divided into 3 time slices in the order of Wi-Fi, BT, and BLE. In the Wi-Fi slice, Wi-Fi’s request to the coexistence arbitration module will have higher priority. Similarly, BT/BLE can enjoy higher priority at their own time slices. The duration of the coexistence period and the proportion of each time slice are divided into four categories according to the Wi-Fi status:

1) IDLE status: the coexistence of BT and BLE is controlled by Bluetooth module.
2) CONNECTED status: the coexistence period starts at the Target Beacon Transmission Time (TBTT) and is more than 100 ms.
3) SCAN status: Wi-Fi slice and coexistence period are longer than in the CONNECTED status. To ensure Bluetooth performance, the Bluetooth time slice will also be adjusted accordingly.
4) CONNECTING status: Wi-Fi slice is longer than in the CONNECTED status. To ensure Bluetooth performance, the Bluetooth time slice will also be adjusted accordingly.

According to the coexistence logic, different coexistence periods and time slice strategies will be selected based on the Wi-Fi and Bluetooth usage scenarios. A Coexistence policy corresponding to a certain usage scenarios is called a “coexistence scheme”. For example, the scenario of Wi-Fi CONNECTED and BLE CONNECTED has a corresponding coexistence scheme. In this scheme, the time slices of Wi-Fi and BLE in a coexistence period each account for 50%. The time allocation is shown in the following figure:

**Fig. 5: Time Slice Under the Status of Wi-Fi CONNECTED and BLE CONNECTED**

Dynamic Priority The coexistence module assigns different priorities to different status of Wi-Fi and Bluetooth. And the priority for each status is dynamic. For example, in every N BLE Advertising events, there is always one event with high priority. If a high-priority BLE Advertising event occurs within the Wi-Fi time slice, the right to use the RF may be preempted by BLE.
Chapter 4. API Guides

Wi-Fi Connectionless Modules Coexistence  To some extent, some combinations of connectionless power-saving parameters \textit{Window} and \textit{Interval} would lead to extra Wi-Fi priority request out of Wi-Fi time slice. It’s for obtaining RF resources at coexistence for customized parameters, while leading to impact on Bluetooth performance.

If connectionless power-saving parameters are configured with default values, the coexistence module would perform in stable mode and the behaviour above would not happen. So please configure Wi-Fi connectionless power-saving parameters to default values unless you have plenty of coexistence performance tests for customized parameters.

Please refer to \textit{connectionless module power save} to get more detail.

4.6.4 How to Use the Coexistence Feature

Coexistence API

For most coexistence cases, ESP32 will switch the coexistence status automatically without calling API. However, ESP32 provides two APIs for the coexistence of BLE MESH and Wi-Fi. When the status of BLE MESH changes, call \texttt{esp_coex_status_bit_clear} to clear the previous status first and then call \texttt{esp_coex_status_bit_set} to set the current status.

BLE MESH Coexistence Status  As the firmware of Wi-Fi and Bluetooth are not aware of the current scenario of the upper layer application, some coexistence schemes require application code to call the coexistence API to take effect. The application layer needs to pass the working status of BLE MESH to the coexistence module for selecting the coexistence scheme.

- \texttt{ESP_COEX_BLE_ST_MESH_CONFIG}: network is provisioning
- \texttt{ESP_COEX_BLE_ST_MESH_TRAFFIC}: data is transmitting
- \texttt{ESP_COEX_BLE_ST_MESH_STANDBY}: in idle status with no significant data interaction

Coexistence API Error Codes

All coexistence APIs have custom return values, i.e. error codes. These error codes can be categorized as:

- No error. For example, the return value \texttt{ESP_OK} signifies the API returned successfully.
- Recoverable errors. For example, the return value \texttt{ESP_ERR_INVALID_ARG} signifies API parameter errors.

Setting Coexistence Compile-time Options

- After writing the coexistence program, you must check \texttt{CONFIG_ESP_COEX_SW_COEXIST_ENABLE} option through menuconfig to open coexistence configuration on software, otherwise the coexistence function mentioned above cannot be used.
- To ensure better communication performance of Wi-Fi and Bluetooth in the case of coexistence, run the task of the Wi-Fi protocol stack, the task of the Bluetooth Controller and Host protocol stack on different CPUs. You can use \texttt{CONFIG_BTDM_CTRL_PINNED_TO_CORE_CHOICE} and \texttt{CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE} (or \texttt{CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE}) to put the tasks of the Bluetooth controller and the host protocol stack on the same CPU, and then use \texttt{CONFIG_ESP_WIFI_TASK_CORE_ID} to place the task of the Wi-Fi protocol stack on another CPU.
- In the case of coexistence, BLE SCAN may be interrupted by Wi-Fi and Wi-Fi releases RF resources before the end of the current BLE scan window. In order to make BLE acquire RF resources again within the current scan window, you can check the \texttt{FULL SCAN} configuration option through \texttt{CONFIG_BTDM_CTRL_FULL_SCAN_SUPPORTED}.
- You can reduce the memory consumption by configuring the following options on menuconfig.
  1) \texttt{CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY}: enable the configuration of dynamic memory for Bluetooth protocol stack.
  2) \texttt{CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM}: reduce the number of Wi-Fi static RX buffers.
3) **CONFIG_ESP_WIFI_DYNAMIC_RX_BUFFER_NUM**: reduce the number of Wi-Fi dynamic RX buffers.
4) **CONFIG_ESP_WIFI_TX_BUFFER**: enable the configuration of dynamic allocation TX buffers.
5) **CONFIG_ESP_WIFI_DYNAMIC_TX_BUFFER_NUM**: reduce the number of Wi-Fi dynamic TX buffers.
6) **CONFIG_ESP_WIFI_TX_BA_WIN**: reduce the number of Wi-Fi Block Ack TX windows.
7) **CONFIG_ESP_WIFI_RX_BA_WIN**: reduce the number of Wi-Fi Block Ack RX windows.
8) **CONFIG_ESP_WIFI_MGMT_SBUF_NUM**: reduce the number of Wi-Fi Management Short Buffer.
9) **CONFIG_ESP_WIFI_RX_IRAM_OPT**: turning off this configuration option will reduce the IRAM memory by approximately 17 KB.
10) **CONFIG_LWIP_TCP_SND_BUF_DEFAULT**: reduce the default TX buffer size for TCP sockets.
11) **CONFIG_LWIP_TCP_WND_DEFAULT**: reduce the default size of the RX window for TCP sockets.
12) **CONFIG_LWIP_TCP_RECVMBX_SIZE**: reduce the size of the TCP receive mailbox.
13) **CONFIG_LWIP_UDP_RECVMBX_SIZE**: reduce the size of the UDP receive mailbox.
14) **CONFIG_LWIP_TCPIP_RECVMBX_SIZE**: reduce the size of TCPIP task receive mailbox.

**Note:** Since the coexistence configuration option depends on the Bluetooth configuration option, please turn on the Bluetooth configuration option first before configuring the coexistence feature in the Wi-Fi configuration option.

### 4.7 Core Dump

#### 4.7.1 Overview

A core dump is a set of software state information that is automatically saved by the panic handler when a fatal error occurs. Core dumps are useful for conducting post-mortem analysis of the software’s state at the moment of failure. ESP-IDF provides support for generating core dumps.

A core dump contains snapshots of all tasks in the system at the moment of failure, where each snapshot includes a task’s control block (TCB) and stack. By analyzing the task snapshots, it is possible to find out what task, at what instruction (line of code), and what call stack of that task lead to the crash. It is also possible to dump the contents of variables on demand, provided those variables are assigned special core dump attributes.

Core dump data is saved to a core dump file according to a particular format, see Core dump internals for more details. However, ESP-IDF’s `idf.py` command provides special subcommands to decode and analyze the core dump file.

#### 4.7.2 Configurations

**Destination**

The **CONFIG_ESP_COREDUMP_TO_FLASH_OR_UART** option enables or disables core dump, and selects the core dump destination if enabled. When a crash occurs, the generated core dump file can either be saved to flash, or output to a connected host over UART.

**Format & Size**

The **CONFIG_ESP_COREDUMP_DATA_FORMAT** option controls the format of the core dump file, namely ELF format or Binary format.

The ELF format contains extended features and allows more information regarding erroneous tasks and crashed software to be saved. However, using the ELF format causes the core dump file to be larger. This format is recommended for new software designs and is flexible enough to be extended in future revisions to save more information.

The Binary format is kept for compatibility reasons. Binary format core dump files are smaller while provide better performance.
Chapter 4. API Guides

The `CONFIG_ESP_COREDUMP_MAX_TASKS_NUM` option configures the number of task snapshots saved by the core dump.

Core dump data integrity checking is supported via the `Components > Core dump > Core dump data integrity check` option.

**Data Integrity Check**

Core dump files include a checksum, which can be used to verify the integrity of the core dump file, i.e., the file has not been corrupted. The `CONFIG_ESP_COREDUMP_CHECKSUM` option controls the type of checksum, namely CRC32 or SHA256 (only supported in the ELF format).

The CRC32 option provides better calculation performance and consumes less memory for storage. The SHA256 hash algorithm provides a greater probability of detecting corruption than a CRC32 with multiple-bit errors.

**Reserved Stack Size**

Core dump routines run from a separate stack due to core dump itself needing to parse and save all other task stacks. The `CONFIG_ESP_COREDUMP_STACK_SIZE` option controls the size of the core dump’s stack in number of bytes.

Setting this option to 0 bytes will cause the core dump routines to run from the ISR stack, thus saving a bit of memory. Setting the option greater than zero will cause a separate stack to be instantiated.

**Note:** If a separate stack is used, the recommended stack size should be larger than 800 bytes to ensure that the core dump routines themselves do not cause a stack overflow.

### 4.7.3 Core Dump to Flash

When the core dump file is saved to flash, the file is saved to a special core dump partition in flash. Specifying the core dump partition will reserve space on the flash chip to store the core dump file.

The core dump partition is automatically declared when using the default partition table provided by ESP-IDF. However, when using a custom partition table, you need to declare the core dump partition, as illustrated below:

```
# Name,   Type, SubType, Offset,  Size
# Note: if you have increased the bootloader size, make sure to update the offsets...to avoid overlap
nvs,     data, nvs, 0x9000, 0x6000
phy_init, data, phy, 0xf000, 0x1000
factory, app, factory, 0x10000, 1M
coredump, data, coredump,, 64K
```

**Important:** If `Flash Encryption` is enabled on the device, please add an `encrypted` flag to the core dump partition declaration.

```
coredump, data, coredump,, 64K, encrypted
```

There are no special requirements for the partition name. It can be chosen according to the application’s needs, but the partition type should be `data` and the sub-type should be `coredump`. Also, when choosing partition size, note that the core dump file introduces a constant overhead of 20 bytes and a per-task overhead of 12 bytes. This overhead does not include the size of TCB and stack for every task. So the partition size should be at least `20 + max tasks number x (12 + TCB size + max task stack size)` bytes.

An example of the generic command to analyze core dump from flash is:
4.7.4 Core Dump to UART

When the core dump file is output to UART, the output file is Base64-encoded. The `CONFIG_ESP_COREDUMP-decode` option allows for selecting whether the output file is automatically decoded by the ESP-IDF monitor or kept encoded for manual decoding.

Automatic Decoding

If `CONFIG_ESP_COREDUMP-decode` is set to automatically decode the UART core dump, ESP-IDF monitor will automatically decode the data, translate any function addresses to source code lines, and display it in the monitor. The output to ESP-IDF monitor would resemble the following output:

```plaintext
==================================================================================================
==================== ESP32 CORE DUMP START ====================
Crashed task handle: 0x3ffc5640, name: 'main', GDB name: 'process 1073501760'

Horrorcore cause 0x1d (StoreProhibitedCause)
excvaddr 0x0
epc1 0x40027657
epc2 0x0
...

==================== THREADS INFO ==========================
Id Target Id Frame
* 1 process 1073501760 0x400251cd in panic_abort (details=0x3ffc553b "abort() was called at PC_
~0x40087b84 on core 0") at /home/User/esp/esp-idf/components/esp_system/panic.c:452
#1 0x40028970 in esp_system_abort (details=0x3ffc553b "abort() was called at PC_
~0x40087b84 on core 0") at /home/User/esp/esp-idf/components/esp_system/port/esp_system_chip.c:93

(continues on next page)
```
Chapter 4. API Guides

(continued from previous page)

```c
#1 0x40000000 in ?? ()
...
--------------------------- ALL MEMORY REGIONS ---------------------------
Name Address Size Attrs
...
.iram0.vectors 0x40024000 0x403 R XA
.dram0.data 0x3ffbf1c0 0x2c0c RW A
...
----------------------- ESP32 CORE DUMP END --------------------------

Manual Decoding

If you set `CONFIG_ESP_COREDUMP_DECODE` to no decoding, then the raw Base64-encoded body of core dump is output to UART between the following header and footer of the UART output:

```c
------------------------- CORE DUMP START -------------------------
<body of Base64-encoded core dump, save it to file on disk>
------------------------ CORE DUMP END ------------------------
```

It is advised to manually save the core dump text body to a file. The `CORE DUMP START` and `CORE DUMP END` lines must not be included in a core dump text file. The saved text can be decoded using the following command:

```
idf.py coredump-info -c </path/to/saved/base64/text>
```

or

```
idf.py coredump-debug -c </path/to/saved/base64/text>
```

**4.7.5 Core Dump Commands**

ESP-IDF provides special commands to help to retrieve and analyze core dumps:

- `idf.py coredump-info` - prints crashed task’s registers, call stack, list of available tasks in the system, memory regions, and contents of memory stored in core dump (TCBs and stacks).
- `idf.py coredump-debug` - creates core dump ELF file and runs GDB debug session with this file. You can examine memory, variables, and task states manually. Note that since not all memory is saved in the core dump, only the values of variables allocated on the stack are meaningful.

**4.7.6 ROM Functions in Backtraces**

It is a possible that at the moment of a crash, some tasks and/or the crashed task itself have one or more ROM functions in their call stacks. Since ROM is not part of the program ELF, it is impossible for GDB to parse such call stacks due to GDB analyzing functions’ prologues to decode backtraces. Thus, call stack parsing will break with an error message upon the first ROM function that is encountered.

To overcome this issue, the ROM ELF provided by Espressif is loaded automatically by ESP-IDF monitor based on the target and its revision. More details about ROM ELF can be found in `esp-rom-elfs`.

**4.7.7 Dumping Variables on Demand**

Sometimes you want to read the last value of a variable to understand the root cause of a crash. Core dump supports retrieving variable data over GDB by applying special attributes to declared variables.
## Supported Notations and RAM Regions

- **COREDUMP_DRAM_ATTR** places the variable into the DRAM area, which is included in the dump.
- **COREDUMP_RTC_ATTR** places the variable into the RTC area, which is included in the dump.
- **COREDUMP_RTC_FAST_ATTR** places the variable into the RTC_FAST area, which is included in the dump.

### Example

1. In *Project Configuration Menu*, enable **COREDUMP TO FLASH**, then save and exit.
2. In your project, create a global variable in the DRAM area, such as:

   ```c
   // uint8_t global_var;
   COREDUMP_DRAM_ATTR uint8_t global_var;
   ```

3. In the main application, set the variable to any value and `assert(0)` to cause a crash.

   ```c
   global_var = 25;
   assert(0);
   ```

4. Build, flash, and run the application on a target device and wait for the dumping information.
5. Run the command below to start core dumping in GDB, where `PORT` is the device USB port:

   ```bash
   idf.py coredump-debug
   ```

6. In GDB shell, type `p global_var` to get the variable content:

   ```gdb
   (gdb) p global_var
   $1 = 25 '\031'
   ```

### 4.7.8 Running `idf.py coredump-info` and `idf.py coredump-debug`

`idf.py coredump-info --help` and `idf.py coredump-debug --help` commands can be used to get more details on usage.

### Related Documents

#### Anatomy of Core Dump Image

A core dump file’s format can be configured to use the ELF format, or a legacy binary format. The ELF format is recommended for all new designs as it provides more information regarding the software’s state at the moment the crash occurs, e.g., CPU registers and memory contents.

The memory state embeds a snapshot of all tasks mapped in the memory space of the program. The CPU state contains register values when the core dump has been generated. The core dump file uses a subset of the ELF structure to register this information.

Loadable ELF segments are used to store the process’ memory state, while ELF notes (ELF.PT_NOTE) are used to store the process’ metadata (e.g., PID, registers, signal etc). In particular, the CPU’s status is stored in a note with a special name and type (**CORE, NT_PRSTATUS type**).

Here is an overview of the core dump layout:

**Note:** The format of the image file shown in the above pictures represents the current version of the image and can be changed in future releases.
Fig. 6: Core Dump ELF Image Format

Fig. 7: Core Dump Binary Image Format
**Overview of Implementation**  The figure below describes some basic aspects related to the implementation of the core dump:

![Diagram of Core Dump Implementation](image)

*Fig. 8: Core Dump Implementation Overview*

**Note:** The diagram above hides some details and represents the current implementation of the core dump which can be changed later.

### 4.8 C++ Support

ESP-IDF is primarily written in C and provides C APIs. However, ESP-IDF supports development of applications in C++. This document covers various topics relevant to C++ development.

The following C++ features are supported:

- Exception Handling
- C++ language standard
- Runtime Type Information (RTTI)
- Thread Local Storage (*thread_local* keyword)
- All C++ features implemented by GCC, except for some **Limitations**, See GCC documentation for details on features implemented by GCC.

#### 4.8.1 esp-idf-cxx Component

*esp-idf-cxx* component provides higher-level C++ APIs for some of the ESP-IDF features. This component is available from the ESP-IDF Component Registry.
4.8.2 C++ language standard

By default, ESP-IDF compiles C++ code with C++23 language standard with GNU extensions (-std=gnu++23).

To compile the source code of a certain component using a different language standard, set the desired compiler flag in the component’s CMakeLists.txt file:

```markdown
idf_component_register(...)
target_compile_options(${COMPONENT_LIB} PRIVATE -std=gnu++11)
```

Use `PUBLIC` instead of `PRIVATE` if the public header files of the component also need to be compiled with the same language standard.

4.8.3 Multithreading

C++ threads, mutexes, and condition variables are supported. C++ threads are built on top of pthreads, which in turn wrap FreeRTOS tasks.

See `cxx/pthread` for an example of creating threads in C++.

4.8.4 Exception Handling

Support for C++ Exceptions in ESP-IDF is disabled by default, but can be enabled using the `CONFIG_COMPILER_CXX_EXCEPTIONS` option.

If an exception is thrown, but there is no `catch` block, the program is terminated by the `abort` function, and the backtrace is printed. See `Fatal Errors` for more information about backtraces.

C++ Exceptions should only be used for exceptional cases, i.e., something happening unexpectedly and occurs rarely, such as events that happen less frequently than 1/100 times. Do not use them for control flow (see also the section about resource usage below). For more information on how to use C++ Exceptions, see the ISO C++ FAQ and CPP Core Guidelines.

See `cxx/exceptions` for an example of C++ exception handling.

### C++ Exception Handling and Resource Usage

Enabling exception handling normally increases application binary size by a few KB.

Additionally, it may be necessary to reserve some amount of RAM for the exception emergency memory pool. Memory from this pool is used if it is not possible to allocate an exception object from the heap.

The amount of memory in the emergency pool can be set using the `CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE` variable.

Some additional stack memory (around 200 bytes) is also used if and only if a C++ Exception is actually thrown, because it requires calling some functions from the top of the stack to initiate exception handling.

The run time of code using C++ exceptions depends on what actually happens at run time.

- If no exception is thrown, the code tends to be somewhat faster since there is no need to check error codes.
- If an exception is thrown, the run time of the code that handles exceptions is orders of magnitude slower than code returning an error code.

If an exception is thrown, the run time of the code that unwinds the stack is orders of magnitude slower than code returning an error code. The significance of the increased run time will depend on the application’s requirements and implementation of error handling (e.g., requiring user input or messaging to a cloud). As a result, exception-throwing code should never be used in real-time critical code paths.
4.8.5 Runtime Type Information (RTTI)

Support for RTTI in ESP-IDF is disabled by default, but can be enabled using `CONFIG_COMPILER_CXX_RTTI` option.

Enabling this option compiles all C++ files with RTTI support enabled, which allows using `dynamic_cast` conversion and `typeid` operator. Enabling this option typically increases the binary size by tens of kB.

See `cxx/rtti` for an example of using RTTI in ESP-IDF.

4.8.6 Developing in C++

The following sections provide tips on developing ESP-IDF applications in C++.

Combining C and C++ Code

When an application is developed using both C and C++, it is important to understand the concept of language linkage.

In order for a C++ function to be callable from C code, it has to be both declared and defined with C linkage:

```c
// declaration in the .h file:
#ifdef __cplusplus
extern "C" { 
#endif

void my_cpp_func(void);

#ifdef __cplusplus }
#endif

// definition in a .cpp file:
extern "C" void my_cpp_func(void) { 
    // ...
}
```

In order for a C function to be callable from C++, it has to be declared with C linkage:

```c
// declaration in .h file:
#ifdef __cplusplus
extern "C" { 
#endif

void my_c_func(void);

#ifdef __cplusplus }
#endif

// definition in a .c file:
void my_c_func(void) { 
    // ...
}
```

Defining app_main in C++

ESP-IDF expects the application entry point, `app_main`, to be defined with C linkage. When `app_main` is defined in a .cpp source file, it has to be designated as extern "C":

```c
extern "C" void app_main(void) { 
    // ...
}
```
Designated Initializers

Many of the ESP-IDF components use Configuration Structures as arguments to the initialization functions. ESP-IDF examples written in C routinely use designated initializers to fill these structures in a readable and a maintainable way.

C and C++ languages have different rules with regards to the designated initializers. For example, C++23 (currently the default in ESP-IDF) does not support out-of-order designated initialization, nested designated initialization, mixing of designated initializers and regular initializers, and designated initialization of arrays. Therefore, when porting ESP-IDF C examples to C++, some changes to the structure initializers may be necessary. See the C++ aggregate initialization reference for more details.

iostream

iostream functionality is supported in ESP-IDF, with a couple of caveats:

1. Normally, ESP-IDF build process eliminates the unused code. However, in the case of iostreams, simply including <iostream> header in one of the source files significantly increases the binary size by about 200 kB.
2. By default, ESP-IDF uses a simple non-blocking implementation of the standard input stream (stdin). To get the usual behavior of std::cin, the application has to initialize the UART driver and enable the blocking mode as shown in common_components/protocol_examples_common/stdin_out.c.

4.8.7 Limitations

- Linker script generator does not support function level placements for functions with C++ linkage.
- Various section attributes (such as IRAM_ATTR) are ignored when used with template functions.
- Vtables are placed into Flash and are not accessible when the flash cache is disabled. Therefore, virtual function calls should be avoided in IRAM-Safe Interrupt Handlers. Placement of Vtables cannot be adjusted using the linker script generator, yet.
- C++ filesystem (std::filesystem) features are not supported.

4.8.8 What to Avoid

Do not use set jmp/long jmp in C++. longjmp blindly jumps up the stack without calling any destructors, easily introducing undefined behavior and memory leaks. Use C++ exceptions instead, they guarantee correctly calling destructors. If you cannot use C++ exceptions, use alternatives (except set jmp/long jmp themselves) such as simple return codes.

4.9 Deep Sleep Wake Stubs

ESP32 supports running a “deep sleep wake stub” when coming out of deep sleep. This function runs immediately as soon as the chip wakes up - before any normal initialisation, bootloader, or ESP-IDF code has run. After the wake stub runs, the SoC can go back to sleep or continue to start ESP-IDF normally.

Deep sleep wake stub code is loaded into “RTC Fast Memory” and any data which it uses must also be loaded into RTC memory. RTC memory regions hold their contents during deep sleep.
4.9.1 Rules for Wake Stubs

Wake stub code must be carefully written:

- As the SoC has freshly woken from sleep, most of the peripherals are in reset states. The SPI flash is unmapped.
- The wake stub code can only call functions implemented in ROM or loaded into RTC Fast Memory (see below.)
- The wake stub code can only access data loaded in RTC memory. All other RAM will be uninitialised and have random contents. The wake stub can use other RAM for temporary storage, but the contents will be overwritten when the SoC goes back to sleep or starts ESP-IDF.
- RTC memory must include any read-only data (.rodata) used by the stub.
- Data in RTC memory is initialised whenever the SoC restarts, except when waking from deep sleep. When waking from deep sleep, the values which were present before going to sleep are kept.
- Wake stub code is a part of the main esp-idf app. During normal running of esp-idf, functions can call the wake stub functions or access RTC memory. It is as if these were regular parts of the app.

4.9.2 Implementing A Stub

The wake stub in esp-idf is called `esp_wake_deep_sleep()`. This function runs whenever the SoC wakes from deep sleep. There is a default version of this function provided in esp-idf, but the default function is weak-linked so if your app contains a function named `esp_wake_deep_sleep()` then this will override the default.

If supplying a custom wake stub, the first thing it should be to call `esp_default_wake_deep_sleep()`. It is not necessary to implement `esp_wake_deep_sleep()` in your app in order to use deep sleep. It is only necessary if you want to have special behaviour immediately on wake.

If you want to swap between different deep sleep stubs at runtime, it is also possible to do this by calling the `esp_set_deep_sleep_wake_stub()` function. This is not necessary if you only use the default `esp_wake_deep_sleep()` function.

All of these functions are declared in the `esp_sleep.h` header under components/esp32.

4.9.3 Loading Code Into RTC Memory

Wake stub code must be resident in RTC Fast Memory. This can be done in one of two ways.

The first way is to use the `RTC_IRAM_ATTR` attribute to place a function into RTC memory:

```c
void RTC_IRAM_ATTR esp_wake_deep_sleep(void) {
    esp_default_wake_deep_sleep();
    // Add additional functionality here
}
```

The second way is to place the function into any source file whose name starts with `rtc_wake_stub`. Files names `rtc_wake_stub*` have their contents automatically put into RTC memory by the linker.

The first way is simpler for very short and simple code, or for source files where you want to mix “normal” and “RTC” code. The second way is simpler when you want to write longer pieces of code for RTC memory.

4.9.4 Loading Data Into RTC Memory

Data used by stub code must be resident in RTC memory.

The data can be placed in RTC Fast memory or in RTC Slow memory which is also used by the ULP.

Specifying this data can be done in one of two ways:

The first way is to use the `RTC_DATA_ATTR` and `RTC_RODATA_ATTR` to specify any data (writeable or read-only, respectively) which should be loaded into RTC memory:
The RTC memory area where this data will be placed can be configured via menuconfig option named CONFIG_ESP32_RTCDATA_IN_FAST_MEM. This option allows to keep slow memory area for ULP programs and once it is enabled the data marked with RTC_DATA_ATTR and RTC_RODATA_ATTR are placed in the RTC fast memory segment otherwise it goes to RTC slow memory (default option). This option depends on the CONFIG_FREERTOS_UNICORE because RTC fast memory can be accessed only by PRO_CPU.

The attributes RTC_FAST_ATTR and RTC_SLOW_ATTR can be used to specify data that will be force placed into RTC_FAST and RTC_SLOW memory respectively. Any access to data marked with RTC_FAST_ATTR is allowed by PRO_CPU only and it is responsibility of user to make sure about it.

Unfortunately, any string constants used in this way must be declared as arrays and marked with RTC_RODATA_ATTR, as shown in the example above.

The second way is to place the data into any source file whose name starts with rtc_wake_stub.

For example, the equivalent example in rtc_wake_stub_counter.c:

```c
int wake_count;

void RTC_IRAM_ATTR esp_wake_deep_sleep(void) {
    esp_default_wake_deep_sleep();
    esp_rom_printf("Wake count \n", wake_count++);
}
```

The second way is a better option if you need to use strings, or write other more complex code.

To reduce wake-up time use the CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP Kconfig option, see more information in Fast boot from Deep Sleep.

### 4.9.5 CRC Check For Wake Stubs

During deep sleep, all RTC Fast memory areas will be validated with CRC. When ESP32 wakes up from deep sleep, the RTC fast memory will be validated with CRC again. If the validation passes, the wake stubs code will be executed. Otherwise, the normal initialization, bootloader and esp-idf codes will be executed.

**Note:** When the CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP option is enabled, all the RTC fast memory except the wake stubs area is added to the heap.

### 4.9.6 Example

ESP-IDF provides an example to show how to implement the Deep-sleep wake stub.

* system/deep_sleep_wake_stub

### 4.10 Error Handling
4.10.1 Overview

Identifying and handling run-time errors is important for developing robust applications. There can be multiple kinds of run-time errors:

- Recoverable errors:
  - Errors indicated by functions through return values (error codes)
  - C++ exceptions, thrown using `throw` keyword
- Unrecoverable (fatal) errors:
  - Failed assertions (using `assert` macro and equivalent methods, see `Assertions`) and `abort()` calls.
  - CPU exceptions: access to protected regions of memory, illegal instruction, etc.
  - System level checks: watchdog timeout, cache access error, stack overflow, stack smashing, heap corruption, etc.

This guide explains ESP-IDF error handling mechanisms related to recoverable errors, and provides some common error handling patterns.

For instructions on diagnosing unrecoverable errors, see `Fatal Errors`.

4.10.2 Error codes

The majority of ESP-IDF-specific functions use `esp_err_t` type to return error codes. `esp_err_t` is a signed integer type. Success (no error) is indicated with `ESP_OK` code, which is defined as zero.

Various ESP-IDF header files define possible error codes using preprocessor defines. Usually these defines start with `ESP_ERR_` prefix. Common error codes for generic failures (out of memory, timeout, invalid argument, etc.) are defined in `esp_err.h` file. Various components in ESP-IDF may define additional error codes for specific situations.

For the complete list of error codes, see `Error Code Reference`.

4.10.3 Converting error codes to error messages

For each error code defined in ESP-IDF components, `esp_err_t` value can be converted to an error code name using `esp_err_to_name()` or `esp_err_to_name_r()` functions. For example, passing `0x101` to `esp_err_to_name()` will return “ESP_ERR_NO_MEM” string. Such strings can be used in log output to make it easier to understand which error has happened.

Additionally, `esp_err_to_name_r()` function will attempt to interpret the error code as a standard POSIX error code, if no matching ESP_ERR_ value is found. This is done using `strerror_r` function. POSIX error codes (such as `ENOENT`, `ENOMEM`) are defined in `errno.h` and are typically obtained from `errno` variable. In ESP-IDF this variable is thread-local: multiple FreeRTOS tasks have their own copies of `errno`. Functions which set `errno` only modify its value for the task they run in.

This feature is enabled by default, but can be disabled to reduce application binary size. See `CONFIG_ESP_ERR_TO_NAME_LOOKUP`. When this feature is disabled, `esp_err_to_name()` and `esp_err_to_name_r()` are still defined and can be called. In this case, `esp_err_to_name()` will return `UNKNOWN ERROR`, and `esp_err_to_name_r()` will return Unknown error `0xXXXX(YYYYY)`, where `0xXXXX` and `YYYYY` are the hexadecimal and decimal representations of the error code, respectively.

4.10.4 ESP_ERROR_CHECK macro

`ESP_ERROR_CHECK` macro serves similar purpose as `assert`, except that it checks `esp_err_t` value rather than a `bool` condition. If the argument of `ESP_ERROR_CHECK` is not equal `ESP_OK`, then an error message is printed on the console, and `abort()` is called.

Error message will typically look like this:
ESP_ERROR_CHECK failed: esp_err_t 0x107 (ESP_ERR_TIMEOUT) at 0x400d1fdf
file: "/Users/user/esp/example/main/main.c" line 20
func: app_main
expression: sdmmc_card_init(host, &card)
Backtrace: 0x40086e7c 0x3ffb4ff0 0x40087328:0x3ffbf5010 0x400d1fdf:0x3ffbf5030...

Note: If IDF monitor is used, addresses in the backtrace will be converted to file names and line numbers.

• The first line mentions the error code as a hexadecimal value, and the identifier used for this error in source code. The latter depends on CONFIG_ESP_ERR_TO_NAME_LOOKUP option being set. Address in the program where error has occurred is printed as well.
• Subsequent lines show the location in the program where ESP_ERROR_CHECK macro was called, and the expression which was passed to the macro as an argument.
• Finally, backtrace is printed. This is part of panic handler output common to all fatal errors. See Fatal Errors for more information about the backtrace.

4.10.5 ESP_ERROR_CHECK_WITHOUT_ABORT macro

ESP_ERROR_CHECK_WITHOUT_ABORT macro serves similar purpose as ESP_ERROR_CHECK, except that it won’t call abort().

4.10.6 ESP_RETURN_ON_ERROR macro

ESP_RETURN_ON_ERROR macro checks the error code, if the error code is not equal ESP_OK, it prints the message and returns.

4.10.7 ESP_GOTO_ON_ERROR macro

ESP_GOTO_ON_ERROR macro checks the error code, if the error code is not equal ESP_OK, it prints the message, sets the local variable ret to the code, and then exits by jumping to goto_tag.

4.10.8 ESP_RETURN_ON_FALSE macro

ESP_RETURN_ON_FALSE macro checks the condition, if the condition is not equal true, it prints the message and returns with the supplied err_code.

4.10.9 ESP_GOTO_ON_FALSE macro

ESP_GOTO_ON_FALSE macro checks the condition, if the condition is not equal true, it prints the message, sets the local variable ret to the supplied err_code, and then exits by jumping to goto_tag.

4.10.10 CHECK MACROS Examples

Some examples:
```c
static const char* TAG = "Test";

esp_err_t test_func(void)
{
    esp_err_t ret = ESP_OK;

    ESP_ERROR_CHECK(x);           // err message
    ESP_ERROR_CHECK WITHOUT_ABORT(x); // err message
    ESP_RETURN_ON_ERROR(x, TAG, "fail reason 1");    // err message
    ESP_RETURN_ON_ERROR(x, TAG, "fail reason 2");    // err message
    ESP_RETURN_ON_FALSE(a, err_code, TAG, "fail reason 3"); // err message
    ESP_GOTO_ON_FALSE(a, err_code, err, TAG, "fail reason 4"); // err message

    err: // clean up
        return ret;
}
```

**Note:** If the option `CONFIG_COMPILER_OPTIMIZATION_CHECKS_SILENT` in Kconfig is enabled, the err message will be discarded, while the other action works as is.

The `ESP_RETURN_XX` and `ESP_GOTO_xx` macros can’t be called from ISR. While there are `xx_ISR` versions for each of them, e.g., `ESP_RETURN_ON_ERROR_ISR`, these macros could be used in ISR.

### 4.10.11 Error handling patterns

1. Attempt to recover. Depending on the situation, we may try the following methods:
   - retry the call after some time;
   - attempt to de-initialize the driver and re-initialize it again;
   - fix the error condition using an out-of-band mechanism (e.g. reset an external peripheral which is not responding).

   **Example:**
   ```c
   esp_err_t err;
   do {
       err = sdio_slave_send_queue(addr, len, arg, timeout);
       // keep retrying while the sending queue is full
   } while (err == ESP_ERR_TIMEOUT);
   if (err != ESP_OK) {
       // handle other errors
   }
   ```

2. Propagate the error to the caller. In some middleware components this means that a function must exit with the same error code, making sure any resource allocations are rolled back.

   **Example:**
   ```c
   sdmmc_card_t* card = calloc(1, sizeof(sdmmc_card_t));
   if (card == NULL) {
       return ESP_ERR_NO_MEM;
   }
   esp_err_t err = sdmmc_card_init(host, &card);
   ```

(continues on next page)
if (err != ESP_OK) {
    // Clean up
    free(card);
    // Propagate the error to the upper layer (e.g. to notify the user).
    // Alternatively, application can define and return custom error code.
    return err;
}

3. Convert into unrecoverable error, for example using ESP_ERROR_CHECK. See ESP_ERROR_CHECK macro section for details.
   Terminating the application in case of an error is usually undesirable behavior for middleware components, but is
   sometimes acceptable at application level.
   Many ESP-IDF examples use ESP_ERROR_CHECK to handle errors from various APIs. This is not the best
   practice for applications, and is done to make example code more concise.
   Example:

   ESP_ERROR_CHECK(spi_bus_initialize(host, bus_config, dma_chan));

4.10.12 C++ Exceptions

   See Exception Handling.

4.11 ESP-BLE-MESH

Bluetooth® mesh networking enables many-to-many (m:m) device communications and is optimized for creating
large-scale device networks.

Devices may relay data to other devices not in direct radio range of the originating device. In this way, mesh networks
can span very large physical areas and contain large numbers of devices. It is ideally suited for building automation,
sensor networks, and other IoT solutions where tens, hundreds, or thousands of devices need to reliably and securely
communicate with one another.

Bluetooth mesh is not a wireless communications technology, but a networking technology. This technology is de-
pendent upon Bluetooth Low Energy (BLE) - a wireless communications protocol stack.

Built on top of Zephyr Bluetooth Mesh stack, the ESP-BLE-MESH implementation supports device provisioning and
node control. It also supports such node features as Proxy, Relay, Low power and Friend.

Please see the ESP-BLE-MESH Architecture for information about the implementation of ESP-BLE-MESH architec-
ture and ESP-BLE-MESH API Reference for information about respective API.

ESP-BLE-MESH is implemented and certified based on the latest Mesh Profile v1.0.1, users can refer here for the
certification details of ESP-BLE-MESH.

Note: If you are looking for Wi-Fi based implementation of mesh for ESP32, please check another product by
Espressif called ESP-WIFI-MESH. For more information and documentation see ESP-WIFI-MESH.

4.11.1 Getting Started with ESP-BLE-MESH

This section is intended to help you get started with ESP-BLE-MESH for the hardware based on the ESP32 chip by
Espressif.
We are going to demonstrate process of setting and operation of a small ESP-BLE-MESH network of three nodes. This process will cover device provisioning and node configuration, and then sending on/off commands to Generic OnOff Server Models on specific nodes.

If you are new to ESP-IDF, please first set up development environment, compile, flash and run example application following top level ESP-IDF Get Started documentation.

**What You Need**

**Hardware:**

- Three ESP32 boards, see options.
- USB cables to connect the boards.
- Computer configured with ESP-IDF.
- Mobile phone or tablet running Android or iOS.

**Software:**

- Example application `bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server` code to load to the ESP32 boards.
- Mobile App: nRF Mesh for Android or iOS. Optionally you can use some other Apps:
  - EspBleMesh Android App
  - Silicon Labs Android or iOS App

**Installation Step by Step**

This is a detailed roadmap to walk you through the installation process.

**Step 1. Check Hardware**  
Both ESP32-DevKitC and ESP-WROVER-KIT development boards are supported for ESP-BLE-MESH implementation. You can choose particular board through menuconfig: `idf.py menuconfig`  
`Example Configuration`  
`Board selection for ESP-BLE-MESH`

**Note:** If you plan to use ESP32-DevKitC, connect a RGB LED to GPIO pins 25, 26 and 27.

**Step 2. Configure Software**  
Enter the `bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server` example directory, run `idf.py menuconfig` to select your board and then run `idf.py build` to compile the example.

**Step 3. Upload Application to Nodes**  
After the `bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server` example is compiled successfully, users can run `idf.py flash` to upload the same generated binary files into each of the three development boards.

Once boards are powered on, the RGB LED on each board should turn **GREEN**.

**Step 4. Provision Nodes**  
In this section, we will use the nRF Mesh Android App to demonstrate how to provision an unprovisioned device. Users can also get its iOS version from the App Store.

**4.1 Scanner**  
The Scanner is App’s functionality to search for unprovisioned devices in range. Open the App, press **Scanner** at the bottom and the search will start. After a short while we should see three unprovisioned devices displayed.
Fig. 9: ESP-BLE-MESH Devices Power On

Fig. 10: nRF Mesh - Scanner
4.2 Identify  Users can select any unprovisioned device, then the App will try to set up a connection with the selected device. After the BLE connection is established successfully (sometimes users need to try multiple times to get connected), and proper ESP-BLE-MESH GATT Service is discovered, users can see the **IDENTIFY** interface button on the screen. The **IDENTIFY** operation can be used to tell users which device is going to be provisioned.

**Note:** The **IDENTIFY** operation also needs some cooperation on the device side, then users can see which device is in the provisioning process. Currently when pressing the **IDENTIFY** interface button, no signs can be seen from the device except from the log on the serial monitor.

After the **IDENTIFY** interface button is pressed, users can see the **PROVISION** interface button.

![Fig. 11: nRF Mesh - IDENTIFY - PROVISION](image)

4.3 Provision  Then, the App will try to provision the unprovisioned device. When the device is provisioned successfully, the RGB LED on the board will turn off, and the App will implement the following procedures:

1. Disconnect with the node
2. Try to reconnect with the node
3. Connect successfully and discover ESP-BLE-MESH GATT Service
4. Get Composition Data of the node and add AppKey to it

When all the procedures are finished, the node is configured properly. And after pressing **OK**, users can see that unicast address is assigned, and Composition Data of the node is decoded successfully.

Sometimes in procedure 2, the App may fail to reconnect with the node. In this case, after pressing **OK**, users can see that only unicast address of the node has been assigned, but no Composition Data has been got. Then users need to press **CONNECT** on the top right, and the previously provisioned node will be displayed on the screen, and users need to choose it and try to connect with the node.

After connecting successfully, the App will show the interface buttons which can be used to get Composition Data and add AppKey.

If the device is the second or the third one which has been provisioned by the App, and after pressing **CONNECT**, users can see two or three nodes on the screen. In this situation, users can choose any device to connect with, once succeed then go back to the main screen to choose the node which needs to be configured.
Fig. 12: nRF Mesh - Configuration Complete

Fig. 13: nRF Mesh - Initial Configuration Failed
Here an example of three devices listed.

- The left picture shows that the third device is provisioned successfully, but the App failed to connect with it. When it tries to reconnect with the third node, three nodes are displayed on the App.
- The right picture shows that after connecting with any node successfully, the App displays the information of the three nodes. Users can see that the App has got the Composition Data of the first and the second nodes, but for the third one, only the unicast address has been assigned to it while the Composition Data is unknown.

4.4 Configuration

When provisioning and initial configuration are finished, users can start to configure the node, such as binding AppKey with each model with the elements, setting publication information to it, etc.

Example below shows how to bind AppKey with Generic OnOff Server Model within the Primary Element.

Note: No need to bind AppKey with the Configuration Server Model, since it only uses the DevKey to encrypt messages in the Upper Transport Layer.

Step 5. Operate Network

After all the Generic OnOff Server Models within the three elements are bound with proper AppKey, users can use the App to turn on/off the RGB LED.

In the `bluetooth/esp_ble_mesh/ble_mesh_node/onoff_server` example, the first Generic OnOff Server Model is used to control the **RED** color, the second one is used to control the **GREEN** color and the third one is used to control the **BLUE** color.

The following screenshot shows different board with different color on.

Note: For **nRF Mesh** iOS App [version 1.0.4], when the node contains more than one element, the App is not behaving correctly. If users try to turn on/off the second or the third Generic OnOff Server Model, the message sent by the App is destined to the first Generic OnOff Server Model within the Primary Element.
Fig. 15: nRF Mesh - Reconnect - Three Nodes

Fig. 16: nRF Mesh - Model Bind AppKey
Fig. 17: nRF Mesh - Generic OnOff Control

Fig. 18: Three ESP-BLE-MESH Nodes On
4.11.2 ESP-BLE-MESH Examples

• **ESP-BLE-MESH Node OnOff Server** - shows the use of ESP-BLE-MESH as a node having a Configuration Server model and a Generic OnOff Server model. A ESP-BLE-MESH Provisioner can then provision the unprovisioned device and control a RGB LED representing on/off state, see [example code](#).

• **ESP-BLE-MESH Node OnOff Client** - shows how a Generic OnOff Client model works within a node. The node has a Configuration Server model and a Generic OnOff Client model, see [example code](#).

• **ESP-BLE-MESH Provisioner** - shows how a device can act as an ESP-BLE-MESH Provisioner to provision devices. The Provisioner has a Configuration Server model, a Configuration Client model and a Generic OnOff Client model, see [example code](#).

• **ESP-BLE-MESH Fast Provisioning - Client and Server** - this example is used for showing how fast provisioning can be used in order to create a mesh network. It takes no more than 60 seconds to provision 100 devices, see [example client code](#) and [example server code](#).

• **ESP-BLE-MESH and Wi-Fi Coexistence** - an example that demonstrates the Wi-Fi and Bluetooth (BLE/BR/EDR) coexistence feature of ESP32. Simply put, users can use the Wi-Fi while operating Bluetooth, see [example code](#).

• **ESP-BLE-MESH Console** - an example that implements BLE Mesh basic features. Within this example a node can be scanned and provisioned by Provisioner and reply to get/set message from Provisioner, see [example node code](#).

4.11.3 ESP-BLE-MESH Demo Videos

• Espressif Fast Provisioning using ESP-BLE-MESH App
• Espressif ESP-BLE-MESH and Wi-Fi Coexistence

4.11.4 ESP-BLE-MESH FAQ

• 1. Provisioner Development
• 2. Node Development
• 3. ESP-BLE-MESH and Wi-Fi Coexistence
• 4. Fast Provisioning
• 5. Log Help
• 6. Example Help
• 7. Others

4.11.5 Related Documents

**ESP-BLE-MESH Feature List**

**Supported Features**

**Mesh Core**

• **Provisioning: Node Role**
  – PB-ADV and PB-GATT
  – OOB Authentication

• **Provisioning: Provisioner Role**
  – PB-ADV and PB-GATT
  – OOB Authentication

• **Networking**
  – Relay
  – Segmentation and Reassembly
  – Key Refresh Procedure
  – IV Update Procedure
  – Friend
Chapter 4. API Guides

- Low Power
- Proxy Server
- Proxy Client

**Multiple Client Models Run Simultaneously**
- Support multiple client models send packets to different nodes simultaneously
- No blocking between client model and server model

**NVS Storing**
- Store provisioning and configuration information of ESP-BLE-MESH Node

Mesh Models

- **Foundation models**
  - Configuration Server model
  - Configuration Client model
  - Health Server model
  - Health Client model

- **Generic client models**
  - Generic OnOff Client
  - Generic Level Client
  - Generic Default Transition Time Client
  - Generic Power OnOff Client
  - Generic Power Level Client
  - Generic Battery Client
  - Generic Location Client
  - Generic Property Client

- **Sensor client models**
  - Sensor Client

- **Time and Scenes client models**
  - Time Client
  - Scene Client
  - Scheduler Client

- **Lighting client models**
  - Light Lightness Client
  - Light CTL Client
  - Light HSL Client
  - Light xyL Client
  - Light LC Client

- **Generic server models**
  - Generic OnOff Server
  - Generic Level Server
  - Generic Default Transition Time Server
  - Generic Power OnOff Server
  - Generic Power OnOff Setup Server
  - Generic Power Level Server
  - Generic Power Level Setup Server
  - Generic Battery Server
  - Generic Location Server
  - Generic Location Setup Server
  - Generic User Property Server
  - Generic Admin Property Server
  - Generic Manufacturer Property Server
  - Generic Client Property Server

- **Sensor server models**
  - Sensor Server
  - Sensor Setup Server

- **Time and Scenes server models**
  - Time Server
  - Time Setup Server
– Scene Server
– Scene Setup Server
– Scheduler Server
– Scheduler Setup Server

• Lighting server models
  – Light Lightness Server
  – Light Lightness Setup Server
  – Light CTL Server
  – Light CTL Temperature Server
  – Light CTL Setup Server
  – Light HSL Server
  – Light HSL Hue Server
  – Light HSL Saturation Server
  – Light HSL Setup Server
  – Light xyl Server
  – Light xyl Setup Server
  – Light LC Server
  – Light LC Setup Server

Mesh Applications

• ESP-BLE-MESH Node
  – Tutorial
  – Tutorial
  – Example

• ESP-BLE-MESH Provisioner
  – Tutorial
  – Example

• ESP-BLE-MESH Fast Provisioning
  – Fast Provisioning Client Model Tutorial
  – Fast Provisioning Server Model Tutorial
  – Example
  – Demo Video

• ESP-BLE-MESH and Wi-Fi Coexistence
  – Tutorial
  – Example
  – Demo Video

• ESP-BLE-MESH Console Commands
  – Example

Future Release Features

Mesh Core

• Provisioner NVS Storage

Mesh Applications

• Fast OTA
• Friendship

ESP-BLE-MESH Architecture

This document introduces ESP-BLE-MESH architecture overview, ESP-BLE-MESH architecture implementation as well as ESP-BLE-MESH auxiliary routines.
Chapter 4. API Guides

• ESP-BLE-MESH Architecture Overview
  – Describes the five major parts of ESP-BLE-MESH architecture and the functionality of each part.
• ESP-BLE-MESH Architecture Implementation
  – Describes the basic functions of ESP-BLE-MESH files, the correspondence between files and ESP-BLE-MESH architecture, and the interface for calling among files.
• ESP-BLE-MESH Auxiliary Routines
  – Describe the auxiliary routines of ESP-BLE-MESH, such as Mesh network management, Mesh features, etc.

1. ESP-BLE-MESH Architecture Overview

Currently ESP-BLE-MESH has implemented most functions of Mesh Profile and all the Client Models defined in Mesh Model specification. Those missing functions/models are under development and will be provided soon. ESP-BLE-MESH architecture has been granted the official Bluetooth certification.

ESP-BLE-MESH architecture includes five key parts:

• Mesh Protocol Stack
  – Mesh Networking is responsible for processing of messages of ESP-BLE-MESH nodes.
  – Mesh Provisioning is responsible for provisioning flow of ESP-BLE-MESH devices.
  – Mesh Models is responsible for the implementation of SIG-defined models.
• Network Management
  – Implements several network management procedures, including node removal procedure, IV Index recovery procedure, etc.
• Features
  – Include several ESP-BLE-MESH features, e.g. Low Power feature, Friend feature, Relay feature, etc.
• Mesh Bearer Layer
  – Includes Advertising Bearer and GATT Bearer. The bearer layer is crucial to ESP-BLE-MESH protocol stack which is built on Bluetooth Low-Energy technology, because the protocol stack must make use of the bearer layer to transmit data via the BLE advertising channel and connection channel.
• Applications
  – Based on ESP-BLE-MESH protocol stack and Mesh Models.
  – By calling API and handling Event, Applications interact with Mesh Networking and Mesh Provisioning in ESP-BLE-MESH protocol stack, as well as a series of Models provided by Mesh Models.

1.1 Mesh Protocol Stack

1.1.1 Mesh Networking

Mesh Networking in the protocol stack architecture implements the following functions:

• The communication between nodes in the Mesh network.
• Encryption and decryption of messages in the Mesh network.
• Management of Mesh network resources (Network Key, IV Index, etc.).
• Segmentation and reassembly of Mesh network messages.
• Model mapping of messages between different models.
• For more features, please see ESP-BLE-MESH Feature List.

The implementation of Mesh Networking functions is based on hierarchy structure. Functions of each layer are shown in Table 1.1:
Fig. 19: Figure 1.1 ESP-BLE-MESH Architecture Diagram
Table 3: Table 1.1 Mesh Networking Architecture Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Layer</td>
<td>Access Layer not only defines the format of application data, but also defines and controls the encryption and decryption of the data packets conducted by Upper Transport Layer.</td>
</tr>
<tr>
<td>Upper Transport Layer</td>
<td>Upper Transport Layer encrypts, decrypts, and authenticates application data to and from the access layer; it also handles special messages called “transport control messages”, including messages related to “friendship” and heartbeat messages.</td>
</tr>
<tr>
<td>Lower Transport Layer</td>
<td>Lower Transport Layer handles segmentation and reassembly of PDU.</td>
</tr>
<tr>
<td>Network Layer</td>
<td>Network Layer defines the address type and format of the network messages, and implements the relay function of the device.</td>
</tr>
</tbody>
</table>

1.1.2 Mesh Provisioning Mesh Provisioning in the protocol stack architecture implements the following functions:

- Provisioning of unprovisioned devices.
- Allocation of Mesh network resources (unicast address, IV Index, NetKey, etc.).
- Four authentication methods support during provisioning.
- For more features, please see ESP-BLE-MESH Feature List.

The implementation of Mesh Provisioning functions is based on hierarchy structure. Functions of each layer are shown in Table 1.2:

Table 4: Table 1.2 Mesh Provisioning Architecture Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning PDUs</td>
<td>Provisioning PDUs from different layers are handled using provisioning protocol.</td>
</tr>
<tr>
<td>Generic Provisioning PDU/Proxy PDU</td>
<td>The Provisioning PDUs are transmitted to an unprovisioned device using a Generic Provisioning layer or Proxy protocol layer.</td>
</tr>
<tr>
<td>PB-ADV/PB-GATT</td>
<td>These layers define how the Provisioning PDUs are transmitted as transactions that can be segmented and reassembled.</td>
</tr>
<tr>
<td>Advertising/Provisioning Service</td>
<td>The provisioning bearers define how sessions are established such that the transactions from the generic provisioning layer can be delivered to a single device.</td>
</tr>
</tbody>
</table>

1.1.3 Mesh Models Mesh Models in the protocol stack architecture implements the following functions:

- Configuration Client/Server Models
- Health Client/Server Models
- Generic Client/Server Models
- Sensor Client/Server Models
- Time and Scenes Client/Server Models
- Lighting Client/Server Models

Functions of each layer are shown in Table 1.3:

Table 5: Table 1.3 Mesh Models Architecture Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Layer</td>
<td>Model Layer implements models used to standardize the operation of typical user scenarios, including Generic Client/Server Models, Sensor Client/Server Models, Time and Scenes Client/Server Models, Lighting Client/Server Models and several vendor models.</td>
</tr>
<tr>
<td>Foundation Model Layer</td>
<td>Foundation Model Layer implements models related to ESP-BLE-MESH configuration, management, self diagnosis, etc.</td>
</tr>
</tbody>
</table>

1.2 Mesh Network Management Network Management implements the following functions:
Chapter 4. API Guides

- Node removal procedure is used to remove a node from the network.
- IV Index recovery procedure is used to recover a node’s IV Index.
- IV update procedure is used to update the nodes’ IV Index.
- Key refresh procedure is used to update the nodes’ NetKey, AppKey, etc.
- Network creation procedure is used to create a mesh network.
- NVS storage is used to store node’s networking information.

1.3 Mesh Features Features includes the following options:

- Low Power feature is used to reduce node’s power consumption.
- Friend feature is used to store messages for Low Power nodes.
- Relay feature is used to relay/forward Network PDUs received by a node over the advertising bearer.
- Proxy Server/Client are two node roles in proxy protocol, which enable nodes to send and receive Network PDUs, mesh beacons, proxy configuration messages and Provisioning PDUs over a connection-oriented bearer.

1.4 Mesh Bearer Layer Bearers in the protocol stack architecture are responsible for passing of data between ESP-BLE-MESH protocol stack and Bluetooth Low Energy Core.

Bearers can be taken as a carrier layer based on Bluetooth Low Energy Core, which implements the function of receiving and transmitting data for the ESP-BLE-MESH protocol stack.

Table 6: Table 1.3 Mesh Bearers Description

<table>
<thead>
<tr>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>GATT Bearer</td>
<td>The GATT Bearer uses the Proxy protocol to transmit and receive Proxy PDUs between two devices over a GATT connection.</td>
</tr>
<tr>
<td>Advertising Bearer</td>
<td>When using the Advertising Bearer, a mesh packet shall be sent in the Advertising Data of a Bluetooth Low Energy advertising PDU using the Mesh Message AD Type.</td>
</tr>
</tbody>
</table>

1.5 Mesh Applications The Applications in the protocol stack architecture implement the corresponding functions by calling the API provided by the ESP-BLE-MESH protocol stack and processing the Event reported by the protocol stack. There are some common applications, such as gateway, lighting and etc.

Interaction between application layer (Applications) and API / Event

- Application layer calls API
  - Call the provisioning-related API for provisioning.
  - Call the model-related API to send messages.
  - Call the device-attributes-related API to get local information about the device.
- Application layer processes Event
  The application layer is designed based on events, which take parameters to the application layer. Events are mainly divided into two categories.
  - **The events completed by calling API.**
    - Such as nodes sending messages.
  - **The events that the protocol stack actively reports to the application layer.**
    - The Event that the protocol stack actively reports.
    - The Event that Model actively reports.
- The event is reported by the callback function registered by the application layer, and the callback function also contains the corresponding processing of the event.

Interaction between API / Event and ESP-BLE-MESH protocol stack

- API used by user mainly calls functions provided by Mesh Networking, Mesh Provisioning and Mesh Models.
- The interaction between API / Event and the protocol stack does not operate across the hierarchy of the protocol stack. For example, API does not call functions related to Network Layer.
2. ESP-BLE-MESH Architecture Implementation

The design and implementation of ESP-BLE-MESH architecture is based on layers and modules. In details, Section 2.1 (Mesh Networking Implementation), Section 2.2 (Mesh Provisioning Implementation) and Section 2.3 (Mesh Bearers Implementation) are based on layers, and Section 2.4 (Mesh Models Implementation) is on modules.

- **Layer-based Approach**: With Layer-based approach, the architecture is designed according to the layers specified in the Mesh Profile Specification. Each layer has its unique files which include APIs of this layer and etc. The specific design is shown in Figure 2.1.
- **Module-based Approach**: Every file implements an independent function that can be called by other programs.

The design of ESP-BLE-MESH architecture uses layer-based approach. The sequence of layers which data packets are processed through is fixed, i.e., the processing of packets will form a message flow. Thus, we could see flows of messages from the Protocol Stack Interface Diagram in Figure 2.1.

2.1 Mesh Protocol Stack Implementation

2.1.1 Mesh Networking Implementation

The list of files and the functions implemented in each file in Mesh Networking are shown in Table 2.1:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>access.c</td>
<td>ESP-BLE-MESH Access Layer</td>
</tr>
<tr>
<td>transport.c</td>
<td>ESP-BLE-MESH Lower/Upper Transport Layer</td>
</tr>
<tr>
<td>net.c</td>
<td>ESP-BLE-MESH Network Layer</td>
</tr>
<tr>
<td>adv.c</td>
<td>A task used to send ESP-BLE-MESH advertising packets, a callback used to handle received advertising packets and APIs used to allocate adv buffers</td>
</tr>
</tbody>
</table>

2.1.2 Mesh Provisioning Implementation

The implementation of Mesh Provisioning is divided into two chunks due to the Node/Provisioner coexistence.

Specific files that provide implementation of provisioning of Node are shown in Table 2.2:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>prov.c</td>
<td>ESP-BLE-MESH Node provisioning (PB-ADV &amp; PB-GATT)</td>
</tr>
<tr>
<td>proxy_server.c</td>
<td>ESP-BLE-MESH Proxy Server related functionalities</td>
</tr>
<tr>
<td>beacon.c</td>
<td>APIs used to handle ESP-BLE-MESH Beacons</td>
</tr>
</tbody>
</table>

Specific files that implement functions of Provisioner are shown in Table 2.3:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>provisioner_prov.c</td>
<td>ESP-BLE-MESH Provisioner provisioning (PB-ADV &amp; PB-GATT)</td>
</tr>
<tr>
<td>proxy_client.c</td>
<td>ESP-BLE-MESH Proxy Client related functionalities</td>
</tr>
<tr>
<td>provisioner_main.c</td>
<td>ESP-BLE-MESH Provisioner networking related functionalities</td>
</tr>
</tbody>
</table>

2.1.3 Mesh Models Implementation

Mesh Models are used to implement the specific functions of model in nodes. Server model is used to maintain node status. Client model is used to obtain and modify node state.
Chapter 4. API Guides

Figure 20: ESP-BLE-MESH Architecture Implementation Diagram

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Table 10: Table 2.4 Mesh Models File Description

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>cfg_cli.c</td>
<td>Send Configuration Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>cfg_srv.c</td>
<td>Receive Configuration Client messages and send proper response messages</td>
</tr>
<tr>
<td>health_cli.c</td>
<td>Send Health Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>health_srv.c</td>
<td>Receive Health Client messages and send proper response messages</td>
</tr>
<tr>
<td>client_common.c</td>
<td>ESP-BLE-MESH model related operations</td>
</tr>
<tr>
<td>generic_client.c</td>
<td>Send ESP-BLE-MESH Generic Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>lighting_client.c</td>
<td>Send ESP-BLE-MESH Lighting Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>sensor_client.c</td>
<td>Send ESP-BLE-MESH Sensor Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>time_scene_client.c</td>
<td>Send ESP-BLE-MESH Time Scene Client messages and receive corresponding response messages</td>
</tr>
<tr>
<td>generic_server.c</td>
<td>Receive ESP-BLE-MESH Generic Client messages and send corresponding response messages</td>
</tr>
<tr>
<td>lighting_server.c</td>
<td>Receive ESP-BLE-MESH Lighting Client messages and send corresponding response messages</td>
</tr>
<tr>
<td>sensor_server.c</td>
<td>Receive ESP-BLE-MESH Sensor Client messages and send corresponding response messages</td>
</tr>
<tr>
<td>time_scene_server.c</td>
<td>Receive ESP-BLE-MESH Time Scene Client messages and send corresponding response messages</td>
</tr>
</tbody>
</table>

2.2 Mesh Bearers Implementation  Portability is fully considered in the implementation of Mesh Bearers. When the ESP-BLE-MESH protocol stack is being ported to other platforms, users only need to modify mesh_bearer_adapt.c (example of NimBLE version).

Table 11: Table 2.5 Mesh Bearers File Description

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>mesh_bearer_adapt.c</td>
<td>ESP-BLE-MESH Bearer Layer adapter, This file provides the interfaces used to receive and send ESP-BLE-MESH ADV &amp; GATT related packets.</td>
</tr>
</tbody>
</table>

Note: mesh_bearer_adapt.c is the implementation of Advertising Bearer and GATT Bearer in Mesh Networking framework.

2.3 Mesh Applications Implementation  We have provided a series of application examples for customer development, and users can develop products based on ESP-BLE-MESH Examples.

3. Auxiliary Routine  Auxiliary routine refers to optional functions in the ESP-BLE-MESH protocol stack. The design of the auxiliary routine generally implement the truncation of code through CONFIG_BLE_MESH.

3.1 Features

- Low Power
- Friend
- Relay
- Proxy Client/Server
Chapter 4. API Guides

3.2 Network Management

- Node Removal procedure
- IV Index Recovery procedure
- IV Update procedure
- Key Refresh procedure
- Network Creation procedure
- NVS Storage

3.3 Auxiliary Routine Implementation

When adopting the design of independent module, the two main factors should be considered:

- The module cannot be implemented hierarchically, and it can be completely independent, which means it does not rely on the implementation of other modules.
- The functions in the module will be used repeatedly, so it is reasonable to design it into a module. Independent module is shown in Table 3.1:

<table>
<thead>
<tr>
<th>File</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>lpn.c</td>
<td>ESP-BLE-MESH Low Power functionality</td>
</tr>
<tr>
<td>friend.c</td>
<td>ESP-BLE-MESH Friend functionality</td>
</tr>
<tr>
<td>net.c</td>
<td>ESP-BLE-MESH Relay feature, network creation, IV Update procedure, IV Index</td>
</tr>
<tr>
<td>proxy_server.c</td>
<td>ESP-BLE-MESH Proxy Server related functionalities</td>
</tr>
<tr>
<td>proxy_client.c</td>
<td>ESP-BLE-MESH Proxy Client related functionalities</td>
</tr>
<tr>
<td>settings.c</td>
<td>ESP-BLE-MESH NVS storage functionality</td>
</tr>
<tr>
<td>main.c</td>
<td>ESP-BLE-MESH stack initialize, stack enable, node removal related functionalities</td>
</tr>
</tbody>
</table>

ESP-BLE-MESH FAQ

This document provides a summary of frequently asked questions about developing with ESP-BLE-MESH, and is divided into seven sections:

- 1. Provisioner Development
- 2. Node Development
- 3. ESP-BLE-MESH and Wi-Fi Coexistence
- 4. Fast Provisioning
- 5. Log Help
- 6. Example Help
- 7. Others

Users could refer to the sections for quick answer to their questions. This document will be updated based on the feedback collected via various channels.

1. Provisioner Development

Generally, a Provisioner is used to provision unprovisioned devices and form a mesh network. And after provisioning, roles of the unprovisioned devices will be changed to those of a node.

1.1 What is the flow for an unprovisioned device to join ESP-BLE-MESH network?

There are two phases for a device to join ESP-BLE-MESH network via a Provisioner, namely, provisioning and configuration.

- The phase of provisioning is to assign unicast address, add NetKey and etc. to a device. By provisioning, the device joins the ESP-BLE-MESH network and its role is changed from an unprovisioned device to a node.
The phase of configuration is to add AppKeys to the node and bind AppKeys to corresponding models. And some items are optional during configuration, including adding subscription addresses to the node, set publication information, etc. By configuration, the node can actually transmit messages to a Provisioner and receive messages from it.

1.2 If a Provisioner wants to change states of a node, what requirements should be met for a Provisioner?

- Client model that corresponds to server model of the node is required.
- NetKey and AppKey used to encrypt messages shall be owned by both the node and the Provisioner.
- The address owned by the node shall be known, which could be its unicast address or subscription address.

1.3 How can NetKey and AppKey be used?

- NetKey is used for encryption of messages in Network Layer. Nodes with the same NetKey are assumed to be in the same subnet while those with different NetKeys cannot communicate with each other.
- AppKey is used for encryption of messages in Upper Transport Layer. If client model and server model are bound to different AppKeys, the communication cannot be achieved.

1.4 How to generate a NetKey or AppKey for Provisioner? Can we use a fixed NetKey or AppKey?

- The API `esp_ble_mesh_provisioner_add_local_net_key()` can be used to add a NetKey with a fixed or random value.
- The API `esp_ble_mesh_provisioner_add_local_app_key()` can be used to add an AppKey with a fixed or random value.

1.5 Is the unicast address of Provisioner fixed?

The value of `prov_unicast_addr` in `esp_ble_mesh_prov_t` is used to set the unicast address of Provisioner, it can be set only once during initialization and can’t be changed afterwards.

1.6 Can the address of Provisioner serve as destination address of the node-reporting-status message?

The unicast address of Provisioner can be set only once during initialization and can’t be changed afterwards. In theory, it can serve as the destination address of the node-reporting-status message, provided that the unicast address of the Provisioner is known by nodes. Nodes can know the unicast address of Provisioner during configuration since Provisioner sends messages to them with its unicast address used as the source address.

Subscription address can also be used. Provisioner subscribes to a group address or virtual address, and nodes send messages to the subscription address.

1.7 Is the unicast address of the node that is firstly provisioned by Provisioner to ESP-BLE-MESH network fixed?

The value of `prov_start_address` in `esp_ble_mesh_prov_t` is used to set the starting address when the Provisioner provisions unprovisioned devices, i.e. the unicast address of the node it firstly provisioned. It can be set only once during initialization and can’t be changed afterwards.

1.8 Is the unicast address of the node that mobile App firstly provisioned fixed?

The App will decide the unicast address, and currently most of them are fixed.
1.9 How to know which unprovisioned device is the Provisioner that is provisioning currently?

The value of `prov_attention` in `esp_ble_mesh_prov_t` is used by Provisioner set to unprovisioned device during provisioning. It can be set only once during initialization and can’t be changed afterwards. When the unprovisioned device is joining the mesh network, it can display in a specific way like flashing light to notify Provisioner that it is being provisioned.

1.10 How many ways to authenticate the devices during provisioning? Which way was used in the provided examples?

There are four authentication methods, i.e. No OOB, Static OOB, Output OOB and Input OOB. In the provided examples, No OOB is used.

1.11 What information can be carried by the advertising packets of the unprovisioned device before provisioning into the network?

- Device UUID
- OOB Info
- URL Hash (optional)

1.12 Can such information be used for device identification?

For example, each unprovisioned device contains a unique Device UUID, which can be used for device identification.

1.13 How is the unicast address assigned when the node provisioned by Provisioner contains multiple elements?

- Provisioner will assign an unicast address for the primary element of the node, and unicast address of the remaining elements are incremented one by one.
- For example: If an unprovisioned device has three elements, i.e. the primary element, the second element and the third element. After provisioning, the primary element address of the node is 0x0002 while the second element address is 0x0003, and the third element address is 0x0004.

1.14 How can Provisioner get and parse the Composition Data of nodes through Configuration Client Model?

- Provisioner can get the Composition Data of nodes using the `Configuration Client Model` API `esp_ble_mesh_config_client_set_state()` with `comp_data_get` in the parameter `esp_ble_mesh_cfg_client_get_state_t` set properly.
- Users can refer to the following code to parse the Composition Data:

```c
#include <stdio.h>
#include <string.h>
#include <stdint.h>

// test date: 0C001A00080003000010501000000801000003103F002A00
// 0C00 1A00 0100 0800 0300 0001 05 01 0000 0080 0100 0010 0310 3F002A00

// CID is 0x000C
// PID is 0x001A
// VID is 0x0001
// CRPL is 0x0008
// Features is 0x0003 - Relay and Friend features.
// Loc is "front" - 0x0100
// NumS is 5
// NumV is 1
// The Bluetooth SIG Models supported are: 0x0000, 0x8000, 0x0001, 0x1000, ...
```

(continues on next page)
/ The Vendor Models supported are: Company Identifier 0x003F and Model_Identifier 0x002A

typedef struct {
    int16_t cid;
    int16_t pid;
    int16_t vid;
    int16_t crpl;
    int16_t features;
    int16_t all_models;
    uint8_t sig_models;
    uint8_t vnd_models;
} esp_ble_mesh_composition_head;

typedef struct {
    uint16_t model_id;
    uint16_t vendor_id;
} tsModel;

typedef struct {
    // reserve space for up to 20 SIG models
    uint16_t SIG_models[20];
    uint8_t numSIGModels;

    // reserve space for up to 4 vendor models
    tsModel Vendor_models[4];
    uint8_t numVendorModels;
} esp_ble_mesh_composition_decode;

int decode_comp_data(esp_ble_mesh_composition_head *head, esp_ble_mesh_composition_decode *data, uint8_t *mystr, int size)
{
    int pos_sig_base;
    int pos_vnd_base;
    int i;

    memcpy(head, mystr, sizeof(*head));

    if(size < sizeof(*head) + head->sig_models * 2 + head->vnd_models * 4) {
        return -1;
    }

    pos_sig_base = sizeof(*head) - 1;

    for(i = 1; i < head->sig_models * 2; i = i + 2) {
        data->SIG_models[i/2] = mystr[i + pos_sig_base] | (mystr[i + pos_sig_base + 1] << 8);
        printf("%d: %4.4x
", i/2, data->SIG_models[i/2]);
    }

    pos_vnd_base = head->sig_models * 2 + pos_sig_base;

    for(i = 1; i < head->vnd_models * 2; i = i + 2) {
        data->Vendor_models[i/2].model_id = mystr[i + pos_vnd_base] | (mystr[i + pos_vnd_base + 1] << 8);
        printf("%d: %4.4x
", i/2, data->Vendor_models[i/2].model_id);
        data->Vendor_models[i/2].vendor_id = mystr[i + pos_vnd_base + 2] | (mystr[i + pos_vnd_base + 3] << 8);
        printf("%d: %4.4x
", i/2, data->Vendor_models[i/2].vendor_id);
    }
return 0;
}

void app_main(void)
{
    esp_ble_mesh_composition_head head = {0};
    esp_ble_mesh_composition_decode data = {0};
    uint8_t mystr[24] = {
        0x0C, 0x00, 0x1A, 0x00,
        0x01, 0x00, 0x08, 0x00,
        0x03, 0x00, 0x00, 0x01,
        0x05, 0x01, 0x00, 0x00,
        0x00, 0x80, 0x01, 0x00,
        0x00, 0x10, 0x03, 0x10,
        0x03, 0x00, 0x2A, 0x00};
    int ret;
    ret = decode_comp_data(&head, &data, mystr, sizeof(mystr));
    if (ret == -1) {
        printf("decode_comp_data error");
    }
}

1.15 How can Provisioner further configure nodes through obtained Composition Data?

Provisioner do the following configuration by calling the Configuration Client Model API esp_ble_mesh_config_client_set_state().

- Add AppKey to nodes with app_key_add in the parameter esp_ble_mesh_cfg_client_set_state_t set properly.
- Add subscription address to the models of nodes with model_sub_add in the parameter esp_ble_mesh_cfg_client_set_state_t set properly.
- Set publication information to the models of nodes with model_pub_set in the parameter esp_ble_mesh_cfg_client_set_state_t set properly.

1.16 Can nodes add corresponding configurations for themselves?

This method can be used in special cases like testing period.

- Here is an example to show nodes add new group addresses for their models.

```c
esp_err_t example_add_fast_prov_group_address(uint16_t model_id, uint16_t... group_addr)
{
    const esp_ble_mesh_comp_t *comp = NULL;
    esp_ble_mesh_elem_t *element = NULL;
    esp_ble_mesh_model_t *model = NULL;
    int i, j;
    if (!ESP_BLE_MESH_ADDR_IS_GROUP(group_addr)) {
        return ESP_ERR_INVALID_ARG;
    }
    comp = esp_ble_mesh_get_composition_data();
    if (!comp) {
        return ESP_FAIL;
    }
    for (i = 0; i < comp->element_count; i++) {
```
element = &comp->elements[i];
model = esp_ble_mesh_find_sig_model(element, model_id);
if (!model) {
    continue;
}
for (j = 0; j < ARRAY_SIZE(model->groups); j++) {
    if (model->groups[j] == group_addr) {
        break;
    }
}
if (j != ARRAY_SIZE(model->groups)) {
    ESP_LOGW(TAG, "%s: Group address already exists, element__
        __index: %d", __func__, i);
    continue;
}
for (j = 0; j < ARRAY_SIZE(model->groups); j++) {
    if (model->groups[j] == ESP_BLE_MESH_ADDR_UNASSIGNED) {
        model->groups[j] = group_addr;
        break;
    }
}
if (j == ARRAY_SIZE(model->groups)) {
    ESP_LOGE(TAG, "%s: Model is full of group addresses, element__
        __index: %d", __func__, i);
}
return ESP_OK;

Note: When the NVS storage of the node is enabled, group address added and AppKey bound by this method will not be saved in the NVS when the device is powered off currently. These configuration information can only be saved if they are configured by Configuration Client Model.

1.17 How does Provisioner control nodes by grouping?

Generally there are two approaches to implement group control in ESP-BLE-MESH network, group address approach and virtual address approach. And supposing there are 10 devices, i.e., five devices with blue lights and five devices with red lights.

• Method 1: 5 blue lights can subscribe to a group address, 5 red lights subscribe to another one. By sending messages to different group addresses, Provisioner can realize group control.
• Method 2: 5 blue lights can subscribe to a virtual address, 5 red lights subscribe to another one. By sending messages to different virtual addresses, Provisioner can realize group control.

1.18 How does Provisioner add nodes to multiple subnets?

Provisioner can add multiple NetKeys to nodes during configuration, and nodes sharing the same NetKey belong to the same subnet. Provisioner can communicate with nodes on different subnets by using different NetKeys.

1.19 How does Provisioner know if a node in the mesh network is offline?

Node offline is usually defined as: the condition that the node cannot be properly communicated with other nodes in the mesh network due to power failure or some other reasons.

There is no connection between nodes and nodes in the ESP-BLE-MESH network. They communicate with each other through advertising channels.
Chapter 4. API Guides

An example is given here to show how to detect a node is offline by Provisioner.

- The node can periodically send heartbeat messages to Provisioner. And if Provisioner failed to receive heartbeat messages in a certain period, the node is considered to be offline.

**Note:** The heartbeat message should be designed into a single package (less than 11 bytes), so the transmission and reception of it can be more efficient.

### 1.20 What operations should be performed when Provisioner removes nodes from the network?

Usually when Provisioner tries to remove node from the mesh network, the procedure includes three main steps:

- Firstly, Provisioner adds the node that need to be removed to the “blacklist”.
- Secondly, Provisioner performs the **Key Refresh procedure**.
- Lastly, the node performs node reset procedure, and switches itself to an unprovisioned device.

### 1.21 In the Key Refresh procedure, how does Provisioner update the Netkey owned by nodes?

- Provisioner updates the NetKey of nodes using the **Configuration Client Model** API `esp_ble_mesh_config_client_set_state()` with `net_key_update` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.
- Provisioner updates the AppKey of nodes using the **Configuration Client Model** API `esp_ble_mesh_config_client_set_state()` with `app_key_update` in the parameter `esp_ble_mesh_cfg_client_set_state_t` set properly.

### 1.22 How does Provisioner manage nodes in the mesh network?

ESP-BLE-MESH implements several functions related to basic node management in the example, such as `esp_ble_mesh_store_node_info()`. And ESP-BLE-MESH also provides the API `esp_ble_mesh_provisioner_set_node_name()` which can be used to set the node’s local name and the API `esp_ble_mesh_provisioner_get_node_name()` which can be used to get the node’s local name.

### 1.23 What does Provisioner need when trying to control the server model of nodes?

Provisioner must include corresponding client model before controlling the server model of nodes. Provisioner shall add its local NetKey and AppKey.

- Provisioner add NetKey by calling the API `esp_ble_mesh_provisioner_add_local_net_key()`.
- Provisioner add AppKey by calling the API `esp_ble_mesh_provisioner_add_local_app_key()`.

Provisioner shall configure its own client model.

- Provisioner bind AppKey to its own client model by calling the API `esp_ble_mesh_provisioner_bind_app_key_to_local_model()`.

### 1.24 How does Provisioner control the server model of nodes?

ESP-BLE-MESH supports all SIG-defined client models. Provisioner can use these client models to control the server models of nodes. And the client models are divided into 6 categories with each category has the corresponding functions.

- **Configuration Client Model**
  - The API `esp_ble_mesh_config_client_get_state()` can be used to get the `esp_ble_mesh_cfg_client_get_state_t` values of Configuration Server Model.
  - The API `esp_ble_mesh_config_client_set_state()` can be used to set the `esp_ble_mesh_cfg_client_set_state_t` values of Configuration Server Model.
Chapter 4. API Guides

- **Health Client Model**
  - The API `esp_ble_mesh_health_client_get_state()` can be used to get the `esp_ble_mesh_health_client_get_state_t` values of Health Server Model.
  - The API `esp_ble_mesh_health_client_set_state()` can be used to set the `esp_ble_mesh_health_client_set_state_t` values of Health Server Model.

- **Generic Client Models**
  - The API `esp_ble_mesh_generic_client_get_state()` can be used to get the `esp_ble_mesh_generic_client_get_state_t` values of Generic Server Models.
  - The API `esp_ble_mesh_generic_client_set_state()` can be used to set the `esp_ble_mesh_generic_client_set_state_t` values of Generic Server Models.

- **Lighting Client Models**
  - The API `esp_ble_mesh_light_client_get_state()` can be used to get the `esp_ble_mesh_light_client_get_state_t` values of Lighting Server Models.
  - The API `esp_ble_mesh_light_client_set_state()` can be used to set the `esp_ble_mesh_light_client_set_state_t` values of Lighting Server Models.

- **Sensor Client Models**
  - The API `esp_ble_mesh_sensor_client_get_state()` can be used to get the `esp_ble_mesh_sensor_client_get_state_t` values of Sensor Server Model.
  - The API `esp_ble_mesh_sensor_client_set_state()` can be used to set the `esp_ble_mesh_sensor_client_set_state_t` values of Sensor Server Model.

- **Time and Scenes Client Models**
  - The API `esp_ble_mesh_time_scene_client_get_state()` can be used to get the `esp_ble_mesh_time_scene_client_get_state_t` values of Time and Scenes Server Models.
  - The API `esp_ble_mesh_time_scene_client_set_state()` can be used to set the `esp_ble_mesh_time_scene_client_set_state_t` values of Time and Scenes Server Models.

2. Node Development

2.1 What kind of models are included by nodes?

- In ESP-BLE-MESH, nodes are all composed of a series of models with each model implements some functions of the node.
- Model has two types, client model and server model. Client model can get and set the states of server model.
- Model can also be divided into SIG model and vendor model. All behaviors of SIG models are officially defined while behaviors of vendor models are defined by users.

2.2 Is the format of messages corresponding to each model fixed?

- Messages, which consist of opcode and payload, are divided by opcode.
- The type and the format of the messages corresponding to models are both fixed, which means the messages transmitted between models are fixed.

2.3 Which functions can be used to send messages with the models of nodes?

- For client models, users can use the API `esp_ble_mesh_client_model_send_msg()` to send messages.
- For server models, users can use the API `esp_ble_mesh_server_model_send_msg()` to send messages.
- For publication, users call the API `esp_ble_mesh_model_publish()` to publish messages.

2.4 How to achieve the transmission of messages without packet loss?
Chapter 4. API Guides

Acknowledged message is needed if users want to transmit messages without packet loss. The default time to wait for corresponding response is set in `CONFIG_BLE_MESH_CLIENT_MSG_TIMEOUT`. If the sender waits for the response until the timer expires, the corresponding timeout event would be triggered.

**Note:** Response timeout can be set in the API `esp_ble_mesh_client_model_send_msg()`. The default value (4 seconds) would be applied if the parameter `msg_timeout` is set to 0.

### 2.5 How to send unacknowledged messages?

For client models, users can use the API `esp_ble_mesh_client_model_send_msg()` with the parameter `need_rsp` set to `false` to send unacknowledged messages.

For server models, the messages sent by using the API `esp_ble_mesh_server_model_send_msg()` are always unacknowledged messages.

### 2.6 How to add subscription address to models?

Subscription address can be added through Configuration Client Model.

### 2.7 What is the difference between messages sent and published by models?

Messages sent by calling the API `esp_ble_mesh_client_model_send_msg()` or `esp_ble_mesh_server_model_send_msg()` will be sent in the duration determined by the Network Transmit state.

Messages published by calling the API `esp_ble_mesh_model_publish()` will be published determined by the Model Publication state. And the publication of messages is generally periodic or with a fixed number of counts. The publication period and publication count are controlled by the Model Publication state, and can be configured through Configuration Client Model.

### 2.8 How many bytes can be carried when sending unsegmented messages?

The total payload length (which can be set by users) of unsegmented message is 11 octets, so if the opcode of the message is 2 octets, then the message can carry 9-octet of valid information. For vendor messages, due to the 3-octets opcode, the remaining payload length is 8 octets.

### 2.9 When should the Relay feature of nodes be enabled?

Users can enable the Relay feature of all nodes when nodes detected in the mesh network are sparse.

For dense mesh network, users can choose to just enable the Relay feature of several nodes.

And users can enable the Relay feature by default if the mesh network size is unknown.

### 2.10 When should the Proxy feature of node be enabled?

If the unprovisioned device is expected to be provisioned by a phone, then it should enable the Proxy feature since almost all the phones do not support sending ESP-BLE-MESH packets through advertising bearer currently. And after the unprovisioned device is provisioned successfully and becoming a Proxy node, it will communicate with the phone using GATT bearer and using advertising bearer to communicate with other nodes in the mesh network.

### 2.11 How to use the Proxy filter?

The Proxy filter is used to reduce the number of Network PDUs exchanged between a Proxy Client (e.g. the phone) and a Proxy Server (e.g. the node). And with the Proxy filter, Proxy Client can explicitly request to receive only mesh messages with certain destination addresses from Proxy Server.
2.12 When a message can be relayed by a Relay node?

If a message need to be relayed, the following conditions should be met.

- The message is in the mesh network.
- The message is not sent to the unicast address of the node.
- The value of TTL in the message is greater than 1.

2.13 If a message is segmented into several segments, should the other Relay nodes just relay when one of these segments is received or wait until the message is received completely?

Relay nodes will forward segments when one of them are received rather than keeping waiting until all the segments are received.

2.14 What is the principle of reducing power consumption using Low Power feature?

- When the radio is turned on for listening, the device is consuming energy. When low power feature of the node is enabled, it will turn off its radio in the most of the time.
- And cooperation is needed between low power node and friend node, thus low power node can receive messages at an appropriate or lower frequency without the need to keep listening.
- When there are some new messages for low power node, its friend node will store the messages for it. And low power node can poll friend nodes to see if there are new messages at a fixed interval.

2.15 How to continue the communication on the network after powering-down and powering-up again?

Enable the configuration Store ESP-BLE-MESH Node configuration persistently in menuconfig.

2.16 How to send out the self-test results of nodes?

It is recommended that nodes can publish its self-test results periodically through Health Server Model.

2.17 How to transmit information between nodes?

One possible application scenario for transmitting information between nodes is that spray nodes would be triggered once smoke alarm detected high smoke concentration. There are two approaches in implementation.

- Approach 1 is that spray node subscribes to a group address. When smoke alarm detects high smoke concentration, it will publish a message whose destination address is the group address which has been subscribed by spray node.
- Approach 2 is that Provisioner can configure the unicast address of spray node to the smoke alarm. When high smoke concentration is detected, smoke alarm can use send messages to the spray node with the spray node’s unicast address as the destination address.

2.18 Is gateway a must for nodes communication?

- Situation 1: nodes only communicate within the mesh network. In this situation, no gateway is need. ESP-BLE-MESH network is a flooded network, messages in the network have no fixed paths, and nodes can communicate with each other freely.
- Situation 2: if users want to control the nodes remotely, for example turn on some nodes before getting home, then a gateway is needed.

2.19 When will the IV Update procedure be performed?

IV Update procedure would be performed once sequence number of messages sent detected by the bottom layer of node reached a critical value.
2.20 How to perform IV Update procedure?

Nodes can perform IV Update procedure with Secure Network Beacon.

3. ESP-BLE-MESH and Wi-Fi Coexistence

3.1 Which modes does Wi-Fi support when it coexists with ESP-BLE-MESH?

Currently only Wi-Fi station mode supports the coexistence.

3.2 Why is the Wi-Fi throughput so low when Wi-Fi and ESP-BLE-MESH coexist?

The ESP32-DevKitC board without PSRAM can run properly but the throughput of it is low since it has no PSRAM. When Bluetooth and Wi-Fi coexist, the throughput of ESP32-DevKitC with PSRAM can be stabilized to more than 1Mbps.

Some configurations in menuconfig shall be enabled to support PSRAM.

- ESP32-specific --> Support for external, SPI-connected RAM --> Try to allocate memories of Wi-Fi and LWIP...
- Bluetooth --> Bluedroid Enable --> BT/BLE will first malloc the memory from the PSRAM
- Bluetooth --> Bluedroid Enable --> Use dynamic memory allocation in BT/BLE stack.
- Bluetooth --> Bluetooth controller --> BLE full scan feature supported.
- Wi-Fi --> Software controls Wi-Fi/Bluetooth coexistence --> Wi-Fi

4. Fast Provisioning

4.1 Why is fast provisioning needed?

Normally when they are several unprovisioned devices, users can provision them one by one. But when it comes to a large number of unprovisioned devices (e.g. 100), provisioning them one by one will take huge amount of time. With fast provisioning, users can provision 100 unprovisioned devices in about 50 seconds.

4.2 Why EspBleMesh App would wait for a long time during fast provisioning?

After the App provisioned one Proxy node, it will disconnect from the App during fast provisioning, and reconnect with the App when all the nodes are provisioned.

4.3 Why is the number of node addresses displayed in the App is more than that of existing node addresses?

Each time after a fast provisioning process, and before starting a new one, the node addresses in the App should be cleared, otherwise the number of the node address will be incorrect.

4.4 What is the usage of the count value which was input in EspBleMesh App?

The count value is provided to the Proxy node which is provisioned by the App so as to determine when to start Proxy advertising in advance.

4.5 When will Configuration Client Model of the node running fastProv_server example start to work?

Configuration Client Model will start to work after the Temporary Provisioner functionality is enabled.
4.6 Will the Temporary Provisioner functionality be enabled all the time?

After the nodes receive messages used to turn on/off lights, all the nodes will disable its Temporary Provisioner functionality and become nodes.

5. Log Help You can find meaning of errors or warnings when they appear at the bottom of ESP-BLE-MESH stack.

5.1 What is the meaning of warning ran out of retransmit attempts?

When the node transmits a segmented message, and due to some reasons, the receiver doesn’t receive the complete message. Then the node will retransmit the message. When the retransmission count reaches the maximum number, which is 4 currently, then this warning will appear.

5.2 What is the meaning of warning Duplicate found in Network Message Cache?

When the node receives a message, it will compare the message with the ones stored in the network cache. If the same has been found in the cache, which means it has been received before, then the message will be dropped.

5.3 What is the meaning of warning Incomplete timer expired?

When the node doesn’t receive all the segments of a segmented message during a certain period (e.g. 10 seconds), then the Incomplete timer will expire and this warning will appear.

5.4 What is the meaning of warning No matching TX context for ack?

When the node receives a segment ack and it doesn’t find any self-send segmented message related with this ack, then this warning will appear.

5.5 What is the meaning of warning No free slots for new incoming segmented messages?

When the node has no space for receiving new segmented message, this warning will appear. Users can make the space larger through the configuration `CONFIG_BLE_MESH_RX_SEG_MSG_COUNT`.

5.6 What is the meaning of error Model not bound to Appkey 0x0000?

When the node sends messages with a model and the model has not been bound to the AppKey with AppKey Index 0x000, then this error will appear.

5.7 What is the meaning of error Busy sending message to DST xxxx?

This error means client model of the node has transmitted a message to the target node and now is waiting for a response, users can not send messages to the same node with the same unicast address. After the corresponding response is received or timer is expired, then another message can be sent.

6. Example Help

6.1 How are the ESP-BLE-MESH callback functions classified?

- The API `esp_ble_mesh_register_prov_callback()` is used to register callback function used to handle provisioning and networking related events.
- The API `esp_ble_mesh_register_config_client_callback()` is used to register callback function used to handle Configuration Client Model related events.
- The API `esp_ble_mesh_register_config_server_callback()` is used to register callback function used to handle Configuration Server Model related events.
Chapter 4. API Guides

- The API `esp_ble_mesh_register_health_client_callback()` is used to register callback function used to handle Health Client Model related events.
- The API `esp_ble_mesh_register_health_server_callback()` is used to register callback function used to handle Health Server Model related events.
- The API `esp_ble_mesh_register_generic_client_callback()` is used to register callback function used to handle Generic Client Models related events.
- The API `esp_ble_mesh_register_light_client_callback()` is used to register callback function used to handle Lighting Client Models related events.
- The API `esp_ble_mesh_register_sensor_client_callback()` is used to register callback function used to handle Sensor Client Model related events.
- The API `esp_ble_mesh_register_time_scene_client_callback()` is used to register callback function used to handle Time and Scenes Client Models related events.
- The API `esp_ble_mesh_register_custom_model_callback()` is used to register callback function used to handle vendor model and unrealized server models related events.

7. Others

7.1 How to print the message context?

The examples use `ESP_LOG_BUFFER_HEX()` to print the message context while the ESP-BLE-MESH protocol stack uses `bt_hex()`.

7.2 Which API can be used to restart ESP32?

The API `esp_restart()`.

7.3 How to monitor the remaining space of the stack of a task?

The API `vTaskList()` can be used to print the remaining space of the task stack periodically.

7.4 How to change the level of log without changing the menuconfig output level?

The API `esp_log_level_set()` can be used to change the log output level rather than using menuconfig to change it.

ESP-BLE-MESH Terminology
Table 13: Table 1 ESP-BLE-MESH Terminology - Role

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprovisioned Device</td>
<td>A device that is not a member of a mesh network is known as an unprovisioned device.</td>
<td>Examples: lighting devices, temperature control devices, manufacturing equipments and electric doors, etc.</td>
</tr>
<tr>
<td>Node</td>
<td>A node is a provisioned device.</td>
<td>The role of unprovisioned device will change to node after being provisioned to ESP-BLE-MESH network. Nodes (such as lighting devices, temperature control devices, manufacturing equipments, and electric doors) are devices that can send, receive, or relay messages in ESP-BLE-MESH network, and they can optionally support one or more subnets.</td>
</tr>
<tr>
<td>Relay Node</td>
<td>A node that supports the Relay feature and has the Relay feature enabled is known as a Relay node.</td>
<td>Relay nodes can receive and resend ESP-BLE-MESH messages, so the messages can be transferred further. Users can decide whether or not to enable forwarding function of nodes according to nodes' status. Messages can be relayed for multiple times, and each relay is considered as a “hop”. Messages can hop up to 126 times, which is enough for message transmission in a wide area.</td>
</tr>
<tr>
<td>Proxy Node</td>
<td>A node that supports the Proxy feature and has the Proxy feature enabled is known as a Proxy node.</td>
<td>Proxy nodes receive messages from one bearer (it generally includes advertising bearer and GATT bearer) and resend it from another one. The purpose is to connect communication equipments that only support GATT bearer to ESP-BLE-MESH network. Generally, mobile apps need a Proxy node to access Mesh network. Without Proxy nodes, mobile apps cannot communicate with members in Mesh network.</td>
</tr>
<tr>
<td>Friend Node</td>
<td>A node that supports the Friend feature, has the Friend feature enabled, and has a friendship with a node that supports the Low Power feature is known as a Friend node.</td>
<td>Friend node, like the backup of Low Power node (LPN), can store messages that are sent to Low Power node and security updates; the stored information will be transferred to Low Power node when Low Power node needs it. Low Power node must establish “friendship” with another node that supports the Friend Feature to reduce duty cycle of its receiver, thus power consumption of Low Power node can be reduced. Low Power node needs to find a Friend node to establish a friendship with it. The process involved is called “friendship establishment” . Cooperation between Low Power node and Friend nodes enables Low Power node to schedule the use of the radio, thus Low Power node can receive messages at an appropriate or lower frequency without the need of keeping listening. Low Power node will poll Friend node to see if there is new message.</td>
</tr>
<tr>
<td>Low Power Node</td>
<td>A node that supports the Low Power feature and has a friendship with a node that supports the Friend feature is known as a Low Power node.</td>
<td>By polling, Low Power node gets information from Friend node, such as messages, security updates, and etc.</td>
</tr>
<tr>
<td>Provisioner</td>
<td>A node that is capable of adding a device to a mesh network.</td>
<td>The device that can provision unprovisioned devices is called a Provisioner. This process usually needs to be implemented through an app that is typically provided by the product manufacturer and can be used on a gateway, a smartphone, tablet or other carriers.</td>
</tr>
</tbody>
</table>
### Table 14: Table 2 ESP-BLE-MESH Terminology - Composition

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>State</td>
<td>A value representing a condition of an element that is exposed by an element of a node.</td>
<td>Each node in a ESP-BLE-MESH network has an independent set of state values that indicate certain states of the device, like brightness, and color of lighting device. Change of state value will lead to change of the physical state of devices. For example, changing the on/off state of a device is actually turning on/off the device.</td>
</tr>
<tr>
<td>Model</td>
<td>A model defines the basic functionality of a node.</td>
<td>A node may contain multiple models, and each model defines basic functionalities of nodes, like the states needed by the nodes, the messages controlling the states, and actions resulted from messages handling. The function implementation of the nodes is based on models, which can be divided into SIG Model and Vendor Model, with the former defined by SIG and latter defined by users.</td>
</tr>
<tr>
<td>Element</td>
<td>An addressable entity within a device.</td>
<td>A node can contain one or more elements, with each having a unicast address and one or more models, and the models contained by the same element must not be the same.</td>
</tr>
<tr>
<td>Composition Data State</td>
<td>The Composition Data state contains information about a node, the elements it includes, and the supported models.</td>
<td>By reading the value of the Composition Data state, users can know basic information of the node, such as the number of elements, and the models in each element. Provisioner gets this message to further provision the device, such as configuring subscription address and publishing address of nodes.</td>
</tr>
</tbody>
</table>

### Table 15: Table 3 ESP-BLE-MESH Terminology - Features

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Power Feature</td>
<td>The ability to operate within a mesh network at significantly reduced receiver duty cycles only in conjunction with a node supporting the Friend feature.</td>
<td>Low Power feature reduces power consumption of nodes. When a Low Power node is searching for a Friend node, and there are multiple Friend nodes nearby, it selects the most suitable Friend node through algorithm.</td>
</tr>
<tr>
<td>Friend Feature</td>
<td>The ability to help a node supporting the Low Power feature to operate by storing messages destined for those nodes.</td>
<td>By enabling friend feature, the node can help to store information for Low Power node. The nodes enabled with friend feature may cause more power and memory consumption.</td>
</tr>
<tr>
<td>Relay Feature</td>
<td>The ability to receive and retransmit mesh messages over the advertising bearer to enable larger networks.</td>
<td>The relay feature enables ESP-BLE-MESH messages to hop among nodes for multiple times, and the transmission distance can exceed the range of direct radio transmission between two nodes, thereby covering the entire network. When a node is enabled with the relay feature to relay messages, it only relays the messages of its own subnet, and does not relay the messages of other subnets. The data integrity will not be considered when the node enabled with relay feature relays segmented messages. The node would relay every segmented message once it receives one rather than waiting for the complete message.</td>
</tr>
<tr>
<td>Proxy Feature</td>
<td>The ability to receive and retransmit mesh messages between GATT and advertising bearers.</td>
<td>The purpose of the proxy feature is to allow nodes without an advertising bearer to access the ESP-BLE-MESH network. The proxy feature is typically used in nodes that need to connect to mobile apps.</td>
</tr>
<tr>
<td>Term</td>
<td>Official Definition</td>
<td>Detailed Explanation</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PB-ADV</td>
<td>PB-ADV is a provisioning bearer used to provision a device using Generic Provisioning PDUs over the advertising channels.</td>
<td>PB-ADV transfers packets generated during the provisioning process over the advertising channels. This way can only be used for provisioning when provisioner and unprovisioned device both support PB-ADV.</td>
</tr>
<tr>
<td>PB-GATT</td>
<td>PB-GATT is a provisioning bearer used to provision a device using Proxy PDUs to encapsulate Provisioning PDUs within the Mesh Provisioning Service.</td>
<td>PB-GATT uses connection channels to transfer packets generated during the provisioning process. If an unprovisioned device wants to be provisioned through this method, it needs to implement the related Mesh Provisioning Service. Unprovisioned devices which don’t implement such service cannot be provisioned into mesh network through PB-GATT bearer.</td>
</tr>
<tr>
<td>Provisioning</td>
<td>Provisioning is a process of adding an unprovisioned device to a mesh network, managed by a Provisioner.</td>
<td>The process of provisioning turns the “unprovisioned device” into a “node”, making it a member of the ESP-BLE-MESH network.</td>
</tr>
<tr>
<td>Authentication Method</td>
<td>Authentication is a step during the provisioning of nodes.</td>
<td>There are four authentication methods for unprovisioned devices: Output OOB, Input OOB, Static OOB, and No OOB.</td>
</tr>
<tr>
<td>Input OOB</td>
<td>Input Out-of-Band</td>
<td>For example, a Provisioner generates and displays a random number, and then prompts users to take appropriate actions to input the random number into the unprovisioned device. Taking lighting switch as an example, users can press the button for several times in a certain period of time to input the random number displayed on the Provisioner. Authentication method of the Input OOB is similar to that of Output OOB, but the role of the device is reversed.</td>
</tr>
<tr>
<td>Output OOB</td>
<td>Output Out-of-Band</td>
<td>For example, an unprovisioned device will choose a random number and output the number in a way that is compatible with its functionality. If the unprovisioned device is a bulb, it can flash a specified number of times. If the unprovisioned device has an LCD screen, the random number can display as a multi-digit value. Users who start provisioning should input the observed number to authenticate the unprovisioned device.</td>
</tr>
<tr>
<td>Static OOB</td>
<td>Static Out-of-Band</td>
<td>Authentication method of Static OOB: use Static OOB information. Use 0 as Static OOB information if No OOB information is needed. Use Static OOB information to authenticate devices which are going through provisioning if OOB information is needed.</td>
</tr>
<tr>
<td>No OOB</td>
<td>No Out-of-Band</td>
<td>Authentication method of No OOB: Set the value of the Static OOB field to 0. Using this way is like not authenticating the unprovisioned devices.</td>
</tr>
</tbody>
</table>
### Table 17: Table 5 ESP-BLE-MESH Terminology - Address

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unassigned Address</td>
<td>This is a special address type, with a value of 0x0000. Its use indicates that an Element has not yet been configured or had a Unicast Address assigned to it.</td>
<td>The addresses owned by elements which has not been configured yet or no address has been allocated are unassigned addresses. These elements will not be used for messages transfer because they have no fixed address. Unassigned address is recommended to set as the value of the address before setting the address of user code.</td>
</tr>
<tr>
<td>Unicast Address</td>
<td>A unicast address is a unique address allocated to each element.</td>
<td>During provisioning, the Provisioner will assign a unicast address to each element of node within the life cycle of the nodes in the network. A unicast address may appear in the source/destination address field of a message. Messages sent to a unicast address can only be processed by the element that owns the unicast address.</td>
</tr>
<tr>
<td>Virtual Address</td>
<td>A virtual address represents a set of destination addresses. Each virtual address logically represents a Label UUID, which is a 128-bit value that does not have to be managed centrally.</td>
<td>Associated with specific UUID labels, a virtual address may serve as the publishing or subscription address of the model. A UUID label is a 128-bit value associated with elements of one or more nodes. For virtual addresses, the 15th and 14th bits are set to 1 and 0 respectively; bits from 13th to 0 are set to hash values (providing 16384 hash values). The hash is a derivation of the Label UUID. To use subscribing elements to check the full 128-bit UUID is very inefficient while hash values provide a more efficient way to determine which elements that which messages are finally sent to.</td>
</tr>
<tr>
<td>Group Address</td>
<td>A group address is an address that is programmed into zero or more elements</td>
<td>Group address is another kind of multicast address in the ESP-BLE-MESH network, which is usually used to group nodes. A message sent to the all-proxies address shall be processed by the primary element of all nodes that have the proxy functionality enabled. A message sent to the all-friends address shall be processed by the primary element of all nodes that have the friend functionality enabled. A message sent to the all-relays address shall be processed by the primary element of all nodes that have the relay functionality enabled. A message sent to the all-nodes address shall be processed by the primary element of all nodes.</td>
</tr>
</tbody>
</table>
### Table 18: Table 6 ESP-BLE-MESH Terminology - Security

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device Key (DevKey)</td>
<td>There is also a device key, which is a special application key that is unique to each node, is known only to the node and a Configuration Client, and is used to secure communications between the node and a Configuration Client.</td>
<td>The device key enables you to provision the devices, configure the nodes. The device key is used to encrypt Configuration Messages, i.e. the message transferred between the Provisioner and the node when the device is configured.</td>
</tr>
<tr>
<td>Application Key (AppKey)</td>
<td>Application keys are used to secure communications at the upper transport layer.</td>
<td>Application key is used for decryption of application data before delivering application data to application layer and encryption of them during the delivery of application layer. Some nodes in the network have a specific purpose and can restrict access to potentially sensitive data based on the needs of the application. With specific application keys, these nodes are associated with specific applications. Generally speaking, the fields using different application keys include security (access control of buildings, machine rooms and CEO offices), lighting (plant, exterior building and sidewalks) and HVAC systems. Application keys are bound to Network keys. This means application keys are only used in a context of a Network key they are bound to. An application key shall only be bound to a single Network key.</td>
</tr>
<tr>
<td>Master Security Material</td>
<td>The master security material is derived from the network key (NetKey) and can be used by other nodes in the same network. Messages encrypted with master security material can be decoded by any node in the same network.</td>
<td>The corresponding friendship messages encrypted with the friendship security material: 1. Friend Poll, 2. Friend Update, 3. Friend Subscription List, add/delete/confirm, 4. The Stored Messages sent by friend nodes to Low Power node. The corresponding friendship messages encrypted with the master security material: 1. Friend Clear, 2. Friend Clear Confirm. Based on the setup of the applications, the messages sent from the Low Power node to the friend nodes will be encrypted with the friendship security material or master security material, with the former being used by the messages transmitted between Low Power node and friend nodes and the latter being used by other network messages.</td>
</tr>
</tbody>
</table>

### Table 19: Table 7 ESP-BLE-MESH Terminology - Message

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reassembly / Segmentation</td>
<td>Segmentation and reassembly (SAR) is a method of communication network, which is divided into small units before transmitting packets and reassembled in a proper order at the communication receiving end.</td>
<td>The lower transport layer will automatically segment the message whose size is too big. The receiving end will return a response message, and the transmitting end will send the data packet again that the receiving end does not receive according to the response message. This is automatically completed by the lower transport layer. Unsegmented messages have at most 15 bytes, of which 4 bytes are transMIC, so the remaining is 11 bytes; in the case of segmentation, there are 12 valid bytes in the first several packets, and 8 in the last one. Special case: A shorter packet requires mandatory segmentation from lower transport layer, in which case the valid byte is 8 bytes.</td>
</tr>
<tr>
<td>Unacknowledged / Acknowledged</td>
<td>There are two types of messages: Unacknowledged or Acknowledged</td>
<td>Based on the whether or not the receiving end needs to send the response message, the messages sent are divided into two kinds. The sending end should set the maximum number of retransmission.</td>
</tr>
</tbody>
</table>
Table 20: Table 8 ESP-BLE-MESH Terminology - Foundation Models

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration Server Model</td>
<td>This model is used to represent a mesh network configuration of a device.</td>
<td>The node must contain the Configuration Server Model, which is responsible for maintaining configuration-related states. The states that Configuration Server Model maintains include: NetKey List, AppKey List, Model to AppKey List, Node Identity, Key Refresh Phase, Heartbeat Publish, Heartbeat Subscription, Network Transmit, Relay Retransmit etc.</td>
</tr>
<tr>
<td>Configuration Client Model</td>
<td>The model is used to represent an element that can control and monitor the configuration of a node.</td>
<td>The Configuration Client Model uses messages to control the state maintained by the Configuration Server Model. The Provisioner must contain the Configuration Client Model, with which the configuration messages, like Configuration Composition Data Get can be sent.</td>
</tr>
<tr>
<td>Health Server Model</td>
<td>This model is used to represent a mesh network diagnostics of a device.</td>
<td>The Health Server Model is primarily used by devices to check their states and see if there is an error. The states maintained by Health Server model include: Current Fault, Registered Fault, Health Period, and Attention Timer.</td>
</tr>
<tr>
<td>Health Client Model</td>
<td>The model is used to represent an element that can control and monitor the health of a node.</td>
<td>The Health Client Model uses messages to control the state maintained by the Health Server Model. The model can get the self-test information of other nodes through the message “Health Fault Get”.</td>
</tr>
</tbody>
</table>

Table 21: Table 9 ESP-BLE-MESH Terminology - Network Management

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Refresh procedure</td>
<td>This procedure is used when the security of one or more network keys and/or one or more of the application keys has been compromised or could be compromised.</td>
<td>Key Refresh Procedure is used to update network key and application key of ESP-BLE-MESH network. Key Refresh Procedure is used when the security of one or more network keys and/or one or more application keys is threatened or potentially threatened. Keys are usually updated after some nodes in the network are removed.</td>
</tr>
<tr>
<td>IV (Initialization Vector) Update Procedure</td>
<td>A node can also use an IV Update procedure to signal to peer nodes that it is updating the IV Index.</td>
<td>The IV Update procedure is used to update the value of ESP-BLE-MESH network’s IV Index. This value is related to the random number required for message encryption. To ensure that the value of the random number is not repeated, this value is periodically incremented. IV Index is a 32-bit value and a shared network resource. For example, all nodes in a mesh network share the same IV Index value. Starting from 0x00000000, the IV Index increments during the IV Update procedure and maintained by a specific process, ensuring the IV Index shared in the mesh network is the same. This can be done when the node believes that it has the risk of exhausting its sequence number, or when it determines that another node is nearly exhausting its sequence number. Note: The update time must not be less than 96 hours. It can be triggered when a secure network beacon is received, or when the node determines that its sequence number is greater than a certain value.</td>
</tr>
</tbody>
</table>

For more terms, please see: ESP-BLE-MESH Glossary of Terms.

Bluetooth SIG Documentation

- BLE Mesh Core Specification
- BLE Mesh Model Specification
- An Intro to Bluetooth Mesh Part 1 / Part 2
This guide provides information regarding the ESP-WIFI-MESH protocol. Please see the *ESP-WIFI-MESH API Reference* for more information about API usage.

### 4.12.1 Overview

ESP-WIFI-MESH is a networking protocol built atop the Wi-Fi protocol. ESP-WIFI-MESH allows numerous devices (henceforth referred to as nodes) spread over a large physical area (both indoors and outdoors) to be interconnected under a single WLAN (Wireless Local-Area Network). ESP-WIFI-MESH is self-organizing and self-healing meaning the network can be built and maintained autonomously.

The ESP-WIFI-MESH guide is split into the following sections:

1. Introduction
2. ESP-WIFI-MESH Concepts
3. Building a Network
4. Managing a Network
5. Data Transmission
6. Channel Switching
7. Performance
8. Further Notes

### 4.12.2 Introduction

Fig. 21: Traditional Wi-Fi Network Architecture
A traditional infrastructure Wi-Fi network is a point-to-multipoint network where a single central node known as the access point (AP) is directly connected to all other nodes known as stations. The AP is responsible for arbitrating and forwarding transmissions between the stations. Some APs also relay transmissions to/from an external IP network via a router. Traditional infrastructure Wi-Fi networks suffer the disadvantage of limited coverage area due to the requirement that every station must be in range to directly connect with the AP. Furthermore, traditional Wi-Fi networks are susceptible to overloading as the maximum number of stations permitted in the network is limited by the capacity of the AP.

ESP-WIFI-MESH differs from traditional infrastructure Wi-Fi networks in that nodes are not required to connect to a central node. Instead, nodes are permitted to connect with neighboring nodes. Nodes are mutually responsible for relaying each others transmissions. This allows an ESP-WIFI-MESH network to have much greater coverage area as nodes can still achieve interconnectivity without needing to be in range of the central node. Likewise, ESP-WIFI-MESH is also less susceptible to overloading as the number of nodes permitted on the network is no longer limited by a single central node.

### 4.12.3 ESP-WIFI-MESH Concepts
Chapter 4.  API Guides

Terminology

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Node</td>
<td>Any device that is or can be part of an ESP-WIFI-MESH network</td>
</tr>
<tr>
<td>Root Node</td>
<td>The top node in the network</td>
</tr>
<tr>
<td>Child Node</td>
<td>A node X is a child node when it is connected to another node Y where the connection makes node X more distant from the root node than node Y (in terms of number of connections).</td>
</tr>
<tr>
<td>Parent Node</td>
<td>The converse notion of a child node</td>
</tr>
<tr>
<td>Descendant Node</td>
<td>Any node reachable by repeated proceeding from parent to child</td>
</tr>
<tr>
<td>Sibling Nodes</td>
<td>Nodes that share the same parent node</td>
</tr>
<tr>
<td>Connection</td>
<td>A traditional Wi-Fi association between an AP and a station. A node in ESP-WIFI-MESH will use its station interface to associate with the softAP interface of another node, thus forming a connection. The connection process includes the authentication and association processes in Wi-Fi.</td>
</tr>
<tr>
<td>Upstream</td>
<td>The connection from a node to its parent node</td>
</tr>
<tr>
<td>Downstream</td>
<td>The connection from a node to one of its child nodes</td>
</tr>
<tr>
<td>Wireless Hop</td>
<td>The portion of the path between source and destination nodes that corresponds to a single wireless connection. A data packet that traverses a single connection is known as single-hop whereas traversing multiple connections is known as multi-hop.</td>
</tr>
<tr>
<td>Subnetwork</td>
<td>A subnetwork is subdivision of an ESP-WIFI-MESH network which consists of a node and all of its descendant nodes. Therefore the subnetwork of the root node consists of all nodes in an ESP-WIFI-MESH network.</td>
</tr>
<tr>
<td>MAC Address</td>
<td>Media Access Control Address used to uniquely identify each node or router within an ESP-WIFI-MESH network.</td>
</tr>
<tr>
<td>DS</td>
<td>Distribution System (External IP Network)</td>
</tr>
</tbody>
</table>

Tree Topology

ESP-WIFI-MESH is built atop the infrastructure Wi-Fi protocol and can be thought of as a networking protocol that combines many individual Wi-Fi networks into a single WLAN. In Wi-Fi, stations are limited to a single connection with an AP (upstream connection) at any time, whilst an AP can be simultaneously connected to multiple stations (downstream connections). However ESP-WIFI-MESH allows nodes to simultaneously act as a station and an AP. Therefore a node in ESP-WIFI-MESH can have multiple downstream connections using its softAP interface, whilst simultaneously having a single upstream connection using its station interface. This naturally results in a tree network topology with a parent-child hierarchy consisting of multiple layers.

ESP-WIFI-MESH is a multiple hop (multi-hop) network meaning nodes can transmit packets to other nodes in the network through one or more wireless hops. Therefore, nodes in ESP-WIFI-MESH not only transmit their own packets, but simultaneously serve as relays for other nodes. Provided that a path exists between any two nodes on the physical layer (via one or more wireless hops), any pair of nodes within an ESP-WIFI-MESH network can communicate.

Note: The size (total number of nodes) in an ESP-WIFI-MESH network is dependent on the maximum number of layers permitted in the network, and the maximum number of downstream connections each node can have. Both of these variables can be configured to limit the size of the network.

Node Types

**Root Node:** The root node is the top node in the network and serves as the only interface between the ESP-WIFI-MESH network and an external IP network. The root node is connected to a conventional Wi-Fi router and relays packets to/from the external IP network to nodes within the ESP-WIFI-MESH network. **There can only be one root node within an ESP-WIFI-MESH network** and the root node’s upstream connection may only be with the router. Referring to the diagram above, node A is the root node of the network.
Chapter 4. API Guides

Fig. 23: ESP-WIFI-MESH Tree Topology

Fig. 24: ESP-WIFI-MESH Node Types
**Leaf Nodes:** A leaf node is a node that is not permitted to have any child nodes (no downstream connections). Therefore a leaf node can only transmit or receive its own packets, but cannot forward the packets of other nodes. If a node is situated on the network’s maximum permitted layer, it will be assigned as a leaf node. This prevents the node from forming any downstream connections thus ensuring the network does not add an extra layer. Some nodes without a softAP interface (station only) will also be assigned as leaf nodes due to the requirement of a softAP interface for any downstream connections. Referring to the diagram above, nodes L/M/N are situated on the networks maximum permitted layer hence have been assigned as leaf nodes.

**Intermediate Parent Nodes:** Connected nodes that are neither the root node or a leaf node are intermediate parent nodes. An intermediate parent node must have a single upstream connection (a single parent node), but can have zero to multiple downstream connections (zero to multiple child nodes). Therefore an intermediate parent node can transmit and receive packets, but also forward packets sent from its upstream and downstream connections. Referring to the diagram above, nodes B to J are intermediate parent nodes. Intermediate parent nodes without downstream connections such as nodes E/F/G/I/J are not equivalent to leaf nodes as they are still permitted to form downstream connections in the future.

**Idle Nodes:** Nodes that have yet to join the network are assigned as idle nodes. Idle nodes will attempt to form an upstream connection with an intermediate parent node or attempt to become the root node under the correct circumstances (see *Automatic Root Node Selection*). Referring to the diagram above, nodes K and O are idle nodes.

**Beacon Frames & RSSI Thresholding**

Every node in ESP-WIFI-MESH that is able to form downstream connections (i.e. has a softAP interface) will periodically transmit Wi-Fi beacon frames. A node uses beacon frames to allow other nodes to detect its presence and know of its status. Idle nodes will listen for beacon frames to generate a list of potential parent nodes, one of which the idle node will form an upstream connection with. ESP-WIFI-MESH uses the Vendor Information Element to store metadata such as:

- Node Type (Root, Intermediate Parent, Leaf, Idle)
- Current layer of Node
- Maximum number of layers permitted in the network
- Current number of child nodes
- Maximum number of downstream connections to accept

The signal strength of a potential upstream connection is represented by RSSI (Received Signal Strength Indication) of the beacon frames of the potential parent node. To prevent nodes from forming a weak upstream connection, ESP-WIFI-MESH implements an RSSI threshold mechanism for beacon frames. If a node detects a beacon frame with an RSSI below a preconfigured threshold, the transmitting node will be disregarded when forming an upstream connection.

**Panel A** of the illustration above demonstrates how the RSSI threshold affects the number of parent node candidates an idle node has.

**Panel B** of the illustration above demonstrates how an RF shielding object can lower the RSSI of a potential parent node. Due to the RF shielding object, the area in which the RSSI of node X is above the threshold is significantly reduced. This causes the idle node to disregard node X even though node X is physically adjacent. The idle node will instead form an upstream connection with the physically distant node Y due to a stronger RSSI.

**Note:** Nodes technically still receive all beacon frames on the MAC layer. The RSSI threshold is an ESP-WIFI-MESH feature that simply filters out all received beacon frames that are below the preconfigured threshold.

**Preferred Parent Node**

When an idle node has multiple parent nodes candidates (potential parent nodes), the idle node will form an upstream connection with the preferred parent node. The preferred parent node is determined based on the following criteria:

- Which layer the parent node candidate is situated on
- The number of downstream connections (child nodes) the parent node candidate currently has
The selection of the preferred parent node will always prioritize the parent node candidate on the shallowest layer of the network (including the root node). This helps minimize the total number of layers in an ESP-WIFI-MESH network when upstream connections are formed. For example, given a second layer node and a third layer node, the second layer node will always be preferred.

If there are multiple parent node candidates within the same layer, the parent node candidate with the least child nodes will be preferred. This criteria has the effect of balancing the number of downstream connections amongst nodes of the same layer.

Panel A of the illustration above demonstrates an example of how the idle node G selects a preferred parent node given the five parent node candidates B/C/D/E/F. Nodes on the shallowest layer are preferred, hence nodes B/C are prioritized since they are second layer nodes whereas nodes D/E/F are on the third layer. Node C is selected as the preferred parent node due it having fewer downstream connections (fewer child nodes) compared to node B.

Panel B of the illustration above demonstrates the case where the root node is within range of the idle node G. In
other words, the root node’s beacon frames are above the RSSI threshold when received by node G. The root node is always the shallowest node in an ESP-WIFI-MESH network hence is always the preferred parent node given multiple parent node candidates.

**Note:** Users may also define their own algorithm for selecting a preferred parent node, or force a node to only connect with a specific parent node (see the Mesh Manual Networking Example).

### Routing Tables

Each node within an ESP-WIFI-MESH network will maintain its individual routing table used to correctly route ESP-WIFI-MESH packets (see *ESP-WIFI-MESH Packet*) to the correct destination node. The routing table of a particular node will **consist of the MAC addresses of all nodes within the particular node’s subnetwork** (including the MAC address of the particular node itself). Each routing table is internally partitioned into multiple subtables with each subtable corresponding to the subnetwork of each child node.

![Routing Tables](image)

**Fig. 27: ESP-WIFI-MESH Routing Tables Example**

Using the diagram above as an example, the routing table of node B would consist of the MAC addresses of nodes B to I (i.e. equivalent to the subnetwork of node B). Node B’s routing table is internally partitioned into two subtables containing of nodes C to F and nodes G to I (i.e. equivalent to the subnetworks of nodes C and G respectively).

**ESP-WIFI-MESH** utilizes routing tables to determine whether an ESP-WIFI-MESH packet should be forwarded upstream or downstream based on the following rules.

1. If the packet’s destination MAC address is within the current node’s routing table and is not the current node, select the subtable that contains the destination MAC address and forward the data packet downstream to the child node corresponding to the subtable.

2. If the destination MAC address is not within the current node’s routing table, forward the data packet upstream to the current node’s parent node. Doing so repeatedly will result in the packet arriving at the root node where the routing table should contain all nodes within the network.

**Note:** Users can call `esp_mesh_get_routing_table()` to obtain a node’s routing table, or `esp_mesh_get_routing_table_size()` to obtain the size of a node’s routing table. `esp_mesh_get_subnet_nodes_list()` can be used to obtain the corresponding subtable of a specific child node. Likewise `esp_mesh_get_subnet_nodes_num()` can be used to obtain the size of the
4.12.4 Building a Network

General Process

**Warning:** Before the ESP-WIFI-MESH network building process can begin, certain parts of the configuration must be uniform across each node in the network (see `mesh_cfg_t`). Each node must be configured with the same Mesh Network ID, router configuration, and softAP configuration.

An ESP-WIFI-MESH network building process involves selecting a root node, then forming downstream connections layer by layer until all nodes have joined the network. The exact layout of the network can be dependent on factors such as root node selection, parent node selection, and asynchronous power-on reset. However, the ESP-WIFI-MESH network building process can be generalized into the following steps:

1. **Root Node Selection**  The root node can be designated during configuration (see section on *User Designated Root Node*), or dynamically elected based on the signal strength between each node and the router (see *Automatic Root Node Selection*). Once selected, the root node will connect with the router and begin allowing downstream connections to form. Referring to the figure above, node A is selected to be the root node hence node A forms an upstream connection with the router.

2. **Second Layer Formation**  Once the root node has connected to the router, idle nodes in range of the root node will begin connecting with the root node thereby forming the second layer of the network. Once connected, these second layer nodes become intermediate parent nodes (assuming maximum permitted layers > 2) hence the next layer to form. Referring to the figure above, nodes B to D are in range of the root node. Therefore nodes B to D form upstream connections with the root node and become intermediate parent nodes.

3. **Formation of remaining layers**  The remaining idle nodes will connect with intermediate parent nodes within range thereby forming a new layer in the network. Once connected, the idles nodes become intermediate parent node or leaf nodes depending on the networks maximum permitted layers. This step is repeated until there are no more idle nodes.
nodes within the network or until the maximum permitted layer of the network has been reached. Referring to the
figure above, nodes E/F/G connect with nodes B/C/D respectively and become intermediate parent nodes themselves.

4. Limiting Tree Depth To prevent the network from exceeding the maximum permitted number of layers, nodes
on the maximum layer will automatically become leaf nodes once connected. This prevents any other idle node
from connecting with the leaf node thereby prevent a new layer form forming. However if an idle node has no
other potential parent node, it will remain idle indefinitely. Referring to the figure above, the network’s number of
maximum permitted layers is set to four. Therefore when node H connects, it becomes a leaf node to prevent any
downstream connections from forming.

Automatic Root Node Selection

The automatic selection of a root node involves an election process amongst all idle nodes based on their signal
strengths with the router. Each idle node will transmit their MAC addresses and router RSSI values via Wi-Fi beacon
frames. The MAC address is used to uniquely identify each node in the network whilst the router RSSI is used
to indicate a node’s signal strength with reference to the router.

Each node will then simultaneously scan for the beacon frames from other idle nodes. If a node detects a beacon
frame with a stronger router RSSI, the node will begin transmitting the contents of that beacon frame (i.e. voting for
the node with the stronger router RSSI). The process of transmission and scanning will repeat for a preconfigured
minimum number of iterations (10 iterations by default) and result in the beacon frame with the strongest router RSSI
being propagated throughout the network.

After all iterations, each node will individually check for its vote percentage (number of votes/number of
nodes participating in election) to determine if it should become the root node. If a node has a
vote percentage larger than a preconfigured threshold (90% by default), the node will become a root node.

The following diagram demonstrates how an ESP-WIFI-MESH network is built when the root node is automatically
selected.

1. On power-on reset, each node begins transmitting beacon frames consisting of their own MAC addresses and their
router RSSIs.

2. Over multiple iterations of transmission and scanning, the beacon frame with the strongest router RSSI is propa-
gated throughout the network. Node C has the strongest router RSSI (-10 dB) hence its beacon frame is propagated
throughout the network. All nodes participating in the election vote for node C thus giving node C a vote percentage of 100%. Therefore node C becomes a root node and connects with the router.

3. Once Node C has connected with the router, nodes A/B/D/E connect with node C as it is the preferred parent node (i.e. the shallowest node). Nodes A/B/D/E form the second layer of the network.

4. Node F and G connect with nodes D and E respectively and the network building process is complete.

**Note:** The minimum number of iterations for the election process can be configured using `esp_mesh_set_attempts()`. Users should adjust the number of iterations based on the number of nodes within the network (i.e. the larger the network the larger number of scan iterations required).

**Warning:** Vote percentage threshold can also be configured using `esp_mesh_set_vote_percentage()`. Setting a low vote percentage threshold can result in two or more nodes becoming root nodes within the same ESP-WIFI-MESH network leading to the building of multiple networks. If such is the case, ESP-WIFI-MESH has internal mechanisms to autonomously resolve the root node conflict. The networks of the multiple root nodes will be combined into a single network with a single root node. However, root node conflicts where two or more root nodes have the same router SSID but different router BSSID are not handled.

**User Designated Root Node**

The root node can also be designated by user which will entail the designated root node to directly connect with the router and forgo the election process. When a root node is designated, all other nodes within the network must also forgo the election process to prevent the occurrence of a root node conflict. The following diagram demonstrates how an ESP-WIFI-MESH network is built when the root node is designated by the user.

![Diagram of Root Node Designation](image-url)

**Fig. 30: Root Node Designation Example (Root Node = A, Max Layers = 4)**

1. Node A is designated the root node by the user therefore directly connects with the router. All other nodes forgo the election process.

2. Nodes C/D connect with node A as their preferred parent node. Both nodes form the second layer of the network.
3. Likewise, nodes B/E connect with node C, and node F connects with node D. Nodes B/E/F form the third layer of the network.

4. Node G connects with node E, forming the fourth layer of the network. However, the maximum permitted number of layers in this network is configured as four, therefore node G becomes a leaf node to prevent any new layers from forming.

Note: When designating a root node, the root node should call `esp_mesh_set_parent()` in order to directly connect with the router. Likewise, all other nodes should call `esp_mesh_fix_root()` to forgo the election process.

Parent Node Selection

By default, ESP-WIFI-MESH is self-organizing meaning that each node will autonomously select which potential parent node to form an upstream connection with. The autonomously selected parent node is known as the preferred parent node. The criteria used for selecting the preferred parent node is designed to reduce the number of layers in the ESP-WIFI-MESH network and to balance the number of downstream connections between potential parent nodes (see section on Preferred Parent Node).

However, ESP-WIFI-MESH also allows users to disable self-organizing behavior which will allow users to define their own criteria for parent node selection, or to configure nodes to have designated parent nodes (see the Mesh Manual Networking Example).

Asynchronous Power-on Reset

ESP-WIFI-MESH network building can be affected by the order in which nodes power-on. If certain nodes within the network power-on asynchronously (i.e. separated by several minutes), the final structure of the network could differ from the ideal case where all nodes are powered on synchronously. Nodes that are delayed in powering on will adhere to the following rules:

**Rule 1:** If a root node already exists in the network, the delayed node will not attempt to elect a new root node, even if it has a stronger RSSI with the router. The delayed node will instead join the network like any other idle node by connecting with a preferred parent node. If the delayed node is the designated root node, all other nodes in the network will remain idle until the delayed node powers-on.

**Rule 2:** If a delayed node forms an upstream connection and becomes an intermediate parent node, it may also become the new preferred parent of other nodes (i.e. being a shallower node). This will cause the other nodes to switch their upstream connections to connect with the delayed node (see Parent Node Switching).

**Rule 3:** If an idle node has a designated parent node which is delayed in powering-on, the idle node will not attempt to form any upstream connections in the absence of its designated parent node. The idle node will remain idle indefinitely until its designated parent node powers-on.

The following example demonstrates the effects of asynchronous power-on with regards to network building.

1. Nodes A/C/D/F/G/H are powered-on synchronously and begin the root node election process by broadcasting their MAC addresses and router RSSIs. Node A is elected as the root node as it has the strongest RSSI.

2. Once node A becomes the root node, the remaining nodes begin forming upstream connections layer by layer with their preferred parent nodes. The result is a network with five layers.

3. Node B/E are delayed in powering-on but neither attempt to become the root node even though they have stronger router RSSIs (-20 dB and -10 dB) compared to node A. Instead, both delayed nodes form upstream connections with their preferred parent nodes A and C respectively. Both nodes B/E become intermediate parent nodes after connecting.

4. Nodes D/G switch their upstream connections as node B is the new preferred parent node due to it being on a shallower layer (second layer node). Due to the switch, the resultant network has three layers instead of the original five layers.
Fig. 31: Network Building with Asynchronous Power On Example
**Synchronous Power-On:** Had all nodes powered-on synchronously, node E would have become the root node as it has the strongest router RSSI (-10 dB). This would result in a significantly different network layout compared to the network formed under the conditions of asynchronous power-on. **However the synchronous power-on network layout can still be reached if the user manually switches the root node** (see `esp_mesh_waive_root()`).

**Note:** Differences in parent node selection caused by asynchronous power-on are autonomously corrected for to some extent in ESP-WIFI-MESH (see *Parent Node Switching*).

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**Loop-back Avoidance, Detection, and Handling**

A loop-back is the situation where a particular node forms an upstream connection with one of its descendant nodes (a node within the particular node’s subnetwork). This results in a circular connection path thereby breaking the tree topology. ESP-WIFI-MESH prevents loop-back during parent selection by excluding nodes already present in the selecting node’s routing table (see *Routing Tables*) thus prevents a particular node from attempting to connect to any node within its subnetwork.

In the event that a loop-back occurs, ESP-WIFI-MESH utilizes a path verification mechanism and energy transfer mechanism to detect the loop-back occurrence. The parent node of the upstream connection that caused the loop-back will then inform the child node of the loop-back and initiate a disconnection.

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**4.12.5 Managing a Network**

**ESP-WIFI-MESH is a self healing network meaning it can detect and correct for failures in network routing.** Failures occur when a parent node with one or more child nodes breaks down, or when the connection between a parent node and its child nodes becomes unstable. Child nodes in ESP-WIFI-MESH will autonomously select a new parent node and form an upstream connection with it to maintain network interconnectivity. ESP-WIFI-MESH can handle both Root Node Failures and Intermediate Parent Node Failures.

**Root Node Failure**

If the root node breaks down, the nodes connected with it (second layer nodes) will promptly detect the failure of the root node. The second layer nodes will initially attempt to reconnect with the root node. However after multiple failed attempts, the second layer nodes will initialize a new round of root node election. **The second layer node with the strongest router RSSI will be elected as the new root node** whilst the remaining second layer nodes will form an upstream connection with the new root node (or a neighboring parent node if not in range).

If the root node and multiple downstream layers simultaneously break down (e.g. root node, second layer, and third layer), the shallowest layer that is still functioning will initialize the root node election. The following example illustrates an example of self healing from a root node break down.

1. Node C is the root node of the network. Nodes A/B/D/E are second layer nodes connected to node C.
2. Node C breaks down. After multiple failed attempts to reconnect, the second layer nodes begin the election process by broadcasting their router RSSIs. Node B has the strongest router RSSI.
3. Node B is elected as the root node and begins accepting downstream connections. The remaining second layer nodes A/D/E form upstream connections with node B thus the network is healed and can continue operating normally.

**Note:** If a designated root node breaks down, the remaining nodes will not autonomously attempt to elect a new root node as an election process will never be attempted whilst a designated root node is used.
Intermediate Parent Node Failure

If an intermediate parent node breaks down, the disconnected child nodes will initially attempt to reconnect with the parent node. After multiple failed attempts to reconnect, each child node will begin to scan for potential parent nodes (see Beacon Frames & RSSI Thresholding).

If other potential parent nodes are available, each child node will individually select a new preferred parent node (see Preferred Parent Node) and form an upstream connection with it. If there are no other potential parent nodes for a particular child node, it will remain idle indefinitely.

The following diagram illustrates an example of self-healing from an Intermediate Parent Node break down.

1. The following branch of the network consists of nodes A to G.
2. Node C breaks down. Nodes F/G detect the break down and attempt to reconnect with node C. After multiple failed attempts to reconnect, nodes F/G begin to select a new preferred parent node.
3. Node G is out of range from any other parent node hence remains idle for the time being. Node F is in range of nodes B/E, however node B is selected as it is the shallower node. Node F becomes an intermediate parent node after connecting with Node B thus node G can connect with node F. The network is healed, however the network routing as been affected and an extra layer has been added.

Note: If a child node has a designated parent node that breaks down, the child node will make no attempt to connect with a new parent node. The child node will remain idle indefinitely.
**Root Node Switching**

ESP-WIFI-MESH does not automatically switch the root node unless the root node breaks down. Even if the root node’s router RSSI degrades to the point of disconnection, the root node will remain unchanged. Root node switching is the act of explicitly starting a new election such that a node with a stronger router RSSI will be elected as the new root node. This can be a useful method of adapting to degrading root node performance.

To trigger a root node switch, the current root node must explicitly call `esp_mesh_waive_root()` to trigger a new election. The current root node will signal all nodes within the network to begin transmitting and scanning for beacon frames (see Automatic Root Node Selection) whilst remaining connected to the network (i.e. not idle). If another node receives more votes than the current root node, a root node switch will be initiated. The root node will remain unchanged otherwise.

A newly elected root node sends a switch request to the current root node which in turn will respond with an acknowledgment signifying both nodes are ready to switch. Once the acknowledgment is received, the newly elected root node will disconnect from its parent and promptly form an upstream connection with the router thereby becoming the new root node of the network. The previous root node will disconnect from the router whilst maintaining all of its downstream connections and enter the idle state. The previous root node will then begin scanning for potential parent nodes and selecting a preferred parent.

The following diagram illustrates an example of a root node switch.

Fig. 34: Root Node Switch Example

1. Node C is the current root node but has degraded signal strength with the router (-85db). The node C triggers a new election and all nodes begin transmitting and scanning for beacon frames whilst still being connected.
2. After multiple rounds of transmission and scanning, node B is elected as the new root node. Node B sends node C a switch request and node C responds with an acknowledgment.
3. Node B disconnects from its parent and connects with the router becoming the network’s new root node. Node C disconnects from the router, enters the idle state, and begins scanning for and selecting a new preferred parent node. Node C maintains all its downstream connections throughout this process.
4. Node C selects node B as its preferred parent node, forms an upstream connection, and becomes a second layer node. The network layout is similar after the switch as node C still maintains the same subnetwork. However each node in node C’s subnetwork has been placed one layer deeper as a result of the switch. Parent Node Switching may adjust the network layout afterwards if any nodes have a new preferred parent node as a result of the root node switch.
Note: Root node switching must require an election hence is only supported when using a self-organized ESP-WIFI-MESH network. In other words, root node switching cannot occur if a designated root node is used.

Parent Node Switching

Parent Node Switching entails a child node switching its upstream connection to another parent node of a shallower layer. Parent Node Switching occurs autonomously meaning that a child node will change its upstream connection automatically if a potential parent node of a shallower layer becomes available (i.e. due to a Asynchronous Power-on Reset).

All potential parent nodes periodically transmit beacon frames (see Beacon Frames & RSSI Thresholding) allowing for a child node to scan for the availability of a shallower parent node. Due to parent node switching, a self-organized ESP-WIFI-MESH network can dynamically adjust its network layout to ensure each connection has a good RSSI and that the number of layers in the network is minimized.

4.12.6 Data Transmission

ESP-WIFI-MESH Packet

ESP-WIFI-MESH network data transmissions use ESP-WIFI-MESH packets. ESP-WIFI-MESH packets are entirely contained within the frame body of a Wi-Fi data frame. A multi-hop data transmission in an ESP-WIFI-MESH network will involve a single ESP-WIFI-MESH packet being carried over each wireless hop by a different Wi-Fi data frame.

The following diagram shows the structure of an ESP-WIFI-MESH packet and its relation with a Wi-Fi data frame.

![Fig. 35: ESP-WIFI-MESH Packet](image)

The header of an ESP-WIFI-MESH packet contains the MAC addresses of the source and destination nodes. The options field contains information pertaining to the special types of ESP-WIFI-MESH packets such as a group transmission or a packet originating from the external IP network (see MESH_OPT_SEND_GROUP and MESH_OPT_RECV_DS_ADDR).

The payload of an ESP-WIFI-MESH packet contains the actual application data. This data can be raw binary data, or encoded under an application layer protocol such as HTTP, MQTT, and JSON (see mesh_proto_t).

Note: When sending an ESP-WIFI-MESH packet to the external IP network, the destination address field of the header will contain the IP address and port of the target server rather than the MAC address of a node (see mesh_addr_t). Furthermore the root node will handle the formation of the outgoing TCP/IP packet.

Group Control & Multicasting

Multicasting is a feature that allows a single ESP-WIFI-MESH packet to be transmitted simultaneously to multiple nodes within the network. Multicasting in ESP-WIFI-MESH can be achieved by either specifying a list
of target nodes, or specifying a preconfigured group of nodes. Both methods of multicasting are called via `esp_mesh_send()`.

To multicast by specifying a list of target nodes, users must first set the ESP-WIFI-MESH packet’s destination address to the **Multicast-Group Address (01:00:5E:xx:xx:xx)**. This signifies that the ESP-WIFI-MESH packet is a multicast packet with a group of addresses, and that the address should be obtained from the header options. Users must then list the MAC addresses of the target nodes as options (see `mesh_opt_t` and `MESH_OPT_SEND_GROUP`). This method of multicasting requires no prior setup but can incur a large amount of overhead data as each target node’s MAC address must be listed in the options field of the header.

Multicasting by group allows an ESP-WIFI-MESH packet to be transmitted to a preconfigured group of nodes. Each grouping is identified by a unique ID, and a node can be placed into a group via `esp_mesh_set_group_id()`. Multicasting to a group involves setting the destination address of the ESP-WIFI-MESH packet to the target group ID. Furthermore, the `MESH_DATA_GROUP` flag must set. Using groups to multicast incurs less overhead, but requires nodes to previously added into groups.

**Note:** During a multicast, all nodes within the network still receive the ESP-WIFI-MESH packet on the MAC layer. However, nodes not included in the MAC address list or the target group will simply filter out the packet.

### Broadcasting

Broadcasting is a feature that allows a single ESP-WIFI-MESH packet to be transmitted simultaneously to all nodes within the network. Each node essentially forwards a broadcast packet to all of its upstream and downstream connections such that the packet propagates through the network as quickly as possible. However, ESP-WIFI-MESH utilizes the following methods to avoid wasting bandwidth during a broadcast.

1. When an intermediate parent node receives a broadcast packet from its parent, it will forward the packet to each of its child nodes whilst storing a copy of the packet for itself.
2. When an intermediate parent node is the source node of the broadcast, it will transmit the broadcast packet upstream to its parent node and downstream to each of its child nodes.
3. When an intermediate parent node receives a broadcast packet from one of its child nodes, it will forward the packet to its parent node and each of its remaining child nodes whilst storing a copy of the packet for itself.
4. When a leaf node is the source node of a broadcast, it will directly transmit the packet to its parent node.
5. When the root node is the source node of a broadcast, the root node will transmit the packet to all of its child nodes.
6. When the root node receives a broadcast packet from one of its child nodes, it will forward the packet to each of its remaining child nodes whilst storing a copy of the packet for itself.
7. When a node receives a broadcast packet with a source address matching its own MAC address, the node will discard the broadcast packet.
8. When an intermediate parent node receives a broadcast packet from its parent node which was originally transmitted from one of its child nodes, it will discard the broadcast packet.

### Upstream Flow Control

ESP-WIFI-MESH relies on parent nodes to control the upstream data flow of their immediate child nodes. To prevent a parent node’s message buffer from overflowing due to an overload of upstream transmissions, a parent node will allocate a quota for upstream transmissions known as a receiving window for each of its child nodes. **Each child node must apply for a receiving window before it is permitted to transmit upstream.** The size of a receiving window can be dynamically adjusted. An upstream transmission from a child node to the parent node consists of the following steps:

1. Before each transmission, the child node sends a window request to its parent node. The window request consists of a sequence number which corresponds to the child node’s data packet that is pending transmission.
2. The parent node receives the window request and compares the sequence number with the sequence number of the previous packet sent by the child node. The comparison is used to calculate the size of the receiving window which is transmitted back to the child node.

3. The child node transmits the data packet in accordance with the window size specified by the parent node. If the child node depletes its receiving window, it must obtain another receiving windows by sending a request before it is permitted to continue transmitting.

**Note:** ESP-WIFI-MESH does not support any downstream flow control.

**Warning:** Due to **Parent Node Switching**, packet loss may occur during upstream transmissions.

Due to the fact that the root node acts as the sole interface to an external IP network, it is critical that downstream nodes are aware of the root node’s connection status with the external IP network. Failing to do so can lead to nodes attempting to pass data upstream to the root node whilst it is disconnected from the IP network. This results in unnecessary transmissions and packet loss. ESP-WIFI-MESH address this issue by providing a mechanism to stabilize the throughput of outgoing data based on the connection status between the root node and the external IP network. The root node can broadcast its external IP network connection status to all other nodes by calling `esp_mesh_post_toDS_state()`.

**Bi-Directional Data Stream**

The following diagram illustrates the various network layers involved in an ESP-WIFI-MESH Bidirectional Data Stream.

![Fig. 36: ESP-WIFI-MESH Bidirectional Data Stream](image)

Due to the use of **Routing Tables**, ESP-WIFI-MESH is able to handle pack forwarding entirely on the mesh layer. A TCP/IP layer is only required on the root node when it transmits/receives a packet to/from an external IP network.

**4.12.7 Channel Switching**

**Background**

In traditional Wi-Fi networks, **channels** are predetermined frequency ranges. In an infrastructure basic service set (BSS), the serving AP and its connected stations must be on the same operating channels (1 to 14) in which beacons are transmitted. Physically adjacent BSS (Basic Service Sets) operating on the same channel can lead to interference and degraded performance.
Chapter 4. API Guides

In order to allow a BSS adapt to changing physical layer conditions and maintain performance, Wi-Fi contains mechanisms for network channel switching. A network channel switch is an attempt to move a BSS to a new operating channel whilst minimizing disruption to the BSS during this process. However it should be recognized that a channel switch may be unsuccessful in moving all stations to the new operating channel.

In an infrastructure Wi-Fi network, network channel switches are triggered by the AP with the aim of having the AP and all connected stations synchronously switch to a new channel. Network channel switching is implemented by embedding a Channel Switch Announcement (CSA) element within the AP’s periodically transmitted beacon frames. The CSA element is used to advertise to all connected stations regarding an upcoming network channel switch and will be included in multiple beacon frames up until the switch occurs.

A CSA element contains information regarding the New Channel Number and a Channel Switch Count which indicates the number of beacon frame intervals (TBTTs) remaining until the network channel switch occurs. Therefore, the Channel Switch Count is decremented every beacon frame and allows connected stations to synchronize their channel switch with the AP.

ESP-WIFI-MESH Network Channel Switching

ESP-WIFI-MESH Network Channel Switching also utilize beacon frames that contain a CSA element. However, being a multi-hop network makes the switching process in ESP-WIFI-MESH is more complex due to the fact that a beacon frame might not be able to reach all nodes within the network (i.e. in a single hop). Therefore, an ESP-WIFI-MESH network relies on nodes to forward the CSA element so that it is propagated throughout the network.

When an intermediate parent node with one or more child nodes receives a beacon frame containing a CSA, the node will forward the CSA element by including the element in its next transmitted beacon frame (i.e. with the same New Channel Number and Channel Switch Count). Given that all nodes within an ESP-WIFI-MESH network receive the same CSA, the nodes can synchronize their channel switches using the Channel Switch Count, albeit with a short delay due to CSA element forwarding.

An ESP-WIFI-MESH network channel switch can be triggered by either the router or the root node.

Root Node Triggered A root node triggered channel switch can only occur when the ESP-WIFI-MESH network is not connected to a router. By calling esp_mesh_switch_channel(), the root node will set an initial Channel Switch Count value and begin including a CSA element in its beacon frames. Each CSA element is then received by second layer nodes, and forwarded downstream in their own beacon frames.

Router Triggered When an ESP-WIFI-MESH network is connected to a router, the entire network must use the same channel as the router. Therefore, the root node will not be permitted to trigger a channel switch when it is connected to a router.

When the root node receives beacon frame containing a CSA element from the router, the root node will set Channel Switch Count value in the CSA element to a custom value before forwarding it downstream via beacon frames. It will also decrement the Channel Switch Count of subsequent CSA elements relative to the custom value. This custom value can be based on factors such as the number of network layers, the current number of nodes etc.

The setting the Channel Switch Count value to a custom value is due to the fact that the ESP-WIFI-MESH network and its router may have a different and varying beacon intervals. Therefore, the Channel Switch Count value provided by the router is irrelevant to an ESP-WIFI-MESH network. By using a custom value, nodes within the ESP-WIFI-MESH network are able to switch channels synchronously relative to the ESP-WIFI-MESH network’s beacon interval. However, this will also result in the ESP-WIFI-MESH network’s channel switch being unsynchronized with the channel switch of the router and its connected stations.

Impact of Network Channel Switching

- Due to the ESP-WIFI-MESH network channel switch being unsynchronized with the router’s channel switch, there will be a temporary channel discrepancy between the ESP-WIFI-MESH network and the router.

  - The ESP-WIFI-MESH network’s channel switch time is dependent on the ESP-WIFI-MESH network’s beacon interval and the root node’s custom Channel Switch Count value.
– The channel discrepancy prevents any data exchange between the root node and the router during that ESP-WIFI-MESH network’s switch.
– In the ESP-WIFI-MESH network, the root node and intermediate parent nodes will request their connected child nodes to stop transmissions until the channel switch takes place by setting the Channel Switch Mode field in the CSA element to 1.
– Frequent router triggered network channel switches can degrade the ESP-WIFI-MESH network’s performance. Note that this can be caused by the ESP-WIFI-MESH network itself (e.g. due to wireless medium contention with ESP-WIFI-MESH network). If this is the case, users should disable the automatic channel switching on the router and use a specified channel instead.

**When there is a temporary channel discrepancy, the root node remains technically connected to the router.**

– Disconnection occurs after the root node fails to receive any beacon frames or probe responses from the router over a fixed number of router beacon intervals.
– Upon disconnection, the root node will automatically re-scan all channels for the presence of a router.

**If the root node is unable to receive any of the router’s CSA beacon frames (e.g. due to short switch time given by the router):**

– After the router switches channels, the root node will no longer be able to receive the router’s beacon frames and probe responses and result in a disconnection after a fixed number of beacon intervals.
– The root node will re-scan all channels for the router after disconnection.
– The root node will maintain downstream connections throughout this process.

**Note:** Although ESP-WIFI-MESH network channel switching aims to move all nodes within the network to a new operating channel, it should be recognized that a channel switch might not successfully move all nodes (e.g. due to reasons such as node failures).

### Channel and Router Switching Configuration

ESP-WIFI-MESH allows for autonomous channel switching to be enabled/disabled via configuration. Likewise, autonomous router switching (i.e. when a root node autonomously connects to another router) can also be enabled/disabled by configuration. Autonomous channel switching and router switching is dependent on the following configuration parameters and run-time conditions.

**Allow Channel Switch:** This parameter is set via the allow_channel_switch field of the mesh_cfg_t structure and permits an ESP-WIFI-MESH network to dynamically switch channels when set.

**Preset Channel:** An ESP-WIFI-MESH network can have a preset channel by setting the channel field of the mesh_cfg_t structure to the desired channel number. If this field is unset, the allow_channel_switch parameter is overridden such that channel switches are always permitted.

**Allow Router Switch:** This parameter is set via the allow_router_switch field of the mesh_router_t and permits an ESP-WIFI-MESH to dynamically switch to a different router when set.

**Preset Router BSSID:** An ESP-WIFI-MESH network can have a preset router by setting the bssid field of the mesh_router_t structure to the BSSID of the desired router. If this field is unset, the allow_router_switch parameter is overridden such that router switches are always permitted.

**Root Node Present:** The presence of a root node will can also affect whether or a channel or router switch is permitted.

The following table illustrates how the different combinations of parameters/conditions affect whether channel switching and/or router switching is permitted. Note that X represents a “don’t care” for the parameter.
### 4.12.8 Performance

The performance of an ESP-WIFI-MESH network can be evaluated based on multiple metrics such as the following:

**Network Building Time:** The amount of time taken to build an ESP-WIFI-MESH network from scratch.

**Healing Time:** The amount of time taken for the network to detect a node break down and carry out appropriate actions to heal the network (such as generating a new root node or forming new connections).

**Per-hop latency:** The latency of data transmission over one wireless hop. In other words, the time taken to transmit a data packet from a parent node to a child node or vice versa.

**Network Node Capacity:** The total number of nodes the ESP-WIFI-MESH network can simultaneously support. This number is determined by the maximum number of downstream connections a node can accept and the maximum number of layers permissible in the network.

The following table lists the common performance figures of an ESP-WIFI-MESH network:

<table>
<thead>
<tr>
<th>Preset Channel</th>
<th>Allow Channel Switch</th>
<th>Preset Router BSSID</th>
<th>Allow Router Switch</th>
<th>Root Node Present</th>
<th>Permitted Switches?</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>X</td>
<td>N</td>
<td>X</td>
<td>X</td>
<td>Channel and Router</td>
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<td>N</td>
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<td>Channel Only</td>
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<td>Channel and Router</td>
</tr>
</tbody>
</table>

Note: The following test conditions were used to generate the performance figures above.

- Number of test devices: **100**
- Maximum Downstream Connections to Accept: **6**
- Maximum Permissible Layers: **6**

Note: Throughput depends on packet error rate and hop count.

Note: The throughput of root node’s access to the external IP network is directly affected by the number of nodes in the ESP-WIFI-MESH network and the bandwidth of the router.
Note: The performance figures can vary greatly between installations based on network configuration and operating environment.

4.12.9 Further Notes

- Data transmission uses Wi-Fi WPA2-PSK encryption
- Mesh networking IE uses AES encryption

Router and internet icon made by Smashicons from www.flaticon.com

4.13 Support for External RAM

4.13.1 Introduction

ESP32 has a few hundred kilobytes of internal RAM, residing on the same die as the rest of the chip components. It can be insufficient for some purposes, ESP32 has the ability to use up to 4 MB of virtual addresses for external SPI RAM memory. The external memory is incorporated in the memory map and, with certain restrictions, is usable in the same way as internal data RAM.

4.13.2 Hardware

ESP32 supports SPI PSRAM (Pseudostatic RAM) connected in parallel with the SPI flash chip. While ESP32 is capable of supporting several types of RAM chips, ESP-IDF currently only supports Espressif branded PSRAM chips (e.g., ESP-PSRAM32, ESP-PSRAM64, etc).

Note: Some PSRAM chips are 1.8 V devices and some are 3.3 V. The working voltage of the PSRAM chip must match the working voltage of the flash component. Consult the datasheet for your PSRAM chip and ESP32 device to find out the working voltages. For a 1.8 V PSRAM chip, make sure to either set the MTDI pin to a high signal level on bootup, or program ESP32 eFuses to always use the VDD_SIO level of 1.8 V. Not doing this can damage the PSRAM and/or flash chip.

Note: Espressif produces both modules and system-in-package chips that integrate compatible PSRAM and flash and are ready to mount on a product PCB. Consult the Espressif website for more information. If you’re using a custom PSRAM chip, ESP-IDF SDK might not be compatible with it.

For specific details about connecting the SoC or module pins to an external PSRAM chip, consult the SoC or module datasheet.

4.13.3 Configuring External RAM

ESP-IDF fully supports the use of external RAM in applications. Once the external RAM is initialized at startup, ESP-IDF can be configured to integrate the external RAM in several ways:

- Integrate RAM into the ESP32 Memory Map
- Add External RAM to the Capability Allocator
- Provide External RAM via malloc() (default)
Integrate RAM into the ESP32 Memory Map

Select this option by choosing “Integrate RAM into memory map” from CONFIG_SPIRAM_USE.

This is the most basic option for external SPI RAM integration. Most likely, you will need another, more advanced option.

During the ESP-IDF startup, external RAM is mapped into the data address space, starting at address 0x3F800000 (byte-accessible). The length of this region is the same as the SPI RAM size (up to the limit of 4 MB).

Applications can manually place data in external memory by creating pointers to this region. So if an application uses external memory, it is responsible for all management of the external SPI RAM: coordinating buffer usage, preventing corruption, etc.

Add External RAM to the Capability Allocator

Select this option by choosing “Make RAM allocatable using heap_caps_malloc(…, MALLOC_CAP_SPIRAM)” from CONFIG_SPIRAM_USE.

When enabled, memory is mapped to address 0x3F800000 and also added to the capabilities-based heap memory allocator using MALLOC_CAP_SPIRAM.

To allocate memory from external RAM, a program should call heap_caps_malloc(size, MALLOC_CAP_SPIRAM). After use, this memory can be freed by calling the normal free() function.

Provide External RAM via malloc()

Select this option by choosing “Make RAM allocatable using malloc() as well” from CONFIG_SPIRAM_USE. This is the default option.

In this case, memory is added to the capability allocator as described for the previous option. However, it is also added to the pool of RAM that can be returned by the standard malloc() function.

This allows any application to use the external RAM without having to rewrite the code to use heap_caps_malloc(…, MALLOC_CAP_SPIRAM).

An additional configuration item, CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL, can be used to set the size threshold when a single allocation should prefer external memory:

- When allocating a size less than the threshold, the allocator will try internal memory first.
- When allocating a size equal to or larger than the threshold, the allocator will try external memory first.

If a suitable block of preferred internal/external memory is not available, the allocator will try the other type of memory.

Because some buffers can only be allocated in internal memory, a second configuration item CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL defines a pool of internal memory which is reserved for only explicitly internal allocations (such as memory for DMA use). Regular malloc() will not allocate from this pool. The MALLOC_CAP_DMA and MALLOC_CAP_INTERNAL flags can be used to allocate memory from this pool.

Allow .bss Segment to Be Placed in External Memory

Enable this option by checking CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY.

If enabled, a region of the address space starting from 0x3F800000 will be used to store zero-initialized data (BSS segment) from the lwIP, net80211, libpp, and bluedroid ESP-IDF libraries.

Additional data can be moved from the internal BSS segment to external RAM by applying the macro EXT_RAM_BSS_ATTR to any static declaration (which is not initialized to a non-zero value).
It is also possible to place the BSS section of a component or a library to external RAM using linker fragment scheme `extram_bss`.

This option reduces the internal static memory used by the BSS segment.

Remaining external RAM can also be added to the capability heap allocator using the method shown above.

**Allow .noinit Segment to Be Placed in External Memory**

Enable this option by checking `CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY`. If enabled, a region of the address space provided in external RAM will be used to store non-initialized data. The values placed in this segment will not be initialized or modified even during startup or restart.

By applying the macro `EXT_RAM_NOINIT_ATTR`, data could be moved from the internal NOINIT segment to external RAM. Remaining external RAM can still be added to the capability heap allocator using the method shown above, *Add External RAM to the Capability Allocator*.

### 4.13.4 Restrictions

External RAM use has the following restrictions:

- When flash cache is disabled (for example, if the flash is being written to), the external RAM also becomes inaccessible. Any read operations from or write operations to it will lead to an illegal cache access exception. This is also the reason why ESP-IDF does not by default allocate any task stacks in external RAM (see below).

- External RAM uses the same cache region as the external flash. This means that frequently accessed variables in external RAM can be read and modified almost as quickly as in internal RAM. However, when accessing large chunks of data (>32 KB), the cache can be insufficient, and speeds will fall back to the access speed of the external RAM. Moreover, accessing large chunks of data can push out cached flash, possibly making the execution of code slower afterwards.

- In general, external RAM will not be used as task stack memory. `xTaskCreate()` and similar functions will always allocate internal memory for stack and task TCBs.

The option `CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY` can be used to allow placing task stacks into external memory. In these cases `xTaskCreateStatic()` must be used to specify a task stack buffer allocated from external memory, otherwise task stacks will still be allocated from internal memory.

### 4.13.5 Failure to Initialize

By default, failure to initialize external RAM will cause the ESP-IDF startup to abort. This can be disabled by enabling the config item `CONFIG_SPIRAM_IGNORE_NOTFOUND`.

If `CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY` is enabled, the option to ignore failure is not available as the linker will have assigned symbols to external memory addresses at link time.

- Regarding stacks in PSRAM: For tasks that do not call ROM code in any way (directly or indirectly), the `CONFIG_SPIRAM_ALLOW_STACK_EXTERNAL_MEMORY` option will eliminate the check in `xTaskCreateStatic()`, allowing a task’s stack to be in external RAM. However, using this is **not advised**.

- When used at 80 MHz clock speed, external RAM must also occupy either the HSPI or VSPI bus. Select which SPI host will be used by `CONFIG_SPIRAM_OCCUPY_SPI_HOST`.

### 4.13.6 Chip Revisions

There are some issues with certain revisions of ESP32 that have repercussions for use with external RAM. The issues are documented in the [ESP32 Series SoC Errata](http://example.com) document. In particular, ESP-IDF handles the bugs mentioned in the following ways:
Chapter 4. API Guides

ESP32 Rev v0.0

ESP-IDF has no workaround for the bugs in this revision of silicon, and it cannot be used to map external PSRAM into ESP32’s main memory map.

ESP32 Rev v1.0

The bugs in this revision of silicon cause issues if certain sequences of machine instructions operate on external memory. (ESP32 Series SoC Errata 3.2). As a workaround, the `-mfix-esp32-psram-cache-issue` flag has been added to the ESP32 GCC compiler such that these sequences are filtered out. As a result, the compiler only outputs code that can safely be executed. The `CONFIG_SPIRAM_CACHE_WORKAROUND` option can be used to enable this workaround.

Aside from linking to a recompiled version of Newlib with the additional flag, ESP-IDF also does the following:

- Avoids using some ROM functions
- Allocates static memory for the Wi-Fi stack

ESP32 Rev v3.0

ESP32 rev v3.0 fixes the PSRAM cache issue found in rev v1.0. When `CONFIG_ESP32_REV_MIN` option is set to rev v3.0, compiler workarounds related to PSRAM will be disabled. For more information about ESP32 v3.0, see ESP32 Chip Revision v3.0 User Guide.

4.14 Fatal Errors

4.14.1 Overview

In certain situations, execution of the program cannot be continued in a well defined way. In ESP-IDF, these situations include:

- CPU Exceptions: Illegal Instruction, Load/Store Alignment Error, Load/Store Prohibited error, Double Exception.
- System level checks and safeguards:
  - `Interrupt watchdog` timeout
  - `Task watchdog` timeout (only fatal if `CONFIG_ESP32_TASK_WDT_PANIC` is set)
  - Cache access error
  - Brownout detection event
  - Stack overflow
  - Stack smashing protection check
  - Heap integrity check
  - Undefined behavior sanitizer (UBSAN) checks
- Failed assertions, via `assert`, `configASSERT` and similar macros.

This guide explains the procedure used in ESP-IDF for handling these errors, and provides suggestions on troubleshooting the errors.

4.14.2 Panic Handler

Every error cause listed in the `Overview` will be handled by the `panic handler`.

The panic handler will start by printing the cause of the error to the console. For CPU exceptions, the message will be similar to
Chapter 4. API Guides

Guru Meditation Error: Core 0 panic'ed (IllegalInstruction). Exception was unhandled.

For some of the system level checks (interrupt watchdog, cache access error), the message will be similar to
Guru Meditation Error: Core 0 panic'ed (Cache disabled but cached memory region accessed). Exception was unhandled.

In all cases, the error cause will be printed in parentheses. See Guru Meditation Errors for a list of possible error causes.

Subsequent behavior of the panic handler can be set using CONFIG_ESP_SYSTEM_PANIC configuration choice. The available options are:

- Print registers and reboot (CONFIG_ESP_SYSTEM_PANIC_PRINT_REBOOT) — default option.
  This will print register values at the point of the exception, print the backtrace, and restart the chip.
- Print registers and halt (CONFIG_ESP_SYSTEM_PANIC_PRINT_HALT)
  Similar to the above option, but halt instead of rebooting. External reset is required to restart the program.
- Silent reboot (CONFIG_ESP_SYSTEM_PANIC_SILENT_REBOOT)
  Don’t print registers or backtrace, restart the chip immediately.
- Invoke GDB Stub (CONFIG_ESP_SYSTEM_PANIC_GDBSTUB)
  Start GDB server which can communicate with GDB over console UART port. This option will only provide read-only debugging or post-mortem debugging. See GDB Stub for more details.
- Invoke dynamic GDB Stub (ESP_SYSTEM_GDBSTUB_RUNTIME)
  Start GDB server which can communicate with GDB over console UART port. This option allows the user to debug a program at run time and set break points, alter the execution, etc. See GDB Stub for more details.

The behavior of the panic handler is affected by three other configuration options.

- If CONFIG_ESP_DEBUG_OCDWARE is enabled (which is the default), the panic handler will detect whether a JTAG debugger is connected. If it is, execution will be halted and control will be passed to the debugger. In this case, registers and backtrace are not dumped to the console, and GDBStub / Core Dump functions are not used.
- If the Core Dump feature is enabled, then the system state (task stacks and registers) will be dumped to either Flash or UART, for later analysis.
- If CONFIG_ESP_PANIC_HANDLER_IRAM is disabled (disabled by default), the panic handler code is placed in flash memory, not IRAM. This means that if ESP-IDF crashes while flash cache is disabled, the panic handler will automatically re-enable flash cache before running GDB Stub or Core Dump. This adds some minor risk, if the flash cache status is also corrupted during the crash.
  If this option is enabled, the panic handler code (including required UART functions) is placed in IRAM, and hence will decrease the usable memory space in SRAM. But this may be necessary to debug some complex issues with crashes while flash cache is disabled (for example, when writing to SPI flash) or when flash cache is corrupted when an exception is triggered.
- If CONFIG_ESP_SYSTEM_PANIC_REBOOT_DELAY_SECONDS is enabled (disabled by default) and set to a number higher than 0, the panic handler will delay the reboot for that amount of time in seconds. This can help if the tool used to monitor serial output does not provide a possibility to stop and examine the serial output. In that case, delaying the reboot will allow users to examine and debug the panic handler output (backtrace, etc.) for the duration of the delay. After the delay, the device will reboot. The reset reason is preserved.

The following diagram illustrates the panic handler behavior:

### 4.14.3 Register Dump and Backtrace

Unless the CONFIG_ESP_SYSTEM_PANIC_SILENT_REBOOT option is enabled, the panic handler prints some of the CPU registers, and the backtrace, to the console

<table>
<thead>
<tr>
<th>Core 0 register dump:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PC</strong>: 0x400e14ed</td>
</tr>
<tr>
<td><strong>A2</strong>: 0x00000000</td>
</tr>
</tbody>
</table>

(continues on next page)
Fig. 37: Panic Handler Flowchart (click to enlarge)
The register values printed are the register values in the exception frame, i.e., values at the moment when the CPU exception or another fatal error has occurred.

A Register dump is not printed if the panic handler has been executed as a result of an abort() call.

In some cases, such as interrupt watchdog timeout, the panic handler may print additional CPU registers (EPC1-EPC4) and the registers/backtrace of the code running on the other CPU.

The backtrace line contains PC:SP pairs, where PC is the Program Counter and SP is Stack Pointer, for each stack frame of the current task. If a fatal error happens inside an ISR, the backtrace may include PC:SP pairs both from the task which was interrupted, and from the ISR.

If **IDF Monitor** is used, Program Counter values will be converted to code locations (function name, file name, and line number), and the output will be annotated with additional lines:

To find the location where a fatal error has happened, look at the lines which follow the “Backtrace” line. Fatal error location is the top line, and subsequent lines show the call stack.

### 4.14.4 GDB Stub

If the **CONFIG_ESP_SYSTEM_PANIC_GDBSTUB** option is enabled, the panic handler will not reset the chip when a fatal error happens. Instead, it will start a GDB remote protocol server, commonly referred to as GDB Stub. When this happens, a GDB instance running on the host computer can be instructed to connect to the ESP32 UART port.

If **IDF Monitor** is used, GDB is started automatically when a GDB Stub prompt is detected on the UART. The output looks like this:
Entering gdb stub now.
$70b#e6GNU gdb (crosstool-NG crosstool-ng-1.22.0-80-gff1f415) 7.10
Copyright (C) 2015 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-build_apple-darwin16.3.0 --target=xtensa-
esp32-elf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
Find the GDB manual and other documentation resources online at:
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from /Users/user/esp/example/build/example.elf...done.
0x400e1b41 in app_main ()
at /Users/user/esp/example/main/main.cpp:36
36   *((int*) 0) = 0;
(gdb)
The GDB prompt can be used to inspect CPU registers, local and static variables, and arbitrary locations in memory. It
is not possible to set breakpoints, change the PC, or continue execution. To reset the program, exit GDB and perform
an external reset: Ctrl-T Ctrl-R in IDF Monitor, or using the external reset button on the development board.

4.14.5 RTC Watchdog Timeout

The RTC watchdog is used in the startup code to keep track of execution time and it also helps to prevent a lock-up
caused by an unstable power source. It is enabled by default (see CONFIG_BOOTLOADER_WDT_ENABLE). If the
execution time is exceeded, the RTC watchdog will restart the system. In this case, the ROM bootloader will print a
message with the RTC Watchdog Timeout reason for the reboot.

rst:0x10 (RTCWDT_RTC_RESET)

The RTC watchdog covers the execution time from the first stage bootloader (ROM bootloader) to applica-
tion startup. It is initially set in the ROM bootloader, then configured in the bootloader with the CONFIG_BOOTLOADER_WDT_TIME_MS option (9000 ms by default). During the application initialization stage,
it is reconfigured because the source of the slow clock may have changed, and finally disabled right before the
app_main() call. There is an option CONFIG_BOOTLOADER_WDT_DISABLE_IN_USER_CODE which pre-
vents the RTC watchdog from being disabled before app_main. Instead, the RTC watchdog remains active and
must be fed periodically in your application’s code.

4.14.6 Guru Meditation Errors

This section explains the meaning of different error causes, printed in parens after the Guru Meditation Er-
ror: Core panic'ed message.

Note: See the Guru Meditation Wikipedia article for historical origins of “Guru Meditation”.

IllegalInstruction

This CPU exception indicates that the instruction which was executed was not a valid instruction. Most common
reasons for this error include:
• FreeRTOS task function has returned. In FreeRTOS, if a task function needs to terminate, it should call
  `vTaskDelete()` and delete itself, instead of returning.
• Failure to read next instruction from SPI flash. This usually happens if:
  – Application has reconfigured the SPI flash pins as some other function (GPIO, UART, etc.). Consult the
    Hardware Design Guidelines and the datasheet for the chip or module for details about the SPI flash pins.
  – Some external device has accidentally been connected to the SPI flash pins, and has interfered with
    communication between ESP32 and SPI flash.
• In C++ code, exiting from a non-void function without returning a value is considered to be an unde-
  fined behavior. When optimizations are enabled, the compiler will often omit the epilogue in such func-
  tions. This most often results in an IllegalInstruction exception. By default, ESP-IDF build system enables
  `--Wall` which means that missing return statements are treated as compile time errors. However if the
  application project disables compiler warnings, this issue might go undetected and the IllegalIn-
  struction exception will occur at run time.

**InstrFetchProhibited**

This CPU exception indicates that the CPU could not read an instruction because the address of the instruction does
not belong to a valid region in instruction RAM or ROM.

Usually, this means an attempt to call a function pointer, which does not point to valid code. PC (Program Counter)
register can be used as an indicator: it will be zero or will contain a garbage value (not 0x4xxxxxxxx).

**LoadProhibited, StoreProhibited**

These CPU exceptions happen when an application attempts to read from or write to an invalid memory location.
The address which has been written/read is found in the `EXCVADDR` register in the register dump. If this address
is zero, it usually means that the application has attempted to dereference a NULL pointer. If this address is close
to zero, it usually means that the application has attempted to access a member of a structure, but the pointer to
the structure is NULL. If this address is something else (garbage value, not in 0x3fxxxxxx - 0x6xxxxxxx range),
it likely means that the pointer used to access the data is either not initialized or has been corrupted.

**IntegerDivideByZero**

Application has attempted to do an integer division by zero.

**LoadStoreAlignment**

Application has attempted to read or write a memory location, and the address alignment does not match the load/store
size. For example, a 32-bit read can only be done from a 4-byte aligned address, and a 16-bit write can only be done
to a 2-byte aligned address.

**LoadStoreError**

This exception may happen in the following cases:

• If the application has attempted to do an 8- or 16- bit read to, or write from, a memory region which only
  supports 32-bit reads/writes. For example, dereferencing a `char*` pointer to instruction memory (IRAM,
  IROM) will result in such an error.
• If the application has attempted to write to a read-only memory region, such as IROM or DROM.

**Unhandled debug exception**

This will usually be followed by a message like:
This error indicates that the application has written past the end of the stack of the task with name `task_name`. Note that not every stack overflow is guaranteed to trigger this error. It is possible that the task writes to memory beyond the stack canary location, in which case the watchdog will not be triggered.

### Interrupt Watchdog Timeout on CPU0/CPU1

Indicates that an interrupt watchdog timeout has occurred. See *Watchdogs* for more information.

### Cache disabled but cached memory region accessed

In some situations, ESP-IDF will temporarily disable access to external SPI Flash and SPI RAM via caches. For example, this happens when spi_flash APIs are used to read/write/erase/mmap regions of SPI Flash. In these situations, tasks are suspended, and interrupt handlers not registered with `ESP_INTR_FLAG_IRAM` are disabled. Make sure that any interrupt handlers registered with this flag have all the code and data in IRAM/DRAM. Refer to the *SPI Flash API documentation* for more details.

### 4.14.7 Other Fatal Errors

#### Brownout

ESP32 has a built-in brownout detector, which is enabled by default. The brownout detector can trigger a system reset if the supply voltage goes below a safe level. The brownout detector can be configured using `CONFIG_ESP_BROWNOUT_DET` and `CONFIG_ESP_BROWNOUT_DET_LVL_SEL` options.

When the brownout detector triggers, the following message is printed:

```
Brownout detector was triggered
```

The chip is reset after the message is printed.

Note that if the supply voltage is dropping at a fast rate, only part of the message may be seen on the console.

#### Corrupt Heap

ESP-IDF’s heap implementation contains a number of run-time checks of the heap structure. Additional checks ("Heap Poisoning") can be enabled in menuconfig. If one of the checks fails, a message similar to the following will be printed:

```
CORRUPT HEAP: Bad tail at 0x3ffe270a. Expected Oxbaad5678 got Oxbaac5678 assertion "head != NULL" failed: file "/Users/user/esp/esp-idf/components/heap/multi_heap_poisoning.c", line 201, function: multi_heap_free abort() was called at PC 0x400dca43 on core 0
```

Consult *Heap Memory Debugging* documentation for further information.

#### Stack Smashing

Stack smashing protection (based on GCC `fstack-protector*` flags) can be enabled in ESP-IDF using `CONFIG_COMPILER_STACK_CHECK_MODE` option. If stack smashing is detected, message similar to the following will be printed:

```
```
Stack smashing protect failure!
abort() was called at PC 0x400d2138 on core 0

Backtrace: 0x4008e6c0:0x3ffc1780 0x4008e8b7:0x3ffc17a0 0x400d2138:0x3ffc17c0
  ← 0x400e79d5:0x3ffc17a0 0x400e79a7:0x3ffc1840 0x400e79df:0x3ffc18a0
  ← 0x400e2235:0x3ffc18c0 0x400e1916:0x3ffc18f0 0x400e19cd:0x3ffc1910
  ← 0x400e1a11:0x3ffc1930 0x400e1bb2:0x3ffc1950 0x400d2c44:0x3ffc1a80

The backtrace should point to the function where stack smashing has occurred. Check the function code for unbounded access to local arrays.

**Undefined Behavior Sanitizer (UBSAN) Checks**

Undefined behavior sanitizer (UBSAN) is a compiler feature which adds run-time checks for potentially incorrect operations, such as:

- overflows (multiplication overflow, signed integer overflow)
- shift base or exponent errors (e.g. shift by more than 32 bits)
- integer conversion errors

See GCC documentation of `-fsanitize=undefined` option for the complete list of supported checks.

**Enabling UBSAN**  
UBSAN is disabled by default. It can be enabled at file, component, or project level by adding the `-fsanitize=undefined` compiler option in the build system.

When enabling UBSAN for code which uses the SOC hardware register header files (`soc/xxx_reg.h`), it is recommended to disable shift-base sanitizer using `-fno-sanitize=shift-base` option. This is due to the fact that ESP-IDF register header files currently contain patterns which cause false positives for this specific sanitizer option.

To enable UBSAN at project level, add the following code at the end of the project’s `CMakeLists.txt` file:

```
idf_build_set_property(COMPILE_OPTIONS "-fsanitize=undefined" "-fno-sanitize=shift-base" APPEND)
```

Alternatively, pass these options through the `EXTRA_CFLAGS` and `EXTRA_CXXFLAGS` environment variables.

Enabling UBSAN results in significant increase of code and data size. Most applications, except for the trivial ones, will not fit into the available RAM of the microcontroller when UBSAN is enabled for the whole application. Therefore it is recommended that UBSAN is instead enabled for specific components under test.

To enable UBSAN for a specific component (`component_name`) from the project’s `CMakeLists.txt` file, add the following code at the end of the file:

```
idf_component_get_property(lib component_name COMPONENT_LIB)
target_compile_options(${lib} PRIVATE "-fsanitize=undefined" "-fno-sanitize=shift-base")
```

**Note:** See the build system documentation for more information about build properties and component properties.

To enable UBSAN for a specific component (`component_name`) from `CMakeLists.txt` of the same component, add the following at the end of the file:

```
target_compile_options(${COMPONENT_LIB} PRIVATE "-fsanitize=undefined" "-fno-sanitize=shift-base")
```
Chapter 4. API Guides

UBSAN Output When UBSAN detects an error, a message and the backtrace are printed, for example:

```
Undefined behavior of type out_of_bounds
Backtrace:
0x4008b383: panic_abort at /path/to/esp-idf/components/esp_system/panic.c:367
0x4008c791: esp_system_abort at /path/to/esp-idf/components/esp_system/system_api.c:106
0x4008c587: __ubsan_default_handler at /path/to/esp-idf/components/esp_system/ubsan.c:152
0x4008c6be: __ubsan_handle_out_of_bounds at /path/to/esp-idf/components/esp_system/ubsan.c:223
0x400db74f: test_ub at main.c:128
0x400db99c: app_main at main.c:56 (discriminator 1)
```

When using IDF Monitor, the backtrace will be decoded to function names and source code locations, pointing to the location where the issue has happened (here it is main.c:128):

```
0x4008b383: panic_abort at /path/to/esp-idf/components/esp_system/panic.c:367
0x4008c791: esp_system_abort at /path/to/esp-idf/components/esp_system/system_api.c:106
0x4008c587: __ubsan_default_handler at /path/to/esp-idf/components/esp_system/ubsan.c:152
0x4008c6be: __ubsan_handle_out_of_bounds at /path/to/esp-idf/components/esp_system/ubsan.c:223
0x400db74f: test_ub at main.c:128
0x400db99c: app_main at main.c:56 (discriminator 1)
```

The types of errors reported by UBSAN can be as follows:

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>type_mismatch, type_mismatch_v1</td>
<td>Incorrect pointer value: null, unaligned, not compatible with the given type.</td>
</tr>
<tr>
<td>add_overflow, sub_overflow, mul_overflow, negate_overflow</td>
<td>Integer overflow during addition, subtraction, multiplication, negation.</td>
</tr>
<tr>
<td>divrem_overflow</td>
<td>Integer division by 0 or INT_MIN.</td>
</tr>
<tr>
<td>shift_out_of_bounds</td>
<td>Overflow in left or right shift operators.</td>
</tr>
<tr>
<td>out_of_bounds</td>
<td>Access outside of bounds of an array.</td>
</tr>
<tr>
<td>unreachable</td>
<td>Unreachable code executed.</td>
</tr>
<tr>
<td>missing_return</td>
<td>Non-void function has reached its end without returning a value (C++ only).</td>
</tr>
<tr>
<td>vla_bound_not_positive</td>
<td>Size of variable length array is not positive.</td>
</tr>
<tr>
<td>load_invalid_value</td>
<td>Value of bool or enum (C++ only) variable is invalid (out of bounds).</td>
</tr>
<tr>
<td>nonnull_arg</td>
<td>Null argument passed to a function which is declared with a non-null attribute.</td>
</tr>
<tr>
<td>nonnull_return</td>
<td>Null value returned from a function which is declared with returnsnonnull attribute.</td>
</tr>
<tr>
<td>builtin_unreachable</td>
<td>__builtin_unreachable function called.</td>
</tr>
<tr>
<td>pointer_overflow</td>
<td>Overflow in pointer arithmetic.</td>
</tr>
</tbody>
</table>

4.15 Flash Encryption

This is a quick start guide to ESP32’s flash encryption feature. Using application code as an example, it demonstrates how to test and verify flash encryption operations during development and production.
4.15.1 Introduction

Flash encryption is intended for encrypting the contents of the ESP32’s off-chip flash memory. Once this feature is enabled, firmware is flashed as plaintext, and then the data is encrypted in place on the first boot. As a result, physical readout of flash will not be sufficient to recover most flash contents.

With flash encryption enabled, the following types of data are encrypted by default:

- Firmware bootloader
- Partition Table
- All “app” type partitions

Other types of data can be encrypted conditionally:

- Any partition marked with the encrypted flag in the partition table. For details, see Encrypted Partition Flag.
- Secure Boot bootloader digest if Secure Boot is enabled (see below).

Secure Boot is a separate feature which can be used together with flash encryption to create an even more secure environment.

**Important:** For production use, flash encryption should be enabled in the “Release” mode only.

**Important:** Enabling flash encryption limits the options for further updates of ESP32. Before using this feature, read the document and make sure to understand the implications.

4.15.2 Relevant eFuses

The flash encryption operation is controlled by various eFuses available on ESP32. The list of eFuses and their descriptions is given in the table below. The names in eFuse column are also used by espfuse.py tool. For usage in the eFuse API, modify the name by adding ESP_EFUSE_, for example: esp_efuse_read_field_bit(ESP_EFUSE_DISABLE_DL_ENCRYPT).

<table>
<thead>
<tr>
<th>eFuse</th>
<th>Description</th>
<th>Bit Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODING_SCHEME</td>
<td>Controls actual number of block1 bits used to derive final 256-bit AES key. Possible values: 0 for 256 bits, 1 for 192 bits, 2 for 128 bits. Final AES key is derived based on the FLASH_CRYPT_CONFIG value.</td>
<td>2</td>
</tr>
<tr>
<td>flash_encryption (block1)</td>
<td>AES key storage.</td>
<td>256 bit key block</td>
</tr>
<tr>
<td>FLASH_CRYPT_CONFIG</td>
<td>Controls the AES encryption process.</td>
<td>4</td>
</tr>
<tr>
<td>DISABLE_DL_ENCRYPT</td>
<td>If set, disables flash encryption operation while running in Firmware Download mode.</td>
<td>1</td>
</tr>
<tr>
<td>DISABLE_DL_DECRYPT</td>
<td>If set, disables flash decryption while running in UART Firmware Download mode.</td>
<td>1</td>
</tr>
<tr>
<td>FLASH_CRYPT_CNT</td>
<td>Enables/disables encryption at boot time. If even number of bits set (0, 2, 4, 6) - encrypt flash at boot time. If odd number of bits set (1, 3, 5, 7) - do not encrypt flash at boot time.</td>
<td>7</td>
</tr>
</tbody>
</table>

**Note:**

- R/W access control is available for all the eFuse bits listed in the table above.
- The default value of these bits is 0 after manufacturing.
Read and write access to eFuse bits is controlled by appropriate fields in the registers `WR_DIS` and `RD_DIS`. For more information on ESP32 eFuses, see `eFuse manager`. To change protection bits of eFuse field using `espefuse.py`, use these two commands: `read_protect_efuse` and `write_protect_efuse`. Example `espefuse.py write_protect_efuse DISABLE_DL_ENCRYPT`.

### 4.15.3 Flash Encryption Process

Assuming that the eFuse values are in their default states and the firmware bootloader is compiled to support flash encryption, the flash encryption process executes as shown below:

1. On the first power-on reset, all data in flash is un-encrypted (plaintext). The ROM bootloader loads the firmware bootloader.
2. Firmware bootloader reads the `FLASH_CRYPT_CNT` eFuse value (0b0000000). Since the value is 0 (even number of bits set), it configures and enables the flash encryption block. It also sets the `FLASH_CRYPT_CONFIG` eFuse to 0xF. For more information on the flash encryption block, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) > Flash Encryption Block [PDF].
3. Firmware bootloader uses RNG (random) module to generate an AES-256 bit key and then writes it into the `flash_encryption` eFuse. The key cannot be accessed via software as the write and read protection bits for the `flash_encryption` eFuse are set. The flash encryption operations happen entirely by hardware, and the key cannot be accessed via software.
4. Flash encryption block encrypts the flash contents - the firmware bootloader, applications and partitions marked as encrypted. Encrypting in-place can take time, up to a minute for large partitions.
5. Firmware bootloader sets the first available bit in `FLASH_CRYPT_CNT` (0b0000001) to mark the flash contents as encrypted. Odd number of bits is set.
6. For `Development Mode`, the firmware bootloader sets only the eFuse bits `DISABLE_DL_DECRYPT` and `DISABLE_DL_CACHE` to allow the UART bootloader to re-flash encrypted binaries. Also, the `FLASH_CRYPT_CNT` eFuse bits are NOT write-protected.
7. For `Release Mode`, the firmware bootloader sets the eFuse bits `DISABLE_DL_ENCRYPT`, `DISABLE_DL_DECRYPT`, and `DISABLE_DL_CACHE` to 1 to prevent the UART bootloader from decrypting the flash contents. It also write-protection the `FLASH_CRYPT_CNT` eFuse bits. To modify this behavior, see `Enabling UART Bootloader Encryption/Decryption`.
8. The device is then rebooted to start executing the encrypted image. The firmware bootloader calls the flash decryption block to decrypt the flash contents and then loads the decrypted contents into IRAM.

During the development stage, there is a frequent need to program different plaintext flash images and test the flash encryption process. This requires that Firmware Download mode is able to load new plaintext images as many times as it might be needed. However, during manufacturing or production stages, Firmware Download mode should not be allowed to access flash contents for security reasons.

Hence, two different flash encryption configurations were created: for development and for production. For details on these configurations, see Section `Flash Encryption Configuration`.

### 4.15.4 Flash Encryption Configuration

The following flash encryption modes are available:

- **Development Mode** - recommended for use only during development. In this mode, it is still possible to flash new plaintext firmware to the device, and the bootloader will transparently encrypt this firmware using the key stored in hardware. This allows, indirectly, to read out the plaintext of the firmware in flash.
- **Release Mode** - recommended for manufacturing and production. In this mode, flashing plaintext firmware to the device without knowing the encryption key is no longer possible.

This section provides information on the mentioned flash encryption modes and step by step instructions on how to use them.
**Development Mode**

During development, you can encrypt flash using either an ESP32 generated key or external host-generated key.

**Using ESP32 Generated Key**  Development mode allows you to download multiple plaintext images using Firmware Download mode.

To test flash encryption process, take the following steps:

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in *Relevant eFuses*.

   See how to check [ESP32 Flash Encryption Status](#).

2. In *Project Configuration Menu*, do the following:

   - *Enable flash encryption on boot*.
   - *Select encryption mode* ([Development mode](#) by default).
   - *Select UART ROM download mode* ([enabled](#) by default). Note that for the ESP32 target, the choice is only available when `CONFIG_ESP32_REV_MIN` level is set to 3 (ESP32 V3).
   - *Select the appropriate bootloader log verbosity*.
   - Save the configuration and exit.

Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See [Bootloader Size](#).

3. Run the command given below to build and flash the complete images.

```
idf.py flash monitor
```

**Note:** This command does not include any user files which should be written to the partitions on the flash memory. Please write them manually before running this command otherwise the files should be encrypted separately before writing.

This command will write to flash memory unencrypted images: the firmware bootloader, the partition table and applications. Once the flashing is complete, ESP32 will reset. On the next boot, the firmware bootloader encrypts: the firmware bootloader, application partitions and partitions marked as encrypted then resets. Encrypting in-place can take time, up to a minute for large partitions. After that, the application is decrypted at runtime and executed.

A sample output of the first ESP32 boot after enabling flash encryption is given below:

```
--- idf_monitor on /dev/cu.SLAB_USBtoUART 115200 ---
--- Quit: Ctrl+] | Menu: Ctrl+T | Help: Ctrl+T followed by Ctrl+H ---
ets Jun 8 2016 00:22:57
rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configsys: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0018,len:4
load:0x3fff001c,len:8452
load:0x40078000,len:13608
load:0x40080400,len:6664
entry 0x40080764
I (28) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (29) boot: compile time 15:37:14
I (30) boot: Enabling RNG early entropy source...
I (35) boot: SPI Speed     : 40MHz
I (39) boot: SPI Mode      : DIO
I (43) boot: SPI Flash Size: 4MB
```

(continues on next page)
I (47) boot: Partition Table:
I (51) boot: # Label Usage Type ST Offset Length
I (58) boot: 0 nvs WiFi data 01 02 0000a000 00006000
I (66) boot: 1 phy_init RF data 01 01 00010000 00010000
I (73) boot: 2 factory factory app 00 00 00020000 00100000
I (81) boot: End of partition table
I (85) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x0808c (~
    32908) map
I (105) esp_image: segment 1: paddr=0x000280b4 vaddr=0x3ff00000 size=0x01ea4 (~
    7844) load
I (109) esp_image: segment 2: paddr=0x00029f60 vaddr=0x40080000 size=0x00400 (~
    1024) load
0x40080000: _WindowOverflow4 at esp-idf/esp-idf/components/freertos/xtensa_vectors.
    S:1778
I (114) esp_image: segment 3: paddr=0x00002a368 vaddr=0x40080400 size=0x05ca8 (~
    23720) load
I (132) esp_image: segment 4: paddr=0x00030018 vaddr=0x400d0018 size=0x126a8 (~
    75432) map
0x400d0018: _flash_cache_start at ???:?
I (159) esp_image: segment 5: paddr=0x0000426c8 vaddr=0x400860a8 size=0x01f4c (~
    8012) load
0x400860a8: prvAddNewTaskToReadyList at esp-idf/esp-idf/components/freertos/tasks.
    c:4561
I (168) boot: Loaded app from partition at offset 0x20000
I (168) boot: Checking flash encryption...
I (168) flash_encrypt: Generating new flash encryption key...
I (187) flash_encrypt: Read & write protecting new key...
I (187) flash_encrypt: Setting CRYPTO_CONFIG efuse to 0xF
W (188) flash_encrypt: Not disabling UART bootloader encryption
I (195) flash_encrypt: Disable UART bootloader decryption...
I (201) flash_encrypt: Disable UART bootloader MMU cache...
I (208) flash_encrypt: Disable JTAG...
I (212) flash_encrypt: Disable ROM BASIC interpreter fallback...
I (219) esp_image: segment 0: paddr=0x00001020 vaddr=0x3fff0018 size=0x00004 (~
    4)
I (227) esp_image: segment 1: paddr=0x0000102c vaddr=0x3fff001c size=0x02104 (~
    8452)
I (239) esp_image: segment 2: paddr=0x00003138 vaddr=0x40078000 size=0x03528 (~
    13608)
I (249) esp_image: segment 3: paddr=0x00006668 vaddr=0x40080400 size=0x01a08 (~
    6664)
I (657) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x0808c (~
    32908) map
I (669) esp_image: segment 1: paddr=0x000280b4 vaddr=0x3ff00000 size=0x01ea4 (~
    7844)
I (672) esp_image: segment 2: paddr=0x00029f60 vaddr=0x40080000 size=0x00400 (~
    1024)
0x40080000: _WindowOverflow4 at esp-idf/esp-idf/components/freertos/xtensa_vectors.
    S:1778
I (676) esp_image: segment 3: paddr=0x00002a368 vaddr=0x40080400 size=0x05ca8 (~
    23720)
I (692) esp_image: segment 4: paddr=0x00030018 vaddr=0x400d0018 size=0x126a8 (~
    75432) map
0x400d0018: _flash_cache_start at ???:?
I (719) esp_image: segment 5: paddr=0x0000426c8 vaddr=0x400860a8 size=0x01f4c (~
    8012)
A sample output of subsequent ESP32 boots just mentions that flash encryption is already enabled:

```
rst:0x01 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configspi: 0, SPIWP:0xee
clk_drv:0x000,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x3fff0018,len:4
load:0x3fff001c,len:8452
load:0x40078000,len:13652
ho 0 tail 12 room 4
load:0x40080400,len:6664
entry 0x40080764
I (30) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (30) boot: compile time 16:32:53
I (31) boot: Enabling RNG early entropy source...
I (37) boot: SPI Speed : 40MHz
I (41) boot: SPI Mode : DIO
I (45) boot: SPI Flash Size : 4MB
I (49) boot: Partition Table:
I (52) boot: # Label       Usage   Type ST Offset Length
I (60) boot: 0 nvs         WiFi data 01 02 0000a000 00006000
I (67) boot: 1 phy_init     RF data 01 01 00010000 00001000
I (75) boot: 2 factory     factory app 00 00 00020000 00100000
I (82) boot: End of partition table
I (86) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x0808c (...
0x39208) map
I (107) esp_image: segment 1: paddr=0x000280b4 vaddr=0x3ffb0000 size=0x01ea4 (...
0x7844) load
I (111) esp_image: segment 2: paddr=0x00029f60 vaddr=0x40080000 size=0x00400 (...
0x1024) load
0x40080000: _WindowOverflow4 at esp-idf/esp-idf/components/freertos/xtensa_vectors.
S:1778
I (116) esp_image: segment 3: paddr=0x00002a368 vaddr=0x40080400 size=0x05ca8 (...
0x23720) load
I (134) esp_image: segment 4: paddr=0x00030018 vaddr=0x400d0018 size=0x126a8 (...
0x75432) map
0x400d0018: __flash_cache_start at ???:
I (162) esp_image: segment 5: paddr=0x0000426c8 vaddr=0x400860a8 size=0x01f4c (...
0x8012) load
0x400860a8: prvAddNewTaskToReadyList at esp-idf/esp-idf/components/freertos/tasks.
c:4561
I (171) boot: Loaded app from partition at offset 0x20000
I (171) boot: Checking flash encryption...
I (171) flash_encrypt: flash encryption is enabled (3 plaintext flashes left)
I (178) boot: Disabling RNG early entropy source...
I (184) cpu_start: Pro cpu up.
I (188) cpu_start: Application information:
I (193) cpu_start: Project name: flash-encryption
I (198) cpu_start: App version: v4.0-dev-850-gc4447462d-dirty
I (205) cpu_start: Compile time: Jun 17 2019 16:32:52
I (211) cpu_start: ELF file SHA256: 8770c886bdf561a7...
(continues on next page)
```
I (217) cpu_start: ESP-IDF: v4.0-dev-850-gc4447462d-dirty
I (224) cpu_start: Starting app cpu, entry point is 0x40080e4c
0x40080e4c: call_start_cpu1 at esp-idf/esp-idf/components/esp32/cpu_start.c:265
I (0) cpu_start: App cpu up.
I (235) heap_init: Initializing. RAM available for dynamic allocation:
I (241) heap_init: At 3FFAE6E0 len 00001920 (6 KiB): DRAM
I (247) heap_init: At 3FFB2EC8 len 0002D138 (180 KiB): DRAM
I (254) heap_init: At 3FFE0440 len 00003AE0 (14 KiB): D/IRAM
I (260) heap_init: At 3FFE4350 len 0001BCB0 (111 KiB): D/IRAM
I (266) heap_init: At 40087FF4 len 0001800C (96 KiB): IRAM
I (273) cpu_start: Pro cpu start user code
I (291) cpu_start: Starting scheduler on PRO CPU.
I (0) cpu_start: Starting scheduler on APP CPU.
```

Sample program to check Flash Encryption
This is ESP32 chip with 2 CPU cores, WiFi/BT/BLE, silicon revision 1, 4MB external...

Flash encryption feature is enabled
Flash encryption mode is DEVELOPMENT
Flash in encrypted mode with flash_crypt_cnt = 1
Halting...

At this stage, if you need to update and re-flash binaries, see Re-flashing Updated Partitions.

### Using Host Generated Key

It is possible to pre-generate a flash encryption key on the host computer and burn it into the eFuse. This allows you to pre-encrypt data on the host and flash already encrypted data without needing a plaintext flash update. This feature can be used in both Development Mode and Release Mode. Without a pre-generated key, data is flashed in plaintext and then ESP32 encrypts the data in-place.

**Note:** This option is not recommended for production, unless a separate key is generated for each individual device.

To use a host generated key, take the following steps:

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in Relevant eFuses. See how to check ESP32 Flash Encryption Status.

2. Generate a random key by running:
   ```bash
   espsecure.py generate_flash_encryption_key my_flash_encryption_key.bin
   ```

3. **Before the first encrypted boot**, burn the key into your device’s eFuse using the command below. This action can be done only once.
   ```bash
   espefuse.py --port PORT burn_key flash_encryption my_flash_encryption_key.bin
   ```

   If the key is not burned and the device is started after enabling flash encryption, the ESP32 will generate a random key that software cannot access or modify.

4. In **Project Configuration Menu**, do the following:
   - **Enable flash encryption on boot**
   - **Select encryption mode** (Development mode by default)
   - **Select the appropriate bootloader log verbosity**
   - Save the configuration and exit.

   Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See Bootloader Size.

5. Run the command given below to build and flash the complete images.
Note: This command does not include any user files which should be written to the partitions on the flash memory. Please write them manually before running this command otherwise the files should be encrypted separately before writing.

This command will write to flash memory unencrypted images: the firmware bootloader, the partition table and applications. Once the flashing is complete, ESP32 will reset. On the next boot, the firmware bootloader encrypts: the firmware bootloader, application partitions and partitions marked as encrypted then resets. Encrypting in-place can take time, up to a minute for large partitions. After that, the application is decrypted at runtime and executed.

If using Development Mode, then the easiest way to update and re-flash binaries is `Re-flashing Updated Partitions`.

If using Release Mode, then it is possible to pre-encrypt the binaries on the host and then flash them as ciphertext. See `Manually Encrypting Files`.

**Re-flashing Updated Partitions** If you update your application code (done in plaintext) and want to re-flash it, you will need to encrypt it before flashing. To encrypt the application and flash it in one step, run:

```
idf.py encrypted-app-flash monitor
```

If all partitions needs to be updated in encrypted format, run:

```
idf.py encrypted-flash monitor
```

**Release Mode**

In Release mode, UART bootloader cannot perform flash encryption operations. New plaintext images can ONLY be downloaded using the over-the-air (OTA) scheme which will encrypt the plaintext image before writing to flash.

To use this mode, take the following steps:

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in `Relevant eFuses`.
   See how to check `ESP32 Flash Encryption Status`.

2. In `Project Configuration Menu`, do the following:
   - **Enable flash encryption on boot**
   - **Select Release mode** (Note that once Release mode is selected, the DISABLE_DL_ENCRYPT and DISABLE_DL_DECRYPT eFuse bits will be burned to disable flash encryption hardware in ROM Download Mode.)
   - **Select UART ROM download mode (Permanently disabled (recommended))** (Note that this option is only available when `CONFIG_ESP32_REV_MIN` is set to 3 (ESP32 V3)). The default choice is to keep UART ROM download mode enabled, however it’s recommended to permanently disable this mode to reduce the options available to an attacker.
   - **Select the appropriate bootloader log verbosity**
   - Save the configuration and exit.

   Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See `Bootloader Size`.

3. Run the command given below to build and flash the complete images.

```
idf.py flash monitor
```
Note: This command does not include any user files which should be written to the partitions on the flash memory. Please write them manually before running this command otherwise the files should be encrypted separately before writing.

This command will write to flash memory unencrypted images: the firmware bootloader, the partition table and applications. Once the flashing is complete, ESP32 will reset. On the next boot, the firmware bootloader encrypts: the firmware bootloader, application partitions and partitions marked as encrypted then resets. Encrypting in-place can take time, up to a minute for large partitions. After that, the application is decrypted at runtime and executed.

Once the flash encryption is enabled in Release mode, the bootloader will write-protect the `FLASH_CRYPT_CNT` eFuse.

For subsequent plaintext field updates, use OTA scheme.

Note: If you have pre-generated the flash encryption key and stored a copy, and the UART download mode is not permanently disabled via `CONFIG_SECURE_UART_ROM_DL_MODE` (ESP32 V3 only), then it is possible to update the flash locally by pre-encrypting the files and then flashing the ciphertext. See Manually Encrypting Files.

Best Practices

When using Flash Encryption in production:

- Do not reuse the same flash encryption key between multiple devices. This means that an attacker who copies encrypted data from one device cannot transfer it to a second device.
- When using ESP32 V3, if the UART ROM Download Mode is not needed for a production device then it should be disabled to provide an extra level of protection. Do this by calling `esp_efuse_disable_rom_download_mode()` during application startup. Alternatively, configure the project `CONFIG_ESP32_REV_MIN` level to 3 (targeting ESP32 V3 only) and select the `CONFIG_SECURE_UART_ROM_DL_MODE` to “Permanently disable ROM Download Mode (recommended)” . The ability to disable ROM Download Mode is not available on earlier ESP32 versions.
- Enable Secure Boot as an extra layer of protection, and to prevent an attacker from selectively corrupting any part of the flash before boot.

4.15.5 Possible Failures

Once flash encryption is enabled, the `FLASH_CRYPT_CNT` eFuse value will have an odd number of bits set. It means that all the partitions marked with the encryption flag are expected to contain encrypted ciphertext. Below are the three typical failure cases if the ESP32 is erroneously loaded with plaintext data:

1. If the bootloader partition is re-flashed with a plaintext firmware bootloader image, the ROM bootloader will fail to load the firmware bootloader resulting in the following failure:

```
rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
flash read err, 1000
ets_main.c 371 ets Jun 8 2016 00:22:57
```

```
rst:0x7 (TG0WDT_SYS_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
flash read err, 1000
ets_main.c 371 ets Jun 8 2016 00:22:57
```

(continues on next page)
Note: This error also appears if the flash contents are erased or corrupted.

2. If the firmware bootloader is encrypted, but the partition table is re-flashed with a **plaintext partition table image**, the bootloader will fail to read the partition table resulting in the following failure:

```plaintext
rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configisp: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x40080000,len:16
entry 0x40080764
I (60) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (60) boot: compile time 15:37:14
I (62) boot: Enabling RNG early entropy source...
I (67) boot: SPI Speed : 40MHz
I (72) boot: SPI Mode : DIO
I (76) boot: SPI Flash Size : 4MB
E (80) flash_parts: partition 0 invalid magic number 0x94f6
E (86) boot: Failed to verify partition table
E (91) boot: load partition table error!
```

3. If the bootloader and partition table are encrypted, but the application is re-flashed with a **plaintext application image**, the bootloader will fail to load the application resulting in the following failure:

```plaintext
rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configisp: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:2
load:0x40080000,len:16
entry 0x40080764
I (60) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (60) boot: compile time 15:37:14
I (62) boot: Enabling RNG early entropy source...
I (67) boot: SPI Speed : 40MHz
I (72) boot: SPI Mode : DIO
I (76) boot: SPI Flash Size : 4MB
E (80) flash_parts: partition 0 invalid magic number 0x94f6
E (86) boot: Failed to verify partition table
E (91) boot: load partition table error!
```

(continues on next page)


4.15.6 ESP32 Flash Encryption Status

1. Ensure that you have an ESP32 device with default flash encryption eFuse settings as shown in Relevant eFuses.

To check if flash encryption on your ESP32 device is enabled, do one of the following:

- flash the application example security/flash_encryption onto your device. This application prints the FLASH_CRYPT_CNT eFuse value and if flash encryption is enabled or disabled.
- Find the serial port name under which your ESP32 device is connected, replace PORT with your port name in the following command, and run it:

```
espefuse.py -p PORT summary
```

4.15.7 Reading and Writing Data in Encrypted Flash

ESP32 application code can check if flash encryption is currently enabled by calling `esp_flash_encryption_enabled()`. Also, a device can identify the flash encryption mode by calling `esp_get_flash_encryption_mode()`.

Once flash encryption is enabled, be more careful with accessing flash contents from code.

**Scope of Flash Encryption**

Whenever the FLASH_CRYPT_CNT eFuse is set to a value with an odd number of bits, all flash content accessed via the MMU’s flash cache is transparently decrypted. It includes:

- Executable application code in flash (IROM).
- All read-only data stored in flash (DROM).
- Any data accessed via `spi_flash_mmap()`.
- The firmware bootloader image when it is read by the ROM bootloader.

**Important:** The MMU flash cache unconditionally decrypts all existing data. Data which is stored unencrypted in flash memory will also be “transparently decrypted” via the flash cache and will appear to software as random garbage.

**Reading from Encrypted Flash**

To read data without using a flash cache MMU mapping, you can use the partition read function `esp_partition_read()`. This function will only decrypt data when it is read from an encrypted partition. Data read from unencrypted partitions will not be decrypted. In this way, software can access encrypted and non-encrypted flash in the same way.

You can also use the following SPI flash API functions:

- `esp_flash_read()` to read raw (encrypted) data which will not be decrypted
• `esp_flash_read_encrypted()` to read and decrypt data

Data stored using the Non-Volatile Storage (NVS) API is always stored and read decrypted from the perspective of flash encryption. It is up to the library to provide encryption feature if required. Refer to NVS Encryption for more details.

**Writing to Encrypted Flash**

It is recommended to use the partition write function `esp_partition_write()`. This function will only encrypt data when it is written to an encrypted partition. Data written to unencrypted partitions will not be encrypted. In this way, software can access encrypted and non-encrypted flash in the same way.

You can also pre-encrypt and write data using the function `esp_flash_write_encrypted()`.

Also, the following ROM function exist but not supported in esp-idf applications:

- `esp_rom_spiflash_write_encrypted` pre-encrypts and writes data to flash
- `SPIWrite` writes unencrypted data to flash

Since data is encrypted in blocks, the minimum write size for encrypted data is 16 bytes and the alignment is also 16 bytes.

### 4.15.8 Updating Encrypted Flash

**OTA Updates**

OTA updates to encrypted partitions will automatically write encrypted data if the function `esp_partition_write()` is used.

Before building the application image for OTA updating of an already encrypted device, enable the option *Enable flash encryption on boot* in project configuration menu.

For general information about ESP-IDF OTA updates, please refer to OTA

**Updating Encrypted Flash via Serial**

Flashing an encrypted device via serial bootloader requires that the serial bootloader download interface has not been permanently disabled via eFuse.

In Development Mode, the recommended method is **Re-flashing Updated Partitions**.

In Release Mode, if a copy of the same key stored in eFuse is available on the host then it’s possible to pre-encrypt files on the host and then flash them. See Manualy Encrypting Files.

### 4.15.9 Disabling Flash Encryption

If flash encryption was enabled accidentally, flashing of plaintext data will soft-brick the ESP32. The device will reboot continuously, printing the error `flash read err, 1000 or invalid header: 0xXXXXXX`.

For flash encryption in Development mode, encryption can be disabled by burning the `FLASH_CRYPT_CNT` eFuse. It can only be done three times per chip by taking the following steps:

1. In *Project Configuration Menu*, disable *Enable flash encryption on boot*, then save and exit.
2. Open project configuration menu again and **double-check** that you have disabled this option! If this option is left enabled, the bootloader will immediately re-enable encryption when it boots.
3. With flash encryption disabled, build and flash the new bootloader and application by running `idf.py flash`.
4. Use `espefuse.py` (in components/esptool_py/esptool) to disable the `FLASH_CRYPT_CNT` by running:
Reset the ESP32. Flash encryption will be disabled, and the bootloader will boot as usual.

### 4.15.10 Key Points About Flash Encryption

- Flash memory contents is encrypted using AES-256. The flash encryption key is stored in the flash_encryption eFuse internal to the chip and, by default, is protected from software access.
- The flash encryption algorithm is AES-256, where the key is “tweaked” with the offset address of each 32 byte block of flash. This means that every 32-byte block (two consecutive 16 byte AES blocks) is encrypted with a unique key derived from the flash encryption key.
- Flash access is transparent via the flash cache mapping feature of ESP32 - any flash regions which are mapped to the address space will be transparently decrypted when read.
- Some data partitions might need to remain unencrypted for ease of access or might require the use of flash-friendly update algorithms which are ineffective if the data is encrypted. NVS partitions for non-volatile storage cannot be encrypted since the NVS library is not directly compatible with flash encryption. For details, refer to [NVS Encryption](#).
- If flash encryption might be used in future, the programmer must keep it in mind and take certain precautions when writing code that uses encrypted flash.
- If secure boot is enabled, re-flashing the bootloader of an encrypted device requires a “Re-flashable” secure boot digest (see *Flash Encryption and Secure Boot*).

Enabling flash encryption will increase the size of bootloader, which might require updating partition table offset. See [Bootloader Size](#).

**Important:** Do not interrupt power to the ESP32 while the first boot encryption pass is running. If power is interrupted, the flash contents will be corrupted and will require flashing with unencrypted data again. In this case, re-flashing will not count towards the flashing limit.

### 4.15.11 Limitations of Flash Encryption

Flash encryption protects firmware against unauthorised readout and modification. It is important to understand the limitations of the flash encryption feature:

- Flash encryption is only as strong as the key. For this reason, we recommend keys are generated on the device during first boot (default behaviour). If generating keys off-device, ensure proper procedure is followed and don’t share the same key between all production devices.
- Not all data is stored encrypted. If storing data on flash, check if the method you are using (library, API, etc.) supports flash encryption.
- Flash encryption does not prevent an attacker from understanding the high-level layout of the flash. This is because the same AES key is used for every pair of adjacent 16 byte AES blocks. When these adjacent 16 byte blocks contain identical content (such as empty or padding areas), these blocks will encrypt to produce matching pairs of encrypted blocks. This may allow an attacker to make high-level comparisons between encrypted devices (i.e. to tell if two devices are probably running the same firmware version).
- For the same reason, an attacker can always tell when a pair of adjacent 16 byte blocks (32 byte aligned) contain two identical 16 byte sequences. Keep this in mind if storing sensitive data on the flash, design your flash storage so this doesn’t happen (using a counter byte or some other non-identical value every 16 bytes is sufficient). [NVS Encryption](#) deals with this and is suitable for many uses.
- Flash encryption alone may not prevent an attacker from modifying the firmware of the device. To prevent unauthorised firmware from running on the device, use flash encryption in combination with [Secure Boot](#).
4.15.12 Flash Encryption and Secure Boot

It is recommended to use flash encryption in combination with Secure Boot. However, if Secure Boot is enabled, additional restrictions apply to device re-flashing:

- **OTA Updates** are not restricted, provided that the new app is signed correctly with the Secure Boot signing key.
- **Plaintext serial flash updates** are only possible if the Re-flashable Secure Boot mode is selected and a Secure Boot key was pre-generated and burned to the ESP32 (refer to Secure Boot). In such configuration, idf.py bootloader will produce a pre-digested bootloader and secure boot digest file for flashing at offset 0x0. When following the plaintext serial re-flashing steps it is necessary to re-flash this file before flashing other plaintext data.
- **Re-flashing via Pregenerated Flash Encryption Key** is still possible, provided the bootloader is not re-flashed. Re-flashing the bootloader requires the same Re-flashable option to be enabled in the Secure Boot config.

4.15.13 Advanced Features

The following section covers advanced features of flash encryption.

**Encrypted Partition Flag**

Some partitions are encrypted by default. Other partitions can be marked in the partition table description as requiring encryption by adding the flag `encrypted` to the partitions’ flag field. As a result, data in these marked partitions will be treated as encrypted in the same manner as an app partition.

<table>
<thead>
<tr>
<th># Name, Type, SubType, Offset, Size, Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td>nvs, data, nvs, 0x9000, 0x6000</td>
</tr>
<tr>
<td>phy_init, data, phy, 0xf000, 0x1000</td>
</tr>
<tr>
<td>factory, app, factory, 0x10000, 1M</td>
</tr>
<tr>
<td>secret_data, 0x40, 0x01, 0x20000, 256K, encrypted</td>
</tr>
</tbody>
</table>

For details on partition table description, see `partition table`.

Further information about encryption of partitions:

- Default partition tables do not include any encrypted data partitions.
- With flash encryption enabled, the app partition is always treated as encrypted and does not require marking.
- If flash encryption is not enabled, the flag “encrypted” has no effect.
- You can also consider protecting phy_init data from physical access, readout, or modification, by marking the optional phy partition with the flag `encrypted`.
- The nvs partition cannot be encrypted, because the NVS library is not directly compatible with flash encryption.

**Enabling UART Bootloader Encryption/Decryption**

On the first boot, the flash encryption process burns by default the following eFuses:

- `DISABLE_DL_ENCRYPT` which disables flash encryption operation when running in UART bootloader boot mode.
- `DISABLE_DL_DECRYPT` which disables transparent flash decryption when running in UART bootloader mode, even if the eFuse `FLASH_CRYPT_CNT` is set to enable it in normal operation.
- `DISABLE_DL_CACHE` which disables the entire MMU flash cache when running in UART bootloader mode. However, before the first boot you can choose to keep any of these features enabled by burning only selected eFuses and write-protect the rest of eFuses with unset value 0. For example:

```
esefuse.py --port PORT burn_efuse DISABLE_DL_DECRYPT
esefuse.py --port PORT write_protect_efuse DISABLE_DL_ENCRYPT
```
**Important:** Leaving `DISABLE_DL_DECRYPT` unset (0) makes flash encryption useless.

An attacker with physical access to the chip can use UART bootloader mode with custom stub code to read out the flash contents.

---

### Setting `FLASH_CRYPT_CONFIG`

The eFuse `FLASH_CRYPT_CONFIG` determines the number of bits in the flash encryption key which are “tweaked” with the block offset. For details, see [Flash Encryption Algorithm](#). On the first boot of the firmware bootloader, this value is set to the maximum `0xF`.

It is possible to burn this eFuse manually and write protect it before the first boot in order to select different tweak values. However, this is not recommended.

It is strongly recommended to never write-protect `FLASH_CRYPT_CONFIG` when it is unset. Otherwise, its value will remain zero permanently, and no bits in the flash encryption key will be tweaked. As a result, the flash encryption algorithm will be equivalent to AES ECB mode.

---

### JTAG Debugging

By default, when Flash Encryption is enabled (in either Development or Release mode) then JTAG debugging is disabled via eFuse. The bootloader does this on first boot, at the same time it enables flash encryption.

See [JTAG with Flash Encryption or Secure Boot](#) for more information about using JTAG Debugging with Flash Encryption.

---

### Manually Encrypting Files

Manually encrypting or decrypting files requires the flash encryption key to be pre-burned in eFuse (see [Using Host Generated Key](#)) and a copy to be kept on the host. If the flash encryption is configured in Development Mode then it’s not necessary to keep a copy of the key or follow these steps, the simpler [Re-flashing Updated Partitions](#) steps can be used.

The key file should be a single raw binary file (example: `key.bin`).

For example, these are the steps to encrypt the file `build/my-app.bin` to flash at offset `0x10000`. Run `espsecure.py` as follows:

```bash
espsecure.py encrypt_flash_data --keyfile /path/to/key.bin --address 0x10000 --output my-app-ciphertext.bin build/my-app.bin
```

The file `my-app-ciphertext.bin` can then be flashed to offset `0x10000` using `esptool.py`. To see all of the command line options recommended for `esptool.py`, see the output printed when `idf.py build` succeeds.

**Note:** If the flashed ciphertext file is not recognized by the ESP32 when it boots, check that the keys match and that the command line arguments match exactly, including the correct offset.

If your ESP32 uses non-default `FLASH_CRYPT_CONFIG` value in eFuse then you will need to pass the `--flash_crypt_conf` argument to `espsecure.py` to set the matching value. This will not happen if the device configured flash encryption by itself, but may happen if burning eFuses manually to enable flash encryption.

The command `espsecure.py decrypt_flash_data` can be used with the same options (and different input/output files), to decrypt ciphertext flash contents or a previously encrypted file.

---
4.15.14 Technical Details

The following sections provide some reference information about the operation of flash encryption.

Flash Encryption Algorithm

- AES-256 operates on 16-byte blocks of data. The flash encryption engine encrypts and decrypts data in 32-byte blocks - two AES blocks in series.
- The main flash encryption key is stored in the `flash_encryption` eFuse and, by default, is protected from further writes or software readout.
- AES-256 key size is 256 bits (32 bytes) read from the `flash_encryption` eFuse. The hardware AES engine uses the key in reversed byte order as compared to the storage order in `flash_encryption`.
  - If the `CODING_SCHEME` eFuse is set to 0 (default, “None” Coding Scheme) then the eFuse key block is 256 bits and the key is stored as-is (in reversed byte order).
  - If the `CODING_SCHEME` eFuse is set to 1 (3/4 Encoding) then the eFuse key block is 192 bits (in reversed byte order), so overall entropy is reduced. The hardware flash encryption still operates on a 256-bit key, after being read (and un-reversed), the key is extended as `key = key[0:255] + key[64:127]`.
- AES algorithm is used inverted in flash encryption, so the flash encryption “encrypt” operation is AES decrypt and the “decrypt” operation is AES encrypt. This is for performance reasons and does not alter the efficiency of the algorithm.
- Each 32-byte block (two adjacent 16-byte AES blocks) is encrypted with a unique key. The key is derived from the main flash encryption key in `flash_encryption`, XORed with the offset of this block in the flash (a “key tweak”).
- The specific tweak depends on the `FLASH_CRYPT_CONFIG` eFuse setting. This is a 4-bit eFuse where each bit enables XORing of a particular range of the key bits:
  - Bit 1, bits 0-66 of the key are XORed.
  - Bit 2, bits 67-131 of the key are XORed.
  - Bit 3, bits 132-194 of the key are XORed.
  - Bit 4, bits 195-256 of the key are XORed.
- It is recommended that `FLASH_CRYPT_CONFIG` is always left at the default value 0xF, so that all key bits are XORed with the block offset. For details, see Setting `FLASH_CRYPT_CONFIG`.
- The high 19 bits of the block offset (bit 5 to bit 23) are XORed with the main flash encryption key. This range is chosen for two reasons: the maximum flash size is 16MB (24 bits), and each block is 32 bytes so the least significant 5 bits are always zero.
- There is a particular mapping from each of the 19 block offset bits to the 256 bits of the flash encryption key to determine which bit is XORed with which. See the variable `_FLASH_ENCRYPTION_TWEAK_PATTERN` in the `espsecure.py` source code for complete mapping.
- To see the full flash encryption algorithm implemented in Python, refer to the `_flash_encryption_operation()` function in the `espsecure.py` source code.

4.16 Hardware Abstraction

ESP-IDF provides a group of APIs for hardware abstraction. These APIs allow you to control peripherals at different levels of abstraction, giving you more flexibility compared to using only the ESP-IDF drivers to interact with hardware. ESP-IDF Hardware abstraction is likely to be useful for writing high-performance bare-metal drivers, or for attempting to port an ESP chip to another platform.

This guide is split into the following sections:

1. Architecture
2. LL (Low Level Layer)
3. HAL (Hardware Abstraction Layer)
Warning: Hardware abstraction API (excluding the driver and xxx_types.h) should be considered an experimental feature, thus cannot be considered public API. The hardware abstraction API does not adhere to the API name changing restrictions of ESP-IDF’s versioning scheme. In other words, it is possible that Hardware Abstraction API may change in between non-major release versions.

Note: Although this document mainly focuses on hardware abstraction of peripherals, e.g., UART, SPI, I2C, certain layers of hardware abstraction extend to other aspects of hardware as well, e.g., some of the CPU’s features are partially abstracted.

4.16.1 Architecture

Hardware abstraction in ESP-IDF is comprised of the following layers, ordered from low level of abstraction that is closer to hardware, to high level of abstraction that is further away from hardware.

- Low Level (LL) Layer
- Hardware Abstraction Layer (HAL)
- Driver Layers

The LL Layer, and HAL are entirely contained within the hal component. Each layer is dependent on the layer below it, i.e, driver depends on HAL, HAL depends on LL, LL depends on the register header files.

For a particular peripheral xxx, its hardware abstraction generally consists of the header files described in the table below. Files that are Target Specific have a separate implementation for each target, i.e., a separate copy for each chip. However, the #include directive is still target-independent, i.e., is the same for different targets, as the build system automatically includes the correct version of the header and source files.
Table 23: Hardware Abstraction Header Files

<table>
<thead>
<tr>
<th>Include Directive</th>
<th>Target Specific</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#include 'soc/xxx_caps.h&quot;</td>
<td>Y</td>
<td>This header contains a list of C macros specifying the various capabilities of the ESP32’s peripheral xxx. Hardware capabilities of a peripheral include things such as the number of channels, DMA support, hardware FIFO/buffer lengths, etc.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_struct.h&quot; #include &quot;soc/xxx_reg.h&quot;</td>
<td>Y</td>
<td>The two headers contain a representation of a peripheral’s registers in C structure and C macro format respectively, allowing you to operate a peripheral at the register level via either of these two header files.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_pins.h&quot;</td>
<td>Y</td>
<td>If certain signals of a peripheral are mapped to a particular pin of the ESP32, their mappings are defined in this header as C macros.</td>
</tr>
<tr>
<td>#include &quot;soc/xxx_periph.h&quot;</td>
<td>N</td>
<td>This header is mainly used as a convenience header file to automatically include xxx_caps.h, xxx_struct.h, and xxx_reg.h.</td>
</tr>
</tbody>
</table>
| #include "hal/xxx_types.h" | N | This header contains type definitions and macros that are shared among the LL, HAL, and driver layers. Moreover, it is considered public API thus can be included by the application level. The shared types and definitions usually related to non-implementation specific concepts such as the following:  
  - Protocol-related types/macros such as frames, modes, common bus speeds, etc.  
  - Features/characteristics of an xxx peripheral that are likely to be present on any implementation (implementation-independent) such as channels, operating modes, signal amplification or attenuation intensities, etc. |
| #include "hal/xxx_ll.h" | Y | This header contains the Low Level (LL) Layer of hardware abstraction. LL Layer API are primarily used to abstract away register operations into readable functions. |
| #include "hal/xxx_hal.h" | Y | The Hardware Abstraction Layer (HAL) is used to abstract away peripheral operation steps into functions (e.g., reading a buffer, starting a transmission, handling an event, etc). The HAL is built on top of the LL Layer. |
| #include "driver/xxx.h" | N | The driver layer is the highest level of ESP-IDF’s hardware abstraction. Driver layer API are meant to be called from ESP-IDF applications, and internally utilize OS primitives. Thus, driver layer API are event-driven, and can used in a multi-threaded environment. |

4.16.2 LL (Low Level) Layer

The primary purpose of the LL Layer is to abstract away register field access into more easily understandable functions. LL functions essentially translate various in/out arguments into the register fields of a peripheral in the form of get/set functions. All the necessary bit shifting, masking, offsetting, andendianness of the register fields should be handled by the LL functions.

//Inside xxx_ll.h

static inline void xxx_ll_set_baud_rate(xxx_dev_t *hw,  
    xxx_ll_clk_src_t clock_source,  
    uint32_t baud_rate) {
    uint32_t src_clk_freq = (source_clk == XXX_SCLK_APB) ? APB_CLK_FREQ : REF_CLK_FREQ;
    uint32_t clock_divider = src_clk_freq / baud;
    // Set clock select field
    hw->clk_div_reg.divider = clock_divider >> 4;
    // Set clock divider field

(continues on next page)
The code snippet above illustrates typical LL functions for a peripheral xxx. LL functions typically have the following characteristics:

- All LL functions are defined as **static inline** so that there is minimal overhead when calling these functions due to compiler optimization. These functions are not guaranteed to be inlined by the compiler, so any LL function that is called when the cache is disabled (e.g., from an IRAM ISR context) should be marked with **__attribute__((always_inline))**.
- The first argument should be a pointer to a **xxx_dev_t** type. The **xxx_dev_t** type is a structure representing the peripheral’s registers, thus the first argument is always a pointer to the starting address of the peripheral’s registers. Note that in some cases where the peripheral has multiple channels with identical register layouts, **xxx_dev_t *hw** may point to the registers of a particular channel instead.
- LL functions should be short, and in most cases are deterministic. In other words, in the worst case, runtime of the LL function can be determined at compile time. Thus, any loops in LL functions should be finite bounded; however, there are currently a few exceptions to this rule.
- LL functions are not thread-safe; it is the responsibility of the upper layers (driver layer) to ensure that registers or register fields are not accessed concurrently.

### 4.16.3 HAL (Hardware Abstraction Layer)

The HAL layer models the operational process of a peripheral as a set of general steps, where each step has an associated function. For each step, the details of a peripheral’s register implementation (i.e., which registers need to be set/read) are hidden (abstracted away) by the HAL. By modeling peripheral operation as a set of functional steps, any minor hardware implementation differences of the peripheral between different targets or chip versions can be abstracted away by the HAL (i.e., handled transparently). In other words, the HAL API for a particular peripheral remains mostly the same across multiple targets/chip versions.

The following HAL function examples are selected from the Watchdog Timer HAL as each function maps to one of the steps in a WDT’s operation life cycle, thus illustrating how a HAL abstracts a peripheral’s operation into functional steps.

```c
// Initialize one of the WDTs
void wdt_hal_init(wdt_hal_context_t *hal, wdt_inst_t wdt_inst, uint32_t prescaler, __bool enable_intr);

// Configure a particular timeout stage of the WDT
void wdt_hal_config_stage(wdt_hal_context_t *hal, wdt_stage_t stage, uint32_t timeout, wdt_stage_action_t behavior);

// Start the WDT
void wdt_hal_enable(wdt_hal_context_t *hal);

// Feed (i.e., reset) the WDT
void wdt_hal_feed(wdt_hal_context_t *hal);

// Handle a WDT timeout
void wdt_hal_handle_intr(wdt_hal_context_t *hal);

// Stop the WDT
void wdt_hal_disable(wdt_hal_context_t *hal);

// De-initialize the WDT
void wdt_hal_deinit(wdt_hal_context_t *hal);
```
HAL functions generally have the following characteristics:

- The first argument to a HAL function has the xxx_hal_context_t * type. The HAL context type is used to store information about a particular instance of the peripheral (i.e., the context instance). A HAL context is initialized by the xxx_hal_init() function and can store information such as the following:
  - The channel number of this instance
  - Pointer to the peripheral’s (or channel’s) registers (i.e., a xxx_dev_t * type)
  - Information about an ongoing transaction (e.g., pointer to DMA descriptor list in use)
  - Some configuration values for the instance (e.g., channel configurations)
  - Variables to maintain state information regarding the instance (e.g., a flag to indicate if the instance is waiting for transaction to complete)

- HAL functions should not contain any OS primitives such as queues, semaphores, mutexes, etc. All synchronization/concurrency should be handled at higher layers (e.g., the driver).

- Some peripherals may have steps that cannot be further abstracted by the HAL, thus end up being a direct wrapper (or macro) for an LL function.

- Some HAL functions may be placed in IRAM thus may carry an IRAM_ATTR or be placed in a separate xxx_hal_iram.c source file.

4.17 High Priority Interrupts

The Xtensa architecture supports 32 interrupts, divided over 7 priority levels from level 1 to 7, with level 7 being a non-maskable interrupt (NMI), plus an assortment of exceptions. On the ESP32, the Interrupt allocation can route most interrupt sources to these interrupts via the interrupt mux. Normally, interrupts are written in C, but ESP-IDF allows high-priority interrupts to be written in assembly as well, resulting in very low interrupt latencies.

4.17.1 Interrupt Priorities

<table>
<thead>
<tr>
<th>Priority Level</th>
<th>Symbol</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/A</td>
<td>Exception and low priority interrupts, handled by ESP-IDF.</td>
</tr>
<tr>
<td>2-3</td>
<td>N/A</td>
<td>Medium priority interrupts, handled by ESP-IDF.</td>
</tr>
<tr>
<td>4</td>
<td>xt_highint4</td>
<td>High priority interrupt, free to use.¹</td>
</tr>
<tr>
<td>5</td>
<td>xt_highint5</td>
<td>Normally used by ESP-IDF debug logic.¹</td>
</tr>
<tr>
<td>NMI</td>
<td>xt_nmi</td>
<td>Non-maskable interrupt, free to use.</td>
</tr>
<tr>
<td>dbg</td>
<td>xt_debugexception</td>
<td>Debug exception. Called on e.g., a BREAK instruction.²</td>
</tr>
</tbody>
</table>

Using these symbols is done by creating an assembly file with suffix .S and defining the named symbols, like this:

```assembly
.section .iram1,"ax"
global xt_highint5
.type xt_highint5,@function
.align 4
xt_highint5:
... your code here
rsr  a0, EXCSAVE_5
rfi   5
```

For a real-life example, see the esp_system/port/soc/esp32/highint_hdl.S file; the panic handler interrupt is implemented there.

¹ ESP-IDF debug logic can be configured to run on xt_highint4 or xt_highint5 in CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL. Bluetooth's interrupt can be configured to run on priority level 4 by enabling CONFIG_BTDM_CTRL_HLI. If CONFIG_BTDM_CTRL_HLI is enabled, ESP-IDF debug logic must be running on priority level 5 interrupt.

² If CONFIG_BTDM_CTRL_HLI is enabled, xt_debugexception is used to fix the live lock issue in ESP32 ECO3.
4.17.2 Notes

- Do not call C code from a high-priority interrupt; as these interrupts are run from a critical section, this can cause the target to crash. Note that although the panic handler interrupt does call normal C code, this exception is allowed due to the fact that this handler never returns (i.e., the application does not continue to run after the panic handler), so breaking C code execution flow is not a problem.

When CONFIG_BTDM_CTRL_HLI is enabled, C code is also called from a high-priority interrupt, this is possible thanks to some additional protection added to it.

- Make sure your assembly code gets linked in. Indeed, as the free-to-use symbols are declared as weak, the linker may discard the file containing the symbol. This happens if the only symbol defined, or used from the user file is the xt_* free-to-use symbol. To avoid this, in the assembly file containing the xt_* symbol, define another symbol, like:

  .global ld_include_my_isr_file
  ld_include_my_isr_file:

  Here it is called ld_include_my_isr_file but can have any name, as long as it is not defined anywhere else in the project.

  Then, in the component CMakeLists.txt, add this name as an unresolved symbol to the ld command line arguments:

  target_link_libraries(${COMPONENT_TARGET} "-u ld_include_my_isr_file")

  This will ensure the linker to always includes the file defining ld_include_my_isr_file, so that the ISR is always linked.

  - High-priority interrupts can be routed and handled using esp_intr_alloc() and associated functions. The handler and handler arguments to esp_intr_alloc() must be NULL, however.
  - In theory, medium priority interrupts could also be handled in this way. ESP-IDF does not support this yet.
  - To check Xtensa instruction set architecture (ISA), please refer to Xtensa ISA Summary.

4.18 JTAG Debugging

This document provides a guide to installing OpenOCD for ESP32 and debugging using GDB. The document is structured as follows:

Introduction  Introduction to the purpose of this guide.
How it Works? Description how ESP32, JTAG interface, OpenOCD and GDB are interconnected and working together to enable debugging of ESP32.
Selecting JTAG Adapter What are the criteria and options to select JTAG adapter hardware.
Setup of OpenOCD Procedure to install OpenOCD and verify that it is installed.
Configuring ESP32 Target Configuration of OpenOCD software and setting up of JTAG adapter hardware, which together make up the debugging target.
Launching Debugger Steps to start up a debug session with GDB from Eclipse and from Command Line.
Debugging Examples If you are not familiar with GDB, check this section for debugging examples provided from Eclipse as well as from Command Line.
Building OpenOCD from Sources Procedure to build OpenOCD from sources for Windows, Linux and macOS operating systems.
Tips and Quirks This section provides collection of tips and quirks related to JTAG debugging of ESP32 with OpenOCD and GDB.
4.18.1 Introduction

The ESP32 has two powerful Xtensa cores, allowing for a great deal of variety of program architectures. The FreeRTOS OS that comes with ESP-IDF is capable of multi-core preemptive scheduling, allowing for an intuitive way of writing software.

The downside of the ease of programming is that debugging without the right tools is harder: figuring out a bug that is caused by two threads, running even simultaneously on two different CPU cores, can take a long time when all you have are printf() statements. A better (and in many cases quicker) way to debug such problems is by using a debugger, connected to the processors over a debug port.

Espressif has ported OpenOCD to support the ESP32 processor and the multi-core FreeRTOS (which is the foundation of most ESP32 apps). Additionally, some extra tools have been written to provide extra features that OpenOCD does not support natively.

This document provides a guide to installing OpenOCD for ESP32 and debugging using GDB under Linux, Windows and macOS. Except for OS specific installation procedures, the s/w user interface and use procedures are the same across all supported operating systems.

Note: Screenshots presented in this document have been made for Eclipse Neon 3 running on Ubuntu 16.04 LTS. There may be some small differences in what a particular user interface looks like, depending on whether you are using Windows, macOS or Linux and/or a different release of Eclipse.

4.18.2 How it Works?

The key software and hardware components that perform debugging of ESP32 with OpenOCD over JTAG (Joint Test Action Group) interface is presented in the diagram below under the “Debugging With JTAG” label. These components include xtensa-esp32-elf-gdb debugger, OpenOCD on chip debugger, and the JTAG adapter connected to ESP32 target.

![Debugging with JTAG](image)

Likewise, the “Application Loading and Monitoring” label indicates the key software and hardware components that allow an application to be compiled, built, and flashed to ESP32, as well as to provide means to monitor diagnostic messages from ESP32.

![Application Loading and Monitoring](image)
“Debugging With JTAG” and “Application Loading and Monitoring” is integrated under the Eclipse IDE in order to provide a quick and easy transition between writing/compiling/loading/debugging code. The Eclipse IDE (and the integrated debugging software) is available for Windows, Linux and macOS platforms. Depending on user preferences, both the debugger and idf.py build can also be used directly from terminal/command line, instead of Eclipse.

If the ESP-WROVER-KIT is used, then connection from PC to ESP32 is done effectively with a single USB cable. This is made possible by the FT2232H chip, which provides two USB channels, one for JTAG and the other for UART connection.

### 4.18.3 Selecting JTAG Adapter

The quickest and most convenient way to start with JTAG debugging is by using ESP-WROVER-KIT. Each version of this development board has JTAG interface already built in. No need for an external JTAG adapter and extra wiring / cable to connect JTAG to ESP32. ESP-WROVER-KIT is using FT2232H JTAG interface operating at 20 MHz clock speed, which is difficult to achieve with an external adapter.

If you decide to use separate JTAG adapter, look for one that is compatible with both the voltage levels on the ESP32 as well as with the OpenOCD software. The JTAG port on the ESP32 is an industry-standard JTAG port which lacks (and does not need) the TRST pin. The JTAG I/O pins all are powered from the VDD_3P3_RTC pin (which normally would be powered by a 3.3 V rail) so the JTAG adapter needs to be able to work with JTAG pins in that voltage range.

On the software side, OpenOCD supports a fair amount of JTAG adapters. See [https://openocd.org/doc/html/Debug-Adapter-Hardware.html](https://openocd.org/doc/html/Debug-Adapter-Hardware.html) for an (unfortunately slightly incomplete) list of the adapters OpenOCD works with. This page lists SWD-compatible adapters as well; take note that the ESP32 does not support SWD. JTAG adapters that are hardcoded to a specific product line, e.g. ST-LINK debugging adapters for STM32 families, will not work.

The minimal signalling to get a working JTAG connection are TDI, TDO, TCK, TMS and GND. Some JTAG debuggers also need a connection from the ESP32 power line to a line called e.g. Vtar to set the working voltage. SRST can optionally be connected to the CH_PD of the ESP32, although for now, support in OpenOCD for that line is pretty minimal.

ESP-Prog is an example for using an external board for debugging by connecting it to the JTAG pins of ESP32.

### 4.18.4 Setup of OpenOCD

If you have already set up ESP-IDF with CMake build system according to the [Getting Started Guide](https://openocd.org/doc/html/), then OpenOCD is already installed. After `setting up the environment` in your terminal, you should be able to run OpenOCD. Check this by executing the following command:

```
openocd --version
```

The output should be as follows (although the version may be more recent than listed here):

```
Open On-Chip Debugger v0.10.0-esp32-20190708 (2019-07-08-11:04)
Licensed under GNU GPL v2
For bug reports, read https://openocd.org/doc/doxygen/bugs.html
```

You may also verify that OpenOCD knows where its configuration scripts are located by printing the value of `OPENOCD_SCRIPTS` environment variable, by typing `echo $OPENOCD_SCRIPTS` (for Linux and macOS) or `echo %OPENOCD_SCRIPTS%` (for Windows). If a valid path is printed, then OpenOCD is set up correctly.

If any of these steps do not work, please go back to the `setting up the tools` section of the Getting Started Guide.

**Note:** It is also possible to build OpenOCD from source. Please refer to [Building OpenOCD from Sources](https://openocd.org/doc/html/) section for details.
4.18.5 Configuring ESP32 Target

Once OpenOCD is installed, you can proceed to configuring the ESP32 target (i.e ESP32 board with JTAG interface). Configuring the target is split into the following three steps:

- Configure and connect JTAG interface
- Run OpenOCD
- Upload application for debugging

Configure and connect JTAG interface

This step depends on the JTAG and ESP32 board you are using (see the two cases described below).

Configure ESP-WROVER-KIT JTAG Interface

All versions of ESP-WROVER-KIT boards have built-in JTAG functionality. Putting it to work requires setting jumpers or DIP switches to enable JTAG functionality, and configuring USB drivers. Please refer to step by step instructions below.

Configure Hardware

- Enable on-board JTAG functionality by setting JP8 according to ESP-WROVER-KIT V4.1 Getting Started Guide, Section Setup Options.
- Verify if ESP32 pins used for JTAG communication are not connected to some other h/w that may disturb JTAG operation:

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO / GPIO15</td>
<td>TDO</td>
</tr>
<tr>
<td>MTDI / GPIO12</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK / GPIO13</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO14</td>
<td>TMS</td>
</tr>
</tbody>
</table>

Configure USB Drivers

Install and configure USB drivers, so OpenOCD is able to communicate with JTAG interface on ESP-WROVER-KIT board as well as with UART interface used to upload application for flash. Follow steps below specific to your operating system.

Note: ESP-WROVER-KIT uses an FT2232 adapter. The following instructions can also be used for other FT2232 based JTAG adapters.

Windows

2. Wait until USB ports of ESP-WROVER-KIT are recognized by Windows and drives are installed. If they do not install automatically, then download them from https://ftdichip.com/drivers/d2xx-drivers/ and install manually.
3. Download Zadig tool (Zadig.X.X.exe) from https://zadig.akeo.ie/ and run it.
4. In Zadig tool go to “Options” and check “List All Devices”.
5. Check the list of devices that should contain two ESP-WROVER-KIT specific USB entries: “Dual RS232-HS (Interface 0)” and “Dual RS232-HS (Interface 1)”. The driver name would be “FTDIBUS (xxxx)” and USB ID: 0403 6010.
6. The first device (Dual RS232-HS (Interface 0)) is connected to the JTAG port of the ESP32. Original “FTDIBUS (xxxx)” driver of this device should be replaced with “WinUSB (v6xxxx)” . To do so, select “Dual RS232-HS (Interface 0) and reinstall attached driver to the “WinUSB (v6xxxx)” , see picture above.
Fig. 39: Configuration of JTAG USB driver in Zadig tool

**Note:** Do not change the second device “Dual RS232-HS (Interface 1)”. It is routed to ESP32’s serial port (UART) used for upload of application to ESP32’s flash.

Now ESP-WROVER-KIT’s JTAG interface should be available to the OpenOCD. To carry on with debugging environment setup, proceed to section *Run OpenOCD*.

### Linux


2. Open a terminal, enter `ls -l /dev/ttyUSB*` command and check, if board’s USB ports are recognized by the OS. You are looking for similar result:

   ```
   user-name@computer-name:~/esp$ ls -l /dev/ttyUSB*
   crw-rw---- 1 root dialout 188, 0 Jul 10 19:04 /dev/ttyUSB0
   crw-rw---- 1 root dialout 188, 1 Jul 10 19:04 /dev/ttyUSB1
   ```

3. To set up access permissions to USB devices supported by OpenOCD, copy the udev rules file into the `/etc/udev/rules.d` directory.

4. Log off and login, then cycle the power to the board to make the changes effective. In terminal enter again `ls -l /dev/ttyUSB*` command to verify, if group-owner has changed from dialout to plugdev:

   ```
   user-name@computer-name:~/esp$ ls -l /dev/ttyUSB*
   crw-rw-r-- 1 root plugdev 188, 0 Jul 10 19:07 /dev/ttyUSB0
   crw-rw-r-- 1 root plugdev 188, 1 Jul 10 19:07 /dev/ttyUSB1
   ```

   If you see similar result and you are a member of plugdev group, then the set up is complete.

The `/dev/ttyUSBn` interface with lower number is used for JTAG communication. The other interface is routed to ESP32’s serial port (UART) used for upload of application to ESP32’s flash.

Now ESP-WROVER-KIT’s JTAG interface should be available to the OpenOCD. To carry on with debugging environment setup, proceed to section *Run OpenOCD*.

### MacOS

On macOS, using FT2232 for JTAG and serial port at the same time needs some additional steps. When the OS loads FT232 serial port driver, it does so for both channels of FT2232 chip. However only one of these channels is used as a serial port, while the other is used as JTAG. If the OS has loaded FT232 serial port driver for the channel used for JTAG, OpenOCD will not be able to connect to the chip. There are two ways around this:
1. Manually unload the FTDI serial port driver before starting OpenOCD, start OpenOCD, then load the serial port driver.
2. Modify FTDI driver configuration so that it doesn’t load itself for channel A of FT2232 chip, which is the channel used for JTAG on ESP-WROVER-KIT.

**Manually unloading the driver**

1. Install FTDI driver from [https://ftdichip.com/drivers/vcp-drivers/](https://ftdichip.com/drivers/vcp-drivers/)
2. Connect USB cable to the ESP-WROVER-KIT.
3. Unload the serial port driver:

   ```
   sudo kextunload -b com.FTDI.driver.FTDIUSBSerialDriver
   ```

   In some cases you may need to unload Apple’s FTDI driver as well:
   - macOS < 10.15:
     ```
     sudo kextunload -b com.apple.driver.AppleUSBFTDI
     ```
   - macOS 10.15:
     ```
     sudo kextunload -b com.apple.DriverKit-AppleUSBFTDI
     ```

   **Warning:** Attempting to use serial over the wrong channel with the FTDI driver will cause a kernel panic. The ESP-WROVER-KIT uses channel A for JTAG and channel B for serial.

4. Run OpenOCD:

   ```
   openocd -f board/esp32-wrover-kit-3.3v.cfg
   ```

5. In another terminal window, load FTDI serial port driver again:

   ```
   sudo kextload -b com.FTDI.driver.FTDIUSBSerialDriver
   ```

   **Note:** If you need to restart OpenOCD, there is no need to unload FTDI driver again — just stop OpenOCD and start it again. The driver only needs to be unloaded if ESP-WROVER-KIT was reconnected or power was toggled.

This procedure can be wrapped into a shell script, if desired.

**Modifying FTDI driver** In a nutshell, this approach requires modification to FTDI driver configuration file, which prevents the driver from being loaded for channel B of FT2232H.

**Note:** Other boards may use channel A for JTAG, so use this option with caution.

**Warning:** This approach also needs signature verification of drivers to be disabled, so may not be acceptable for all users.

1. Open FTDI driver configuration file using a text editor (note `sudo`):

   ```
   sudo nano /Library/Extensions/FTDIUSBSerialDriver.kext/Contents/Info.plist
   ```

2. Find and delete the following lines:

   ```
   <key>FT2232H_B</key>
   <dict>
   <key>CFBundleIdentifier</key>
   <string>com.FTDI.driver.FTDIUSBSerialDriver</string>
   ```

   (continues on next page)
3. Save and close the file
4. Disable driver signature verification:
   1. Open Apple logo menu, choose “Restart...”
   2. When you hear the chime after reboot, press CMD+R immediately
   3. Once Recovery mode starts up, open Terminal
   4. Run the command:

```
csrutil enable --without kext
```
5. Restart again

After these steps, serial port and JTAG can be used at the same time.

To carry on with debugging environment setup, proceed to section Run OpenOCD.

**Configure Other JTAG Interfaces**

For guidance about which JTAG interface to select when using OpenOCD with ESP32, refer to the section Selecting JTAG Adapter. Then follow the configuration steps below to get it working.

**Configure Hardware**

1. Identify all pins/signals on JTAG interface and ESP32 board that should be connected to establish communication.

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO / GPIO15</td>
<td>TDO</td>
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<tr>
<td>MTDI / GPIO12</td>
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<tr>
<td>MTCK / GPIO13</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO14</td>
<td>TMS</td>
</tr>
</tbody>
</table>

2. Verify if ESP32 pins used for JTAG communication are not connected to some other hardware that may disturb JTAG operation.
3. Connect identified pin/signals of ESP32 and JTAG interface.

**Configure Drivers** You may need to install driver software to make JTAG work with computer. Refer to documentation of your JTAG adapter for related details.

On Linux, adding OpenOCD udev rules is required and is done by copying the udev rules file into the `/etc/udev/rules.d` directory.
Connect  Connect JTAG interface to the computer. Power on ESP32 and JTAG interface boards. Check if the JTAG interface is visible on the computer.

To carry on with debugging environment setup, proceed to section Run OpenOCD.

Run OpenOCD

Once target is configured and connected to computer, you are ready to launch OpenOCD.

Open a terminal and set it up for using the ESP-IDF as described in the setting up the environment section of the Getting Started Guide. Then run OpenOCD (this command works on Windows, Linux, and macOS):

```bash
openocd -f board/esp32-wrover-kit-3.3v.cfg
```

Note:  The files provided after -f above are specific for ESP-WROVER-KIT with ESP32-WROOM-32 module. You may need to provide different files depending on the hardware that is used. For guidance see Configuration of OpenOCD for Specific Target.

You should now see similar output (this log is for ESP-WROVER-KIT with ESP32-WROOM-32 module):

```bash
user-name@computer-name:~/esp/esp-idf$ openocd -f board/esp32-wrover-kit-3.3v.cfg
Open On-Chip Debugger v0.10.0-esp32-20190708 (2019-07-08-11:04)
Licensed under GNU GPL v2
For bug reports, read https://openocd.org/doc/doxygen/bugs.html
none separate
adapter speed: 20000 kHz
force hard breakpoints
Info : ftdi: if you experience problems at higher adapter clocks, try the command "ftdi_tdo_sample_edge falling"
Info : clock speed 20000 kHz
Info : JTAG tap: esp32.cpu0 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica), part: 0x2003, ver: 0x1)
Info : JTAG tap: esp32.cpu1 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica), part: 0x2003, ver: 0x1)
Info : esp32: Debug controller was reset (pwrstat=0x5F, after clear 0x0F).
Info : esp32: Core was reset (pwrstat=0x5F, after clear 0x0F).
```

- If there is an error indicating permission problems, please see section on “Permissions delegation” in the OpenOCD README file located in the ~/esp/openocd-esp32 directory.
- In case there is an error in finding the configuration files, e.g, Can't find board/esp32-wrover-kit-3.3v.cfg, check if the OPENOCD_SCRIPTS environment variable is set correctly. This variable is used by OpenOCD to look for the files specified after the -f option. See Setup of OpenOCD section for details. Also check if the file is indeed under the provided path.
- If you see JTAG errors (e.g., ...all ones or ...all zeroes), please check your JTAG connections, whether other signals are connected to JTAG besides ESP32’s pins, and see if everything is powered on correctly.

Upload application for debugging

Build and upload your application to ESP32 as usual, see Step 5. First Steps on ESP-IDF.

Another option is to write application image to flash using OpenOCD via JTAG with commands like this:

```bash
openocd -f board/esp32-wrover-kit-3.3v.cfg -c "program_esp filename.bin 0x10000 --verify exit"
```

OpenOCD flashing command `program_esp` has the following format:
Chapter 4. API Guides

program_esp <image_file> <offset> [verify] [reset] [exit] [compress] [encrypt]

- **image_file** - Path to program image file.
- **offset** - Offset in flash bank to write image.
- **verify** - Optional. Verify flash contents after writing.
- **reset** - Optional. Reset target after programming.
- **exit** - Optional. Finally exit OpenOCD.
- **compress** - Optional. Compress image file before programming.
- **encrypt** - Optional. Encrypt binary before writing to flash. Same functionality with `idf.py encrypted-flash`

You are now ready to start application debugging. Follow the steps described in the section below.

### 4.18.6 Launching Debugger

The toolchain for ESP32 features GNU Debugger, in short GDB. It is available with other toolchain programs under filename: xtensa-esp32-elf-gdb. GDB can be called and operated directly from command line in a terminal. Another option is to call it from within IDE (like Eclipse, Visual Studio Code, etc.) and operate indirectly with help of GUI instead of typing commands in a terminal.

The options of using debugger are discussed under links below.

- **Eclipse**
- **Command Line**
- **Configuration for Visual Studio Code Debug**

It is recommended to first check if debugger works from **Command Line** and then move to using **Eclipse**.

### 4.18.7 Debugging Examples

This section is intended for users not familiar with GDB. It presents example debugging session from **Eclipse** using simple application available under `get-started/blink` and covers the following debugging actions:

1. **Navigating through the code, call stack and threads**
2. **Setting and clearing breakpoints**
3. **Halting the target manually**
4. **Stepping through the code**
5. **Checking and setting memory**
6. **Watching and setting program variables**
7. **Setting conditional breakpoints**

Similar debugging actions are provided using GDB from **Command Line**.

**Note:** **Debugging FreeRTOS Objects** is currently only available for command line debugging.

Before proceeding to examples, set up your ESP32 target and load it with `get-started/blink`.

### 4.18.8 Building OpenOCD from Sources

Please refer to separate documents listed below, that describe build process.

**Building OpenOCD from Sources for Windows**
Chapter 4. API Guides

**Note:** This document outlines how to build a binary of OpenOCD from its source files instead of downloading the pre-built binary. For a quick setup, users can download a pre-built binary of OpenOCD from Espressif GitHub instead of compiling it themselves (see Setup of OpenOCD for more details).

**Note:** All code snippets in this document are assumed to be running in an MSYS2 shell with the MINGW32 subsystem.

### Install Dependencies
Install packages that are required to compile OpenOCD:

```
pacman -S --noconfirm --needed autoconf automake git make \
mingw-w64-i686-gcc \
ingw-w64-i686-toolchain \
ingw-w64-i686-libtool \
ingw-w64-i686-pkg-config \
ingw-w64-cross-winpthreads-git \
p7zip
```

### Download Sources of OpenOCD
The sources for the ESP32-enabled variant of OpenOCD are available from Espressif’s GitHub under https://github.com/espressif/openocd-esp32. These source files can be pulled via Git using the following commands:

```
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

The clone of sources should be now saved in ~/esp/openocd-esp32 directory.

### Downloading libusb
The libusb library is also required when building OpenOCD. The following commands will download a particular release of libusb and uncompress it to the current directory.

```
wget https://github.com/libusb/libusb/releases/download/v1.0.22/libusb-1.0.22.7z
7z x -olibusb ./libusb-1.0.22.7z
```

We now need to export the following variables such that the libusb library gets linked into the OpenOCD build.

```
export CPPFLAGS="-I$(PWD)/libusb/include/libusb-1.0"
export LDFLAGS="-L$(PWD)/libusb/MinGW32/.libs/dll"
```

### Build OpenOCD
The following commands will configure OpenOCD then build it.

```
cd ~/esp/openocd-esp32
export CPPFLAGS="-D__USE_MINGW_ANSI_STDIO=1 -Wno-error"; export CFLAGS="-D__USE_MINGW_ANSI_STDIO=1 -Wno-error"
./bootstrap
./configure --disable-doxygen-pdf --disable-ftdi --enable-jlink --enable-ulink --build=1686-w64-mingw32 --host=1686-w64-mingw32
make
```

```
cp ../libusb/MinGW32/dll/libusb-1.0.dll ./src
```

```
cp /opt/i686-w64-mingw32/bin/libwinpthread-1.dll ./src
```

Once the build is completed, the OpenOCD binary will be placed in ~/esp/openocd-esp32/src/.

You can then optionally call `make install`. This will copy the OpenOCD binary to a user specified location.

- This location can be specified when OpenOCD is configured, or by setting `export DESTDIR="/custom/install/dir"` before calling `make install`.

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If you have an existing OpenOCD (from e.g. another development platform), you may want to skip this call as your existing OpenOCD may get overwritten.

Note:

- Should an error occur, resolve it and try again until the command `make` works.
- If there is a submodule problem from OpenOCD, please `cd` to the `openocd-esp32` directory and input `git submodule update --init`.
- If the `./configure` is successfully run, information of enabled JTAG will be printed under OpenOCD configuration summary.
- If the information of your device is not shown in the log, use `./configure` to enable it as described in `./openocd-esp32/doc/INSTALL.txt`.
- For details concerning compiling OpenOCD, please refer to `openocd-esp32/README.Windows`.
- Don’t forget to copy `libusb-1.0.dll` and `libwinpthread-1.dll` into `OOCD_INSTALLDIR/bin` from `~/esp/openocd-esp32/src`.

Once `make` process is successfully completed, the executable of OpenOCD will be saved in `~/esp/openocd-esp32/src` directory.

Full Listing  For greater convenience, all of commands called throughout the OpenOCD build process have been listed in the code snippet below. Users can copy this code snippet into a shell script then execute it:

```bash
pacman -S --noconfirm --needed autoconf automake git make mingw-w64-i686-gcc mingw-w64-i686-toolchain mingw-w64-i686-libtool mingw-w64-i686-pkg-config mingw-w64-i686-cross-winthreads-git p7zip

cd ~/esp

git clone --recursive https://github.com/espressif/openocd-esp32.git

wget https://github.com/libusb/libusb/releases/download/v1.0.22/libusb-1.0.22.7z
7z x -olibusb ./libusb-1.0.22.7z

export CPPFLAGS="$CPPFLAGS -I$({PWD})/libusb/include/libusb-1.0"; export LDFLAGS="$LDFLAGS -L$({PWD})/libusb/MinGW32/.libs/dll"

export CPPFLAGS="$CPPFLAGS -D__USE_MINGW_ANSI_STDIO=1 -Wno-error"; export CFLAGS="$CFLAGS -Wno-error"

cd ~/esp/openocd-esp32

./bootstrap

./configure --disable-doxygen-pdf --enable-ftdi --enable-jlink --enable-ulink --build-i686-w64-mingw32 --host-i686-w64-mingw32

make

cp ../libusb/MinGW32/dll/libusb-1.0.dll ./src

cp /opt/i686-w64-mingw32/bin/libwinpthread-1.dll ./src

# # optional
# export DESTDIR="$PWD"

# make install

# cp ./src/libusb-1.0.dll $DESTDIR/mingw32/bin
# cp ./src/libwinpthread-1.dll $DESTDIR/mingw32/bin
```

Next Steps  To carry on with debugging environment setup, proceed to section `Configuring ESP32 Target`.

Building OpenOCD from Sources for Linux

The following instructions are alternative to downloading binary OpenOCD from Espressif GitHub. To quickly setup the binary OpenOCD, instead of compiling it yourself, backup and proceed to section `Setup of OpenOCD`.
Download Sources of OpenOCD  The sources for the ESP32-enabled variant of OpenOCD are available from Espressif GitHub under https://github.com/espressif/openocd-esp32. To download the sources, use the following commands:

```
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

The clone of sources should be now saved in ~/esp/openocd-esp32 directory.

Install Dependencies  Install packages that are required to compile OpenOCD.

**Note:** Install the following packages one by one, check if installation was successful and then proceed to the next package. Resolve reported problems before moving to the next step.

```
sudo apt-get install make
sudo apt-get install libtool
sudo apt-get install pkg-config
sudo apt-get install autoconf
sudo apt-get install automake
sudo apt-get install texinfo
sudo apt-get install libusb-1.0
```

**Note:**
- Version of pkg-config should be 0.2.3 or above.
- Version of autoconf should be 2.6.4 or above.
- Version of automake should be 1.9 or above.
- When using USB-Blaster, ASIX Presto, OpenJTAG and FT2232 as adapters, drivers libFTDI and FTD2XX need to be downloaded and installed.
- When using CMSIS-DAP, HIDAPI is needed.

Build OpenOCD  Proceed with configuring and building OpenOCD:

```
cd ~/esp/openocd-esp32
./bootstrap
./configure
make
```

Optionally you can add `sudo make install` step at the end. Skip it, if you have an existing OpenOCD (from e.g. another development platform), as it may get overwritten.

**Note:**
- Should an error occur, resolve it and try again until the command make works.
- If there is a submodule problem from OpenOCD, please cd to the openocd-esp32 directory and input git submodule update --init.
- If the ./configure is successfully run, information of enabled JTAG will be printed under OpenOCD configuration summary.
- If the information of your device is not shown in the log, use ./configure to enable it as described in ./openocd-esp32/doc/INSTALL.txt.
- For details concerning compiling OpenOCD, please refer to openocd-esp32/README.

Once make process is successfully completed, the executable of OpenOCD will be saved in ~/openocd-esp32/bin directory.
Next Steps To carry on with debugging environment setup, proceed to section Configuring ESP32 Target.

Building OpenOCD from Sources for MacOS

The following instructions are alternative to downloading binary OpenOCD from Espressif GitHub. To quickly setup the binary OpenOCD, instead of compiling it yourself, backup and proceed to section Setup of OpenOCD.

Download Sources of OpenOCD The sources for the ESP32-enabled variant of OpenOCD are available from Espressif GitHub under https://github.com/espressif/openocd-esp32. To download the sources, use the following commands:

```
cd ~/esp
git clone --recursive https://github.com/espressif/openocd-esp32.git
```

The clone of sources should be now saved in ~/esp/openocd-esp32 directory.

Install Dependencies Install packages that are required to compile OpenOCD using Homebrew:

```
brew install automake libtool libusb wget gcc@4.9 pkg-config
```

Build OpenOCD Proceed with configuring and building OpenOCD:

```
cd ~/esp/openocd-esp32
./bootstrap
./configure
make
```

Optionally you can add `sudo make install` step at the end. Skip it, if you have an existing OpenOCD (from e.g. another development platform), as it may get overwritten.

Note:

- Should an error occur, resolve it and try again until the command `make` works.
- Error `Unknown command 'raggedright'` may indicate that the required version of texinfo was not installed on your computer or installed but was not linked to your PATH. To resolve this issue make sure `texinfo` is installed and PATH is adjusted prior to the `./bootstrap` by running:

```
brew install texinfo
export PATH=/usr/local/opt/texinfo/bin:$PATH
```

- If there is a submodule problem from OpenOCD, please `cd` to the openocd-esp32 directory and input `git submodule update --init`.
- If the `./configure` is successfully run, information of enabled JTAG will be printed under OpenOCD configuration summary.
- If the information of your device is not shown in the log, use `./configure` to enable it as described in `./openocd-esp32/doc/INSTALL.txt`.
- For details concerning compiling OpenOCD, please refer to `openocd-esp32/README.OSX`.

Once `make` process is successfully completed, the executable of OpenOCD will be saved in `~/esp/openocd-esp32/src/openocd` directory.
Next Steps  
To carry on with debugging environment setup, proceed to section *Configuring ESP32 Target.*  
The examples of invoking OpenOCD in this document assume using pre-built binary distribution described in section *Setup of OpenOCD.*  
To use binaries build locally from sources, change the path to OpenOCD executable to *src/openocd* and set the *OPENOCD_SCRIPTS* environment variable so that OpenOCD can find the configuration files. For Linux and macOS:

```
cd ~/esp/openocd-esp32  
expor OPENOCD_SCRIPTS=$PWD/tcl
```

For Windows:

```
cd %USERPROFILE%\esp\openocd-esp32  
set "OPENOCD_SCRIPTS=%CD%\tcl"
```

Example of invoking OpenOCD build locally from sources, for Linux and macOS:

```
src/openocd -f board/esp32-wrover-kit-3.3v.cfg
```

and Windows:

```
src\openocd -f board\esp32-wrover-kit-3.3v.cfg
```

4.18.9  
**Tips and Quirks**

This section provides collection of links to all tips and quirks referred to from various parts of this guide.

**Tips and Quirks**

This section provides collection of all tips and quirks referred to from various parts of this guide.

**Breakpoints and Watchpoints Available**  
ESP32 debugger supports 2 hardware implemented breakpoints and 64 software ones. Hardware breakpoints are implemented by ESP32 chip’s logic and can be set anywhere in the code: either in flash or IRAM program’s regions. Additionally there are 2 types of software breakpoints implemented by OpenOCD: flash (up to 32) and IRAM (up to 32) breakpoints. Currently GDB can not set software breakpoints in flash. So until this limitation is removed those breakpoints have to be emulated by OpenOCD as hardware ones (see below for details). ESP32 also supports 2 watchpoints, so 2 variables can be watched for change or read by the GDB command watch myVariable. Note that menuconfig option *CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK* uses the last watchpoint and will not provide expected results, if you also try to use it within OpenOCD/GDB. See menuconfig’s help for detailed description.

**What Else Should I Know About Breakpoints?**  
Emulating part of hardware breakpoints using software flash ones means that the GDB command hb myFunction which is invoked for function in flash will use pure hardware breakpoint if it is available otherwise one of the 32 software flash breakpoints is used. The same rule applies to b myFunction-like commands. In this case GDB will decide what type of breakpoint to set itself. If myFunction is resided in writable region (IRAM) software IRAM breakpoint will be used otherwise hardware or software flash breakpoint is used as it is done for hb command.

**Flash Mappings vs SW Flash Breakpoints**  
In order to set/clear software breakpoints in flash, OpenOCD needs to know their flash addresses. To accomplish conversion from the ESP32 address space to the flash one, OpenOCD uses mappings of program’s code regions resided in flash. Those mappings are kept in the image header which is prepended to program binary data (code and data segments) and is specific to every application image written to the flash. So to support software flash breakpoints OpenOCD should know where application image under debugging is
resided in the flash. By default OpenOCD reads partition table at 0x8000 and uses mappings from the first found
application image, but there can be the cases when it will not work, e.g. partition table is not at standard flash location
or even there can be multiple images: one factory and two OTA and you may want to debug any of them. To cover
all possible debugging scenarios OpenOCD supports special command which can be used to set arbitrary location of
application image to debug. The command has the following format:

```
esp appimage_offset <offset>
```

Offset should be in hex format. To reset to the default behaviour you can specify -1 as offset.

**Note:** Since GDB requests memory map from OpenOCD only once when connecting to it, this command should
be specified in one of the TCL configuration files, or passed to OpenOCD via its command line. In the latter case
command line should look like below:

```
openocd -f board/esp32-wrover-kit-3.3v.cfg -c "init; halt; esp appimage_offset...
\t0x210000"
```

Another option is to execute that command via OpenOCD telnet session and then connect GDB, but it seems to be
less handy.

**Why Stepping with “next” Does Not Bypass Subroutine Calls?** When stepping through the code with `next`
command, GDB is internally setting a breakpoint (one out of two available) ahead in the code to bypass the subroutine
calls. This functionality will not work, if the two available breakpoints are already set elsewhere in the code. If this
is the case, delete breakpoints to have one “spare”. With both breakpoints already used, stepping through the code
with `next` command will work as like with `step` command and debugger will step inside subroutine calls.

**Support Options for OpenOCD at Compile Time** ESP-IDF has some support options for OpenOCD debugging
which can be set at compile time:

- `CONFIG_ESP_DEBUG_OCDAWARE` is enabled by default. If a panic or unhandled exception is thrown and a
  JTAG debugger is connected (ie OpenOCD is running), ESP-IDF will break into the debugger.
- `CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK` (disabled by default) sets watchpoint index 1 (the
  second of two) at the end of any task stack. This is the most accurate way to debug task stack overflows.
  Click the link for more details.

Please see the [project configuration menu](#) menu for more details on setting compile-time options.

**FreeRTOS Support** OpenOCD has explicit support for the ESP-IDF FreeRTOS. GDB can see FreeRTOS tasks
as threads. Viewing them all can be done using the GDB `i threads` command, changing to a certain task is
done with `thread n`, with `n` being the number of the thread. FreeRTOS detection can be disabled in target’s
configuration. For more details see [Configuration of OpenOCD for Specific Target](#).

GDB has a Python extension for FreeRTOS support. ESP-IDF automatically loads this module into GDB with the
`idf.py gdb` command when the system requirements are met. See more details in [Debugging FreeRTOS Objects](#).

**Why to Set SPI Flash Voltage in OpenOCD Configuration?** The MTDI pin of ESP32, being among four pins
used for JTAG communication, is also one of ESP32’s bootstrapping pins. On power up ESP32 is sampling binary
level on MTDI to set its internal voltage regulator used to supply power to external SPI flash chip. If binary level on
MDTI pin on power up is low, the voltage regulator is set to deliver 3.3 V, if it is high, then the voltage is set to 1.8
V. The MTDI pin should have a pull-up or may rely on internal weak pull down resistor (see [ESP32 Series Datasheet](#) for
details), depending on the type of SPI chip used. Once JTAG is connected, it overrides the pull-up or pull-down
resistor that is supposed to do the bootstrapping.

To handle this issue OpenOCD’s board configuration file (e.g. `board\esp32-wrover-kit-3.3v.cfg` for
ESP-WROVER-KIT board) provides `ESP32_FLASH_VOLTAGE` parameter to set the idle state of the TDO line to
a specified binary level, therefore reducing the chance of a bad bootup of application due to incorrect flash voltage.
Check specification of ESP32 module connected to JTAG, what is the power supply voltage of SPI flash chip. Then set `ESP32_FLASH_VOLTAGE` accordingly. Most WROOM modules use 3.3 V flash. WROVER earlier than ESP32-WROVER-B use 1.8 V flash, while ESP32-WROVER-B and -E modules use 3.3 V flash.

**Optimize JTAG Speed**  In order to achieve higher data rates and minimize number of dropped packets it is recommended to optimize setting of JTAG clock frequency, so it is at maximum and still provides stable operation of JTAG. To do so use the following tips.

1. The upper limit of JTAG clock frequency is 20 MHz if CPU runs at 80 MHz, or 26 MHz if CPU runs at 160 MHz or 240 MHz.
2. Depending on particular JTAG adapter and the length of connecting cables, you may need to reduce JTAG frequency below 20 MHz or 26 MHz.
3. In particular reduce frequency, if you get DSR/DIR errors (and they do not relate to OpenOCD trying to read from a memory range without physical memory being present there).
4. ESP-WROVER-KIT operates stable at 20 MHz or 26 MHz.

**What is the Meaning of Debugger’s Startup Commands?**  On startup, debugger is issuing sequence of commands to reset the chip and halt it at specific line of code. This sequence (shown below) is user defined to pick up at most convenient/appropriate line and start debugging.

- `set remote hardware-watchpoint-limit 2` — Restrict GDB to using two hardware watchpoints supported by the chip, 2 for ESP32. For more information see https://sourceware.org/gdb/onlinedocs/gdb/Remote-Configuration.html.
- `mon reset halt` — reset the chip and keep the CPUs halted.
- `flushregs` — monitor (mon) command can not inform GDB that the target state has changed. GDB will assume that whatever stack the target had before mon reset halt will still be valid. In fact, after reset the target state will change, and executing flushregs is a way to force GDB to get new state from the target.
- `thb app_main` — insert a temporary hardware breakpoint at `app_main`, put here another function name if required.
- `c` — resume the program. It will then stop at breakpoint inserted at `app_main`.

**Configuration of OpenOCD for Specific Target**  There are several kinds of OpenOCD configuration files (*cfg). All configuration files are located in subdirectories of `share/openocd/scripts` directory of OpenOCD distribution (or `tcl/scripts` directory of the source repository). For the purposes of this guide, the most important ones are `board`, `interface` and `target`.

- `interface` configuration files describe the JTAG adapter. Examples of JTAG adapters are ESP-Prog and J-Link.
- `target` configuration files describe specific chips, or in some cases, modules.
- `board` configuration files are provided for development boards with a built-in JTAG adapter. Such files include an `interface` configuration file to choose the adapter, and `target` configuration file to choose the chip/module.

The following configuration files are available for ESP32:
Table 26: OpenOCD configuration files for ESP32

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>board/esp32-wrover-kit-3.3v.cfg</td>
<td>Board configuration file for ESP-WROVER-KIT with a 3.3 V ESP32-WROOM-32 module or ESP32-WROVER-B / ESP32-WROVER-E module.</td>
</tr>
<tr>
<td>board/esp32-wrover-kit-1.8v.cfg</td>
<td>Board configuration file for ESP-WROVER-KIT with an 1.8 V ESP32-WROVER module.</td>
</tr>
<tr>
<td>board/esp32-ethernet-kit-3.3v.cfg</td>
<td>Board configuration file for ESP-Ethernet-KIT with a 3.3 V ESP32-WROVER-B / ESP32-WROVER-E module.</td>
</tr>
<tr>
<td>target/esp32.cfg</td>
<td>ESP32 target configuration file. Can be used together with one of the interface/configuration files.</td>
</tr>
<tr>
<td>target/esp32-solo-1.cfg</td>
<td>Target configuration file for ESP32-SOLO-1 module. Different from esp32.cfg in that it only configures one CPU.</td>
</tr>
<tr>
<td>interface/ftdi/esp32_devkitj_v1.cfg</td>
<td>JTAG adapter configuration file for ESP-WROVER-KIT and ESP-Prog boards.</td>
</tr>
</tbody>
</table>

If you are using one of the boards which have a pre-defined configuration file, you only need to pass one `-f` argument to OpenOCD, specifying that file.

If you are using a board not listed here, you need to specify both the interface configuration file and target configuration file.

**Custom Configuration Files**  OpenOCD configuration files are written in TCL, and include a variety of choices for customization and scripting. This can be useful for non-standard debugging situations. Please refer to OpenOCD Manual for the TCL scripting reference.

**OpenOCD Configuration Variables**  The following variables can be optionally set before including the ESP-specific target configuration file. This can be done either in a custom configuration file, or from the command line.

The syntax for setting a variable in TCL is:

```
set VARIABLE_NAME value
```

To set a variable from the command line (replace the name of .cfg file with the correct file for your board):

```
openocd -c 'set VARIABLE_NAME value' -f board/esp-xxxxx-kit.cfg
```

It is important to set the variable before including the ESP-specific configuration file, otherwise the variable will not have effect. You can set multiple variables by repeating the `-c` option.

Table 27: Common ESP-related OpenOCD variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_RTOS</td>
<td>Set to <code>none</code> to disable RTOS support. In this case, thread list will not be available in GDB. Can be useful when debugging FreeRTOS itself, and stepping through the scheduler code.</td>
</tr>
<tr>
<td>ESP_FLASH_SIZE</td>
<td>Set to 0 to disable Flash breakpoints support.</td>
</tr>
<tr>
<td>ESP_SEMIHOST_BASEDIR</td>
<td>Set to the path (on the host) which will be the default directory for semihosting functions.</td>
</tr>
</tbody>
</table>
Table 28: ESP32-specific OpenOCD variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32_FLASH_VOLTAGE</td>
<td>When using 1.8 V flash ESP32 based modules, set this variable to 1.8. Refer to Why to Set SPI Flash Voltage in OpenOCD Configuration?</td>
</tr>
<tr>
<td>ESP32_ONLYCPU</td>
<td>For multi-core targets, can be set to 1 to only enable single core debugging.</td>
</tr>
</tbody>
</table>

**How Debugger Resets ESP32?** The board can be reset by entering `mon reset` or `mon reset halt` into GDB.

**Can JTAG Pins be Used for Other Purposes?** Operation of JTAG may be disturbed, if some other hardware is connected to JTAG pins besides ESP32 module and JTAG adapter. ESP32 JTAG is using the following pins:

<table>
<thead>
<tr>
<th>ESP32 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO / GPIO15</td>
<td>TDO</td>
</tr>
<tr>
<td>MTDI / GPIO12</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK / GPIO13</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO14</td>
<td>TMS</td>
</tr>
</tbody>
</table>

Joint communication will likely fail, if configuration of JTAG pins is changed by a user application. If OpenOCD initializes correctly (detects all the CPU cores in the SOC), but loses sync and spews out a lot of DTR/DIR errors when the program is running, it is likely that the application reconfigures the JTAG pins to something else, or the user forgot to connect Vtar to a JTAG adapter that requires it.

Below is an excerpt from series of errors on the dual-core ESP32 reported by GDB after the application stepped into the code that reconfigured MTDO pin to be an input:

```
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates target still busy!
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated -> an exception!
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated -> an overrun!
cpu1: xtensa_resume (line 431): DSR (FFFFFFFF) indicates target still busy!
cpu1: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated -> an exception!
cpu1: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated -> an overrun!
```

**JTAG with Flash Encryption or Secure Boot** By default, enabling Flash Encryption and/or Secure Boot will disable JTAG debugging. On first boot, the bootloader will burn an eFuse bit to permanently disable JTAG at the same time it enables the other features.

The project configuration option `CONFIG_SECURE_BOOT_ALLOW_JTAG` will keep JTAG enabled at this time, removing all physical security but allowing debugging. (Although the name suggests Secure Boot, this option can be applied even when only Flash Encryption is enabled).

However, OpenOCD may attempt to automatically read and write the flash in order to set software breakpoints. This has two problems:

- Software breakpoints are incompatible with Flash Encryption, OpenOCD currently has no support for encrypting or decrypting flash contents.
- If Secure Boot is enabled, setting a software breakpoint will change the digest of a signed app and make the signature invalid. This means if a software breakpoint is set and then a reset occurs, the signature verification will fail on boot.

To disable software breakpoints while using JTAG, add an extra argument `-c 'set ESP_FLASH_SIZE 0'` to the start of the OpenOCD command line, see OpenOCD Configuration Variables.
**Note:** For the same reason, the ESP-IDF app may fail bootloader verification of app signatures, when this option is enabled and a software breakpoint is set.

**JTAG and ESP32-WROOM-32 AT Firmware Compatibility Issue** The ESP32-WROOM series of modules come pre-flashed with AT firmware. This firmware configures the pins GPIO12 to GPIO15 as SPI slave interface, which makes using JTAG impossible.

To make JTAG available, build new firmware that is not using pins GPIO12 to GPIO15 dedicated to JTAG communication. After that, flash the firmware onto your module. See also [Can JTAG Pins be Used for Other Purposes?](#).

**Reporting Issues with OpenOCD/GDB** In case you encounter a problem with OpenOCD or GDB programs itself and do not find a solution searching available resources on the web, open an issue in the OpenOCD issue tracker under https://github.com/espressif/openocd-esp32/issues.

1. In issue report provide details of your configuration:
   a. JTAG adapter type, and the chip/module being debugged.
   b. Release of ESP-IDF used to compile and load application that is being debugged.
   c. Details of OS used for debugging.
   d. Is OS running natively on a PC or on a virtual machine?
2. Create a simple example that is representative to observed issue. Describe steps how to reproduce it. In such an example debugging should not be affected by non-deterministic behaviour introduced by the Wi-Fi stack, so problems will likely be easier to reproduce, if encountered once.
3. Prepare logs from debugging session by adding additional parameters to start up commands.
   OpenOCD:
   ```bash
   openocd -l openocd_log.txt -d3 -f board/esp32-wrover-kit-3.3v.cfg
   ```
   Logging to a file this way will prevent information displayed on the terminal. This may be a good thing taken amount of information provided, when increased debug level `-d3` is set. If you still like to see the log on the screen, then use another command instead:
   ```bash
   openocd -d3 -f board/esp32-wrover-kit-3.3v.cfg 2>&1 | tee openocd.log
   ```
   Debugger:
   ```bash
   xtensa-esp32-elf-gdb -ex "set remotelogfile gdb_log.txt" <all other options>
   ```
   Optionally add command remotelogfile gdb_log.txt to the gdbinit file.
4. Attach both openocd_log.txt and gdb_log.txt files to your issue report.

### 4.18.10 Related Documents

**Using Debugger**

This section covers configuration and running debugger using several methods:

- from Eclipse
- from Command Line
- using `idf.py debug targets`

See also a separate document [Configuration for Visual Studio Code Debug](#) describing how to run a debugger from VS Code.
Note: It is recommended to first check if debugger works using `idf.py debug targets` or from `Command Line` and then move to using Eclipse.

Debugging functionality is provided out of box in standard Eclipse installation. Another option is to use plugins like “GDB Hardware Debugging” plugin. We have found this plugin quite convenient and decided to use throughout this guide.

To begin with, install “GDB Hardware Debugging” plugin by opening Eclipse and going to `Help > Install New Software`.

Once installation is complete, configure debugging session following steps below. Please note that some of configuration parameters are generic and some are project specific. This will be shown below by configuring debugging for “blink” example project. If not done already, add this project to Eclipse workspace following guidance in Eclipse Plugin. The source of get-started/blink application is available in examples directory of ESP-IDF repository.

1. In Eclipse go to `Run > Debug Configuration`. A new window will open. In the window’s left pane double click “GDB Hardware Debugging” (or select “GDB Hardware Debugging” and press the “New” button) to create a new configuration.
2. In a form that will show up on the right, enter the “Name:” of this configuration, e.g. “Blink checking”.
3. On the “Main” tab below, under “Project:” press “Browse” button and select the “blink” project.
4. In next line “C/C++ Application:” press “Browse” button and select “blink.elf” file. If “blink.elf” is not there, then likely this project has not been build yet. See Eclipse Plugin how to do it.
5. Finally, under “Build (if required) before launching” click “Disable auto build”.

A sample window with settings entered in points 1 - 5 is shown below.

![Configuration of GDB Hardware Debugging - Main tab](image)

7. Change default configuration of “Remote host” by entering 3333 under the “Port number”.

   Configuration entered in points 6 and 7 is shown on the following picture.
Fig. 41: Configuration of GDB Hardware Debugging - Debugger tab
8. The last tab to that requires changing of default configuration is “Startup”. Under “Initialization Commands” uncheck “Reset and Delay (seconds)” and “Halt”. Then, in entry field below, enter the following lines:

```
mon reset halt
flushregs
set remote hardware-watchpoint-limit 2
```

**Note:** If you want to update image in the flash automatically before starting new debug session add the following lines of commands at the beginning of “Initialization Commands” textbox:

```
mon reset halt
mon program_esp ${workspace_loc:blink/build/blink.bin} 0x10000 verify
```

For description of `program_esp` command see [Upload application for debugging](#).


10. Further down on the same tab, establish an initial breakpoint to halt CPUs after they are reset by debugger. The plugin will set this breakpoint at the beginning of the function entered under “Set break point at:”. Checkout this option and enter `app_main` in provided field.

11. Checkout “Resume” option. This will make the program to resume after `mon reset halt` is invoked per point 8. The program will then stop at breakpoint inserted at `app_main`. Configuration described in points 8 - 11 is shown below.

![Configuration of GDB Hardware Debugging - Startup tab](image)

Fig. 42: Configuration of GDB Hardware Debugging - Startup tab

If the “Startup” sequence looks convoluted and respective “Initialization Commands” are not clear to you, check [What is the Meaning of Debugger’s Startup Commands?](#) for additional explanation.
12. If you previously completed *Configuring ESP32 Target* steps described above, so the target is running and ready to talk to debugger, go right to debugging by pressing “Debug” button. Otherwise press “Apply” to save changes, go back to *Configuring ESP32 Target* and return here to start debugging.

Once all 1-12 configuration steps are satisfied, the new Eclipse perspective called “Debug” will open as shown on example picture below.

If you are not quite sure how to use GDB, check *Eclipse example debugging session in section Debugging Examples.*

**Command Line**

1. Begin with completing steps described under *Configuring ESP32 Target*. This is prerequisite to start a debugging session.

2. Open a new terminal session and go to directory that contains project for debugging, e.g.

   ```
   cd ~/esp/blink
   ```

3. When launching a debugger, you will need to provide couple of configuration parameters and commands. Instead of entering them one by one in command line, create a configuration file and name it `gdbinit`:

   ```
   target remote :3333
   set remote hardware-watchpoint-limit 2
   mon reset halt
   flushregs
   thb app_main
   c
   ```

   Save this file in current directory.

   For more details what “’s inside `gdbinit` file, see *What is the Meaning of Debugger’s Startup Commands?*
4. Now you are ready to launch GDB. Type the following in terminal:

```
xtensa-esp32-elf-gdb -x gdbinit build/blink.elf
```

5. If previous steps have been done correctly, you will see a similar log concluded with (gdb) prompt:

```
user-name@computer-name:~/esp/blink$ xtensa-esp32-elf-gdb -x gdbinit build/ → blink.elf
GNU gdb (crosstool-NG crosstool-ng-1.22.0-gab375a) 7.10
Copyright (C) 2015 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying" and "show warranty" for details.
This GDB was configured as "--host=x86_64-build_pc-linux-gnu --target=xtensa- → esp32-elf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see: <http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at: <http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from build/blink.elf...done.
0x400d10d8 in esp_vApplicationIdleHook () at /home/user-name/esp/esp-idf/ → components/esp32/./freertos_hooks.c:52
  →
2
JTAG tap: esp32.cpu0 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),→
  →
part: 0x2003, ver: 0x1)
JTAG tap: esp32.slave tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),→
  →
part: 0x2003, ver: 0x1)
esp32: Debug controller was reset (pwrstat=0x5F, after clear 0x0F).
esp32: Core was reset (pwrstat=0x0F, after clear 0x0F).
Target halted. PRO_CPU: PC=0x5000004B (active) APP_CPU: PC=0x00000000
esp32: target state: halted
esp32: Core was reset (pwrstat=0x1F, after clear 0x0F).
Target halted. PRO_CPU: PC=0x40000400 (active) APP_CPU: PC=0x40000400
esp32: target state: halted
Hardware assisted breakpoint 1 at 0x400db717: file /home/user-name/esp/blink/ →
  →
main/./blink.c, line 43.
0x0: 0x00000000
Target halted. PRO_CPU: PC=0x4000d10d8 (active) APP_CPU: PC=0x4000d10d8
[New Thread 1073428656]
[New Thread 1073413708]
[New Thread 1073413161]
[New Thread 1073410672]
[New Thread 1073408876]
[New Thread 1073432196]
[New Thread 1073411552]
[Switching to Thread 1073411996]
Temporary breakpoint 1, app_main () at /home/user-name/esp/blink/main/./blink. →
  →
.c:43
43 xTaskCreate(sblink_task, "blink_task", 512, NULL, 5, NULL);
(gdb)
```

Note the third line from bottom that shows debugger halting at breakpoint established in gdbinit file at function app_main(). Since the processor is halted, the LED should not be blinking. If this is what you see as well, you are ready to start debugging.

If you are not quite sure how to use GDB, check Command Line example debugging session in section Debugging Examples.
**idf.py debug targets** It is also possible to execute the described debugging tools conveniently from `idf.py`. These commands are supported:

1. **idf.py openocd**
   - Runs OpenOCD in a console with configuration defined in the environment or via command line. It uses default script directory defined as `OPENOCD_SCRIPTS` environmental variable, which is automatically added from an Export script (`export.sh` or `export.bat`). It is possible to override the script location using command line argument `--openocd-scripts`.
   - As for the JTAG configuration of the current board, please use the environmental variable `OPENOCD_COMMANDS` or `--openocd-commands` command line argument. If none of the above is defined, OpenOCD is started with `-f board/esp32-wrover-kit-3.3v.cfg` board definition.

2. **idf.py gdb**
   - Starts the gdb the same way as the **Command Line**, but generates the initial gdb scripts referring to the current project elf file.

3. **idf.py gdbtui**
   - The same as 2, but starts the gdb with `tui` argument allowing very simple source code view.

4. **idf.py gdbgui**
   - Starts `gdbgui` debugger frontend enabling out-of-the-box debugging in a browser window. Please run the install script with the `--enable-gdbgui` argument in order to make this option supported, e.g. `install.sh --enable-gdbgui`.
   - It is possible to combine these debugging actions on a single command line allowing convenient setup of blocking and non-blocking actions in one step. `idf.py` implements a simple logic to move the background actions (such as openocd) to the beginning and the interactive ones (such as gdb, monitor) to the end of the action list.
   - An example of a very useful combination is:

   ```
   idf.py openocd gdbgui monitor
   ```
   - The above command runs OpenOCD in the background, starts `gdbgui` to open a browser window with active debugger frontend and opens a serial monitor in the active console.

**Debugging Examples**

This section describes debugging with GDB from **Eclipse** as well as from **Command Line**.

**Eclipse** Verify if your target is ready and loaded with `get-started/blink` example. Configure and start debugger following steps in section **Eclipse**. Pick up where target was left by debugger, i.e. having the application halted at breakpoint established at `app_main()`.

**Examples in this section**

1. **Navigating through the code, call stack and threads**
2. **Setting and clearing breakpoints**
3. **Halting the target manually**
4. **Stepping through the code**
5. **Checking and setting memory**
6. **Watching and setting program variables**
7. **Setting conditional breakpoints**

**Navigating through the code, call stack and threads** When the target is halted, debugger shows the list of threads in “Debug” window. The line of code where program halted is highlighted in another window below, as shown on the following picture. The LED stops blinking.

Specific thread where the program halted is expanded showing the call stack. It represents function calls that lead up to the highlighted line of code, where the target halted. The first line of call stack under Thread #1 contains the last called function `app_main()`, that in turn was called from function `main_task()` shown in a line below. Each
Fig. 44: Debug Perspective in Eclipse
Fig. 45: Target halted during debugging
line of the stack also contains the file name and line number where the function was called. By clicking / highlighting
the stack entries, in window below, you will see contents of this file.

By expanding threads you can navigate throughout the application. Expand Thread #5 that contains much longer call
stack. You will see there, besides function calls, numbers like \(0x4000000c\). They represent addresses of binary
code not provided in source form.

Fig. 46: Navigate through the call stack

In another window on right, you can see the disassembled machine code no matter if your project provides it in source
or only the binary form.

Go back to the `app_main()` in Thread #1 to familiar code of `blink.c` file that will be examined in more details
in the following examples. Debugger makes it easy to navigate through the code of entire application. This comes
handy when stepping through the code and working with breakpoints and will be discussed below.

**Setting and clearing breakpoints** When debugging, we would like to be able to stop the application at critical
lines of code and then examine the state of specific variables, memory and registers / peripherals. To do so we are
using breakpoints. They provide a convenient way to quickly get to and halt the application at specific line.

Let’s establish two breakpoints when the state of LED changes. Basing on code listing above, this happens at lines
33 and 36. To do so, hold the “Control” on the keyboard and double clink on number 33 in file `blink.c` file. A
dialog will open where you can confirm your selection by pressing “OK” button. If you do not like to see the dialog
just double click the line number. Set another breakpoint in line 36.

Information how many breakpoints are set and where is shown in window “Breakpoints” on top right. Click “Show
Breakpoints Supported by Selected Target” to refresh this list. Besides the two just set breakpoints the list may contain
temporary breakpoint at function `app_main()` established at debugger start. As maximum two breakpoints are
allowed (see Breakpoints and Watchpoints Available), you need to delete it, or debugging will fail.
Fig. 47: Setting a breakpoint
Fig. 48: Three breakpoints are set / maximum two are allowed
If you now click “Resume” (click `blink_task()` under “Tread #8”, if “Resume” button is grayed out), the processor will run and halt at a breakpoint. Clicking “Resume” another time will make it run again, halt on second breakpoint, and so on.

You will be also able to see that LED is changing the state after each click to “Resume” program execution.

Read more about breakpoints under Breakpoints and Watchpoints Available and What Else Should I Know About Breakpoints?

Halting the target manually  When debugging, you may resume application and enter code waiting for some event or staying in infinite loop without any break points defined. In such case, to go back to debugging mode, you can break program execution manually by pressing “Suspend” button.

To check it, delete all breakpoints and click “Resume”. Then click “Suspend”. Application will be halted at some random point and LED will stop blinking. Debugger will expand tread and highlight the line of code where application halted.

In particular case above, the application has been halted in line 52 of code in file `freertos_hooks.c` Now you can resume it again by pressing “Resume” button or do some debugging as discussed below.

Stepping through the code  It is also possible to step through the code using “Step Into (F5)” and “Step Over (F6)” commands. The difference is that “Step Into (F5)” is entering inside subroutines calls, while “Step Over (F6)” steps over the call, treating it as a single source line.

Before being able to demonstrate this functionality, using information discussed in previous paragraph, make sure that you have only one breakpoint defined at line 36 of `blink.c`.

Resume program by entering pressing F8 and let it halt. Now press “Step Over (F6)”, one by one couple of times, to see how debugger is stepping one program line at a time.
Fig. 50: Stepping through the code with “Step Over (F6)”
If you press “Step Into (F5)” instead, then debugger will step inside subroutine calls.

![Step Into (F5) button]

Fig. 51: Stepping through the code with “Step Into (F5)”

In this particular case debugger stepped inside `gpio_set_level(BLINK_GPIO, 0)` and effectively moved to `gpio.c` driver code.

See Why Stepping with “next” Does Not Bypass Subroutine Calls? for potential limitation of using `next` command.

Checking and setting memory To display or set contents of memory use “Memory” tab at the bottom of “Debug” perspective.

With the “Memory” tab, we will read from and write to the memory location 0x3FF44004 labeled as GPIO OUT_REG used to set and clear individual GPIO’s.

For more information, see ESP32 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX) [PDF].

Being in the same `blink.c` project as before, set two breakpoints right after `gpio_set_level` instruction. Click “Memory” tab and then “Add Memory Monitor” button. Enter 0x3FF44004 in provided dialog.

Now resume program by pressing F8 and observe “Monitor” tab.

You should see one bit being flipped over at memory location 0x3FF44004 (and LED changing the state) each time F8 is pressed.

To set memory use the same “Monitor” tab and the same memory location. Type in alternate bit pattern as previously observed. Immediately after pressing enter you will see LED changing the state.

Watching and setting program variables A common debugging tasks is checking the value of a program variable as the program runs. To be able to demonstrate this functionality, update file `blink.c` by adding a declaration of a global variable `int i` above definition of function `blink_task`. Then add `i++` inside while(1) of this function to get `i` incremented on each blink.
Fig. 52: Observing memory location 0x3FF44004 changing one bit to “ON”

Fig. 53: Observing memory location 0x3FF44004 changing one bit to “OFF”
Exit debugger, so it is not confused with new code, build and flash the code to the ESP and restart debugger. There is no need to restart OpenOCD.

Once application is halted, enter a breakpoint in the line where you put `i++`.

In next step, in the window with “Breakpoints”, click the “Expressions” tab. If this tab is not visible, then add it by going to the top menu Window > Show View > Expressions. Then click “Add new expression” and enter `i`.

Resume program execution by pressing F8. Each time the program is halted you will see `i` value being incremented.

To modify `i` enter a new number in “Value” column. After pressing “Resume (F8)” the program will keep incrementing `i` starting from the new entered number.

**Setting conditional breakpoints** Here comes more interesting part. You may set a breakpoint to halt the program execution, if certain condition is satisfied. Right click on the breakpoint to open a context menu and select “Breakpoint Properties”. Change the selection under “Type:” to “Hardware” and enter a “Condition:” like `i == 2`.

If current value of `i` is less than 2 (change it if required) and program is resumed, it will blink LED in a loop until condition `i == 2` gets true and then finally halt.

**Command Line** Verify if your target is ready and loaded with `get-started/blink` example. Configure and start debugger following steps in section **Command Line**. Pick up where target was left by debugger, i.e. having the application halted at breakpoint established at `app_main()`:

```
Temporary breakpoint 1, app_main () at /home/user-name/esp/blink/main/.blink.c:43
43 xTaskCreate(&blink_task, "blink_task", configMINIMAL_STACK_SIZE, NULL, 5, __NULL,); (gdb)
```
Fig. 55: Setting a conditional breakpoint
Chapter 4. API Guides

Examples in this section

1. Navigating through the code, call stack and threads
2. Setting and clearing breakpoints
3. Halting and resuming the application
4. Stepping through the code
5. Checking and setting memory
6. Watching and setting program variables
7. Setting conditional breakpoints
8. Debugging FreeRTOS Objects

Navigating through the code, call stack and threads When you see the (gdb) prompt, the application is halted. LED should not be blinking.

To find out where exactly the code is halted, enter l or list, and debugger will show couple of lines of code around the halt point (line 43 of code in file blink.c)

```
(gdb) l
38     }
39 }
40
41 void app_main()
42 {
43     xTaskCreate(&blink_task, "blink_task", configMINIMAL_STACK_SIZE, NULL, 5,
44     NULL);
45 }
```

Check how code listing works by entering, e.g. l 30, 40 to see particular range of lines of code.

You can use bt or backtrace to see what function calls lead up to this code:

```
(gdb) bt
#0 app_main () at /home/user-name/esp/blink/main/./blink.c:43
#1 0x400d057e in main_task (args=0x0) at /home/user-name/esp/esp-idf/components/esp32/./cpu_start.c:339
```

Line #0 of output provides the last function call before the application halted, i.e. app_main () we have listed previously. The app_main () was in turn called by function main_task from line 339 of code located in file cpu_start.c.

To get to the context of main_task in file cpu_start.c, enter frame N, where N = 1, because the main_task is listed under #1:

```
(gdb) frame 1
#1 0x400d057e in main_task (args=0x0) at /home/user-name/esp/esp-idf/components/esp32/./cpu_start.c:339
```

Enter l and this will reveal the piece of code that called app_main() (in line 339):

```
(gdb) l
334     ;
335 }
336 #endif
337 //Enable allocation in region where the startup stacks were located.
338 heap_caps_enable_nonos_stack_heaps();
339 app_main();
340 vTaskDelete(NULL);
341 }
```
(continues on next page)
By listing some lines before, you will see the function name `main_task` we have been looking for:

```c
(gdb) l 326, 341
326 static void main_task(void* args)
327 {
328     // Now that the application is about to start, disable boot watchdogs
329     REG_CLR_BIT(TIMG_WDTCONFIG0_REG(0), TIMG_WDT_FLASHBOOT_MOD_EN_S);
330     REG_CLR_BIT(RTC_CNTL_WDTCONFIG0_REG, RTC_CNTL_WDT_FLASHBOOT_MOD_EN);
331     #if !CONFIG_FREERTOS_UNICORE
332         // Wait for FreeRTOS initialization to finish on APP CPU, before replacing...
333         while (port_xSchedulerRunning[1] == 0) {
334             ;
335         }
336     #endif
337     // Enable allocation in region where the startup stacks were located.
338     heap_caps_enable_nonos_stack_heaps();
339     app_main();
340     vTaskDelete(NULL);
341 }
```

To see the other code, enter `i threads`. This will show the list of threads running on target:

```c
(gdb) i threads
Id    Target Id  Frame
 8  Thread 1073411336 (dport) 0x400d0848 in dport_access_init_core (arg=
 7  Thread 1073408744 (ipc0) xQueueGenericReceive (xQueue=0x3ffae694,
 6  Thread 1073431096 (Tmr Svc) prvTimerTask (pvParameters=0x0)
 5  Thread 1073410208 (ipc1 : Running) 0x4000bfea in ?? ()
 4  Thread 1073432224 (dport) dport_access_init_core (arg=0x0)
 3  Thread 1073411516 (IDLE) prvIdleTask (pvParameters=0x0)
 2  Thread 1073413512 (IDLE) prvIdleTask (pvParameters=0x0)
 1  Thread 1073411772 (main : Running) app_main () at /home/user-name/esp/blink/
        main/.blnk.c:43
```

The thread list shows the last function calls per each thread together with the name of C source file if available. You can navigate to specific thread by entering `thread N`, where N is the thread Id. To see how it works go to thread 5:

```c
(gdb) thread 5
[Switching to thread 5 (Thread 1073410208)]
#0 0x4000bfea in ?? ()
```

Then check the backtrace:
As you see, the backtrace may contain several entries. This will let you check what exact sequence of function calls lead to the code where the target halted. Question marks ?? instead of a function name indicate that application is available only in binary format, without any source file in C language. The value like 0x4000bfea is the memory address of the function call.

Using bt, i threads, thread N and list commands we are now able to navigate through the code of entire application. This comes handy when stepping through the code and working with breakpoints and will be discussed below.

### Setting and clearing breakpoints

When debugging, we would like to be able to stop the application at critical lines of code and then examine the state of specific variables, memory and registers / peripherals. To do so we are using breakpoints. They provide a convenient way to quickly get to and halt the application at specific line.

Let’s establish two breakpoints when the state of LED changes. Basing on code listing above this happens at lines 33 and 36. Breakpoints may be established using command break M where M is the code line number:

```
(gdb) break 33
Breakpoint 2 at 0x400db6f6: file /home/user-name/esp/blink/main/./blink.c, line 33.
(gdb) break 36
Breakpoint 3 at 0x400db704: file /home/user-name/esp/blink/main/./blink.c, line 36.
```

If you now enter c, the processor will run and halt at a breakpoint. Entering c another time will make it run again, halt on second breakpoint, and so on:

```
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB6F6 (active) APP_CPU: PC=0x400D10D8
Breakpoint 2, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./blink.c:33
    33  gpio_set_level(BLINK_GPIO, 0);
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB6F8 (active) APP_CPU: PC=0x400D10D8
Target halted. PRO_CPU: PC=0x400DB704 (active) APP_CPU: PC=0x400D10D8
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./blink.c:36
    36  gpio_set_level(BLINK_GPIO, 1);
(gdb)
```

You will be also able to see that LED is changing the state only if you resume program execution by entering c.

To examine how many breakpoints are set and where, use command info break:
Chapter 4. API Guides

(gdb) info break
Num  Type       Disp  Enb   Address                  What
2    breakpoint keep  y 0x400db6f6  in blink_task at /home/user-name/esp/
     →blink/main/./blink.c:33
     breakpoint already hit 1 time
3    breakpoint keep  y 0x400db704  in blink_task at /home/user-name/esp/
     →blink/main/./blink.c:36
     breakpoint already hit 1 time
(gdb)

Please note that breakpoint numbers (listed under Num) start with 2. This is because first breakpoint has been already established at function app_main() by running command thb app_main on debugger launch. As it was a temporary breakpoint, it has been automatically deleted and now is not listed anymore.

To remove breakpoints enter delete N command (in short d N), where N is the breakpoint number:

(gdb) delete 1
No breakpoint number 1.
(gdb) delete 2
(gdb)

Read more about breakpoints under Breakpoints and Watchpoints Available and What Else Should I Know About Breakpoints?

Halting and resuming the application    When debugging, you may resume application and enter code waiting for some event or staying in infinite loop without any breakpoints defined. In such case, to go back to debugging mode, you can break program execution manually by entering Ctrl+C.

To check it delete all breakpoints and enter c to resume application. Then enter Ctrl+C. Application will be halted at some random point and LED will stop blinking. Debugger will print the following:

(gdb) c
Continuing.
^CTarget halted. PRO_CPU: PC=0x400D0C00 APP_CPU: PC=0x400D0C00 (active)
[New Thread 1073433352]

Program received signal SIGINT, Interrupt.
[Switching to Thread 1073413512]
0x400d0c00 in esp_vApplicationIdleHook () at /home/user-name/esp/esp-idf/
     →components/esp32/./freertos_hooks.c:52
52    asm("waiti 0");
(gdb)

In particular case above, the application has been halted in line 52 of code in file freertos_hooks.c. Now you can resume it again by enter c or do some debugging as discussed below.

Stepping through the code    It is also possible to step through the code using step and next commands (in short s and n). The difference is that step is entering inside subroutines calls, while next steps over the call, treating it as a single source line.

To demonstrate this functionality, using command break and delete discussed in previous paragraph, make sure that you have only one breakpoint defined at line 36 of blink.c:

(gdb) info break
Num  Type       Disp  Enb   Address                  What
3    breakpoint keep  y 0x400db704  in blink_task at /home/user-name/esp/
     →blink/main/./blink.c:36
     breakpoint already hit 1 time
(gdb)

Resume program by entering c and let it halt:
Then enter `n` couple of times to see how debugger is stepping one program line at a time:

```gdb
(gdb) n
Target halted. PRO_CPU: PC=0x400DB756 (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB758 (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04C (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB75B (active)      APP_CPU: PC=0x400D1128
37  vTaskDelay(1000 / portTICK_PERIOD_MS);
(gdb) n
Target halted. PRO_CPU: PC=0x400DB748 (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB746 (active)      APP_CPU: PC=0x400D1128
33  gpio_set_level(BLINK_GPIO, 0);
(gdb)
```

If you enter `s` instead, then debugger will step inside subroutine calls:

```gdb
(gdb) s
Target halted. PRO_CPU: PC=0x400DB748 (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB746 (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04C (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04F (active)      APP_CPU: PC=0x400D1128
gpio_set_level (gpio_num=GPIO_NUM_4, level=0) at /home/user-name/esp/esp-idf/components/driver/gpio/gpio.c:183
183  GPIO_CHECK(GPIO_IS_VALID_OUTPUT_GPIO(gpio_num), "GPIO output gpio_num error ", ESP_ERR_INVALID_ARG);
(gdb)
```

In this particular case debugger stepped inside `gpio_set_level(BLINK_GPIO, 0)` and effectively moved to `gpio.c` driver code.

See Why Stepping with “next” Does Not Bypass Subroutine Calls? for potential limitation of using `next` command.

Checking and setting memory  
Displaying the contents of memory is done with command `x`. With additional parameters you may vary the format and count of memory locations displayed. Run `help x` to see more details.

Companion command to `x` is `set` that let you write values to the memory.

We will demonstrate how `x` and `set` work by reading from and writing to the memory location `0x3FF44004` labeled as GPIO_OUT_REG used to set and clear individual GPIO’s.

For more information, see ESP32 Technical Reference Manual > IO_MUX and GPIO Matrix (GPIO, IO_MUX) [PDF].

Being in the same `blink.c` project as before, set two breakpoints right after `gpio_set_level` instruction. Enter two times `c` to get to the break point followed by `x /1wx 0x3FF44004` to display contents of GPIO_OUT_REG memory location:

```gdb
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB75E (active)      APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB75E (active)      APP_CPU: PC=0x400D1128
Breakpoint 2, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/.
(blink.c:54)
```
vTaskDelay(1000 / portTICK_PERIOD_MS);
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB751 (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB75B (active) APP_CPU: PC=0x400D1128
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./
→ blink.c:37
37 vTaskDelay(1000 / portTICK_PERIOD_MS);
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
...}
0x3ff44004: 0x00000010
(gdb)

If your are blinking LED connected to GPIO4, then you should see fourth bit being flipped each time the LED changes the state:

0x3ff44004: 0x00000000
...
0x3ff44004: 0x00000010

Now, when the LED is off, that corresponds to 0x3ff44004: 0x00000000 being displayed, try using set command to set this bit by writting 0x00000010 to the same memory location:

(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
(gdb) set (unsigned int)0x3FF44004=0x000010
0x3ff44004: 0x00000010

You should see the LED to turn on immediately after entering set (unsigned int)0x3FF44004=0x000010 command.

Watching and setting program variables A common debugging tasks is checking the value of a program variable as the program runs. To be able to demonstrate this functionality, update file blink.c by adding a declaration of a global variable int i above definition of function blink_task. Then add i++ inside while(1) of this function to get i incremented on each blink.

Exit debugger, so it is not confused with new code, build and flash the code to the ESP and restart debugger. There is no need to restart OpenOCD.

Once application is halted, enter the command watch i:

(gdb) watch i
Hardware watchpoint 2: i
(gdb)

This will insert so called “watchpoint” in each place of code where variable i is being modified. Now enter continue to resume the application and observe it being halted:

(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB751 (active) APP_CPU: PC=0x400D0811
[New Thread 1073432196]
Program received signal SIGTRAP, Trace/breakpoint trap.
[Switching to Thread 1073432196]
0x400db751 in blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/./
→ blink.c:33
33 i++;
(gdb)
Chapter 4. API Guides

Resume application couple more times so i gets incremented. Now you can enter print i (in short p i) to check the current value of i:

```
(gdb) p i
$1 = 3
(gdb)
```

To modify the value of i use set command as below (you can then print it out to check if it has been indeed changed):

```
(gdb) set var i = 0
(gdb) p i
$3 = 0
(gdb)
```

You may have up to two watchpoints, see Breakpoints and Watchpoints Available.

**Setting conditional breakpoints**  Here comes more interesting part. You may set a breakpoint to halt the program execution, if certain condition is satisfied. Delete existing breakpoints and try this:

```
(gdb) break blink.c:34 if (i == 2)
Breakpoint 3 at 0x400db753: file /home/user-name/esp/blink/main/.//blink.c, line 34.
(gdb)
```

Above command sets conditional breakpoint to halt program execution in line 34 of blink.c if i == 2.

If current value of i is less than 2 and program is resumed, it will blink LED in a loop until condition i == 2 gets true and then finally halt:

```
(gdb) set var i = 0
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB755 (active) APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB753 (active) APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB755 (active) APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB753 (active) APP_CPU: PC=0x400D112C
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/.//blink.c:34
34   gpio_set_level(BLINK_GPIO, 0);
(gdb)
```

**Debugging FreeRTOS Objects**  This part might be interesting when you are debugging FreeRTOS task interactions. Users that need to use the FreeRTOS task interactions can use the GDB freertos command. The freertos command is not native to GDB and comes from the freertos-gdb Python extension module. The freertos command contains a series of sub-commands as demonstrated in the code snippet:

```
(gdb) freertos
"freertos" must be followed by the name of a subcommand.
List of freertos subcommands:
freertos queue -- Generate a print out of the current queues info.
freertos semaphore -- Generate a print out of the current semaphores info.
freertos task -- Generate a print out of the current tasks and their states.
freertos timer -- Generate a print out of the current timers info.
```

For a more detailed description of this extension, please refer to https://pypi.org/project/freertos-gdb.

**Note:** The freertos-gdb Python module is included as a Python package requirement by ESP-IDF, thus should be automatically installed (see Step 3. Set up the tools for more details).
The FreeRTOS extension automatically loads in case GDB is executed with command via `idf.py gdb`. Otherwise, the module could be enabled via the `python import freertos_gdb` command inside GDB.

Users only need to have Python 3.6 (or above) that contains a Python shared library.

**Obtaining help on commands** Commands presented so far should provide a very basis and intended to let you quickly get started with JTAG debugging. Check help what are the other commands at your disposal. To obtain help on syntax and functionality of particular command, being at `(gdb)` prompt type `help` and command name:

```
(gdb) help next
Step program, proceeding through subroutine calls.
Usage: next [N]
Unlike "step", if the current source line calls a subroutine,
this command does not enter the subroutine, but instead steps over
the call, in effect treating it as a single source line.
(gdb)
```

By typing just `help`, you will get top level list of command classes, to aid you drilling down to more details. Optionally refer to available GDB cheat sheets, for instance [https://darkdust.net/files/GDB%20Cheat%20Sheet.pdf](https://darkdust.net/files/GDB%20Cheat%20Sheet.pdf). Good to have as a reference (even if not all commands are applicable in an embedded environment).

**Ending debugger session** To quit debugger enter `q`:

```
(gdb) q
A debugging session is active.
Inferior 1 [Remote target] will be detached.
Quit anyway? (y or n) y
Detaching from program: /home/user-name/esp/blink/build/blink.elf, Remote target
Ending remote debugging.
user-name@computer-name:~/esp/blink$
```

- Using Debugger
- Debugging Examples
- Tips and Quirks
- Application Level Tracing library
- Introduction to ESP-Prog Board

## 4.19 Linker Script Generation

### 4.19.1 Overview

There are several *memory regions* where code and data can be placed. Code and read-only data are placed by default in flash, writable data in RAM, etc. However, it is sometimes necessary to change these default placements.

For example, it may be necessary to place:

- critical code in RAM for performance reasons.
- executable code in IRAM so that it can be ran while cache is disabled.
- code in RTC memory for use in a wake stub.
- code in RTC memory for use by the ULP coprocessor.
With the linker script generation mechanism, it is possible to specify these placements at the component level within ESP-IDF. The component presents information on how it would like to place its symbols, objects or the entire archive. During build, the information presented by the components are collected, parsed and processed; and the placement rules generated is used to link the app.

### 4.19.2 Quick Start

This section presents a guide for quickly placing code/data to RAM and RTC memory - placements ESP-IDF provides out-of-the-box.

For this guide, suppose we have the following:

- A component named `my_component` that is archived as library `libmy_component.a` during build
- Three source files archived under the library, `my_src1.c`, `my_src2.c` and `my_src3.c` which are compiled as `my_src1.o`, `my_src2.o` and `my_src3.o`, respectively
- Under `my_src1.o`, the function `my_function1` is defined; under `my_src2.o`, the function `my_function2` is defined
- There is bool-type config `PERFORMANCE_MODE` (y/n) and int type config `PERFORMANCE_LEVEL` (with range 0-3) in `my_component`’s Kconfig

#### Creating and Specifying a Linker Fragment File

Before anything else, a linker fragment file needs to be created. A linker fragment file is simply a text file with a `.lf` extension upon which the desired placements will be written. After creating the file, it is then necessary to present it to the build system. The instructions for the build systems supported by ESP-IDF are as follows:

In the component’s CMakeLists.txt file, specify argument `LDFRAGMENTS` in the `idf_component_register` call. The value of `LDFRAGMENTS` can either be an absolute path or a relative path from the component directory to the created linker fragment file.

```bash
# file paths relative to CMakeLists.txt
idf_component_register(...
  LDFRAGMENTS "path/to/linker_fragment_file.lf" "path/to/
  another_linker_fragment_file.lf"
  ...
)
```

#### Specifying placements

It is possible to specify placements at the following levels of granularity:

- Object file (`.obj` or `.o` files)
- Symbol (function/variable)
- Archive (`.a` files)
**Placing object files**  Suppose the entirety of `my_src1.o` is performance-critical, so it is desirable to place it in RAM. On the other hand, the entirety of `my_src2.o` contains symbols needed coming out of deep sleep, so it needs to be put under RTC memory.

In the linker fragment file, we can write:

```plaintext
[mapping:my_component]
archive: libmy_component.a
entries:
  my_src1 (noflash)  # places all my_src1 code/read-only data under IRAM/DRAM
  my_src2 (rtc)     # places all my_src2 code/ data and read-only data under...
                      # RTC fast memory/RTC slow memory
```

What happens to `my_src3.o`? Since it is not specified, default placements are used for `my_src3.o`. More on default placements [here](#).

**Placing symbols**  Continuing our example, suppose that among functions defined under `object1.o`, only `my_function1` is performance-critical; and under `object2.o`, only `my_function2` needs to execute after the chip comes out of deep sleep. This could be accomplished by writing:

```plaintext
[mapping:my_component]
archive: libmy_component.a
entries:
  my_src1:my_function1 (noflash)
  my_src2:my_function2 (rtc)
```

The default placements are used for the rest of the functions in `my_src1.o` and `my_src2.o` and the entire `object3.o`. Something similar can be achieved for placing data by writing the variable name instead of the function name, like so:

```plaintext
my_src1:my_variable (noflash)
```

**Warning:** There are limitations in placing code/data at symbol granularity. In order to ensure proper placements, an alternative would be to group relevant code and data into source files, and use object-granularity placements.

**Placing entire archive**  In this example, suppose that the entire component archive needs to be placed in RAM. This can be written as:

```plaintext
[mapping:my_component]
archive: libmy_component.a
entries:
  * (noflash)
```

Similarly, this places the entire component in RTC memory:

```plaintext
[mapping:my_component]
archive: libmy_component.a
entries:
  * (rtc)
```

**Configuration-dependent placements**  Suppose that the entire component library should only have special placement when a certain condition is true; for example, when `CONFIG_PERFORMANCE_MODE == y`. This could be written as:

```plaintext
[mapping:my_component]
archive: libmy_component.a
```

(continues on next page)
entries:
  if PERFORMANCE_MODE = y:
    * (noflash)
  else:
    * (default)

For a more complex config-dependent placement, suppose the following requirements: when `CONFIG_PERFORMANCE_LEVEL == 1`, only `object1.o` is put in RAM; when `CONFIG_PERFORMANCE_LEVEL == 2`, `object1.o` and `object2.o`; and when `CONFIG_PERFORMANCE_LEVEL == 3` all object files under the archive are to be put into RAM. When these three are false however, put entire library in RTC memory. This scenario is a bit contrived, but, it can be written as:

```
[mapping:my_component]
archive: libmy_component.a
entries:
  if PERFORMANCE_LEVEL = 1:
    my_src1 (noflash)
  elif PERFORMANCE_LEVEL = 2:
    my_src1 (noflash)
    my_src2 (noflash)
  elif PERFORMANCE_LEVEL = 3:
    my_src1 (noflash)
    my_src2 (noflash)
    my_src3 (noflash)
  else:
    * (rtc)
```

Nesting condition-checking is also possible. The following is equivalent to the snippet above:

```
[mapping:my_component]
archive: libmy_component.a
entries:
  if PERFORMANCE_LEVEL <= 3 && PERFORMANCE_LEVEL > 0:
    if PERFORMANCE_LEVEL >= 1:
      object1 (noflash)
      if PERFORMANCE_LEVEL >= 2:
        object2 (noflash)
        if PERFORMANCE_LEVEL >= 3:
          object2 (noflash)
    else:
      * (rtc)
```

The ‘default’ placements

Up until this point, the term ‘default placements’ has been mentioned as fallback placements when the placement rules `rtc` and `noflash` are not specified. It is important to note that the tokens `noflash` or `rtc` are not merely keywords, but are actually entities called fragments, specifically schemes.

In the same manner as `rtc` and `noflash` are schemes, there exists a default scheme which defines what the default placement rules should be. As the name suggests, it is where code and data are usually placed, i.e. code/variables is placed in RAM, etc. More on the default scheme here.

Note: For an example of an ESP-IDF component using the linker script generation mechanism, see `freertos/CMakeLists.txt`. freertos uses this to place its object files to the instruction RAM for performance reasons.

This marks the end of the quick start guide. The following text discusses the internals of the mechanism in a little bit more detail. The following sections should be helpful in creating custom placements or modifying default behavior.
4.19.3 Linker Script Generation Internals

Linking is the last step in the process of turning C/C++ source files into an executable. It is performed by the toolchain’s linker, and accepts linker scripts which specify code/data placements, among other things. With the linker script generation mechanism, this process is no different, except that the linker script passed to the linker is dynamically generated from: (1) the collected linker fragment files and (2) linker script template.

Note: The tool that implements the linker script generation mechanism lives under tools/ldgen.

Linker Fragment Files

As mentioned in the quick start guide, fragment files are simple text files with the .lf extension containing the desired placements. This is a simplified description of what fragment files contain, however. What fragment files actually contain are ‘fragments’. Fragments are entities which contain pieces of information which, when put together, form placement rules that tell where to place sections of object files in the output binary. There are three types of fragments: sections, scheme and mapping.

Grammar  The three fragment types share a common grammar:

```
[type:name]
key: value
key:
value
value
value
...
```

- type: Corresponds to the fragment type, can either be sections, scheme or mapping.
- name: The name of the fragment, should be unique for the specified fragment type.
- key, value: Contents of the fragment; each fragment type may support different keys and different grammars for the key values.
  - For sections and scheme, the only supported key is entries
  - For mappings, both archive and entries are supported.

Note: In cases where multiple fragments of the same type and name are encountered, an exception is thrown.

Note: The only valid characters for fragment names and keys are alphanumeric characters and underscore.

Condition Checking

Condition checking enable the linker script generation to be configuration-aware. Depending on whether expressions involving configuration values are true or not, a particular set of values for a key can be used. The evaluation uses eval_string from kconfiglib package and adheres to its required syntax and limitations. Supported operators are as follows:

- comparison
  - LessThan <
  - LessThanOrEqualTo <=
  - MoreThan >
  - MoreThanOrEqualTo >=
  - Equal =
  - NotEqual !=

- logical
  - Or ||
Chapter 4.  API Guides

– And &&
– Negation !

• grouping
– Parenthesis ()

Condition checking behaves as you would expect an if...elseif/elif...else block in other languages. Condition-checking is possible for both key values and entire fragments. The two sample fragments below are equivalent:

```plaintext
# Value for keys is dependent on config
[type:name]
key_1:
  if CONDITION = y:
    value_1
  else:
    value_2
key_2:
  if CONDITION = y:
    value_a
  else:
    value_b
```

```plaintext
# Entire fragment definition is dependent on config
if CONDITION = y:
  [type:name]
  key_1:
    value_1
  key_2:
    value_a
else:
  [type:name]
  key_1:
    value_2
  key_2:
    value_b
```

Comments

Comment in linker fragment files begin with #. Like in other languages, comment are used to provide helpful descriptions and documentation and are ignored during processing.

Types  Sections

Sections fragments defines a list of object file sections that the GCC compiler emits. It may be a default section (e.g. .text,.data) or it may be user defined section through the __attribute__ keyword.

The use of an optional `+` indicates the inclusion of the section in the list, as well as sections that start with it. This is the preferred method over listing both explicitly.

```plaintext
[sections:name]
entries:
  .section+
  .section
  ...
```

Example:

```plaintext
# Non-preferred
[sections:text]
entries:
  .text
  .text.*
```

(continues on next page)
# Preferred, equivalent to the one above

```
[sections:text]
entries:
  .text+ # means .text and .text.*
  .literal+ # means .literal and .literal.*
```

## Scheme

Scheme fragments define what target a sections fragment is assigned to.

```
[scheme:name]
entries:
  sections -> target
  sections -> target
  ...
```

### Example:

```
[scheme:noflash]
entries:
  text -> iram0_text # the entries under the sections fragment named...
  --text will go to iram0_text
  rodata -> dram0_data # the entries under the sections fragment named...
  --rodata will go to dram0_data
```

The **default scheme**

There exists a special scheme with the name `default`. This scheme is special because catch-all placement rules are generated from its entries. This means that, if one of its entries is `text -> flash_text`, the placement rule will be generated for the target `flash_text`.

```
*(.literal .literal.* .text .text.*)
```

These catch-all rules then effectively serve as fallback rules for those whose mappings were not specified.

The **default scheme** is defined in `esp_system/app.lf`. The `noflash` and `rtc` scheme fragments which are built-in schemes referenced in the quick start guide are also defined in this file.

## Mapping

Mapping fragments define what scheme fragment to use for mappable entities, i.e. object files, function names, variable names, archives.

```
[mapping:name]
archive: archive # output archive file name, as built (i.e. libxxx.
  -> a)
entries:
  object:symbol (scheme) # symbol granularity
  object (scheme) # object granularity
  * (scheme) # archive granularity
```

There are three levels of placement granularity:

- **symbol**: The object file name and symbol name are specified. The symbol name can be a function name or a variable name.
- **object**: Only the object file name is specified.
- **archive**: `*` is specified, which is a short-hand for all the object files under the archive.

To know what an entry means, let us expand a sample object-granularity placement:
object (scheme)

Then expanding the scheme fragment from its entries definitions, we have:

object (sections -> target,
sections -> target,
...)

Expanding the sections fragment with its entries definition:

object (.section, # given this object file
 .section, # put its sections listed here at this
 ... -> target, # target

 .section,
 .section, # same should be done for these sections
 ... -> target,
 ...) # and so on

Example:

[mapping:map]
archive: libfreertos.a
entries:
  * (noflash)

Aside from the entity and scheme, flags can also be specified in an entry. The following flags are supported (note: <> = argument name, [] = optional):

1. ALIGN(<alignment>[, pre, post])
   Align the placement by the amount specified in alignment. Generates

2. SORT([<sort_by_first>,<sort_by_second>])
   Emits SORT_BY_NAME, SORT_BY_ALIGNMENT, SORT_BY_INIT_PRIORITY or SORT in
   the input section description.
   Possible values for sort_by_first and sort_by_second are: name, alignment,
   init_priority.
   If both sort_by_first and sort_by_second are not specified, the input sections are sorted
   by name. If both are specified, then the nested sorting follows the same rules discussed in
   https://sourceware.org/binutils/docs/ld/Input-Section-Wildcards.html.

3. KEEP()
   Prevent the linker from discarding the placement by surrounding the input section description with
   KEEP command. See https://sourceware.org/binutils/docs/ld/Input-Section-Keep.html for more
   details.

4. SURROUND(<name>)
   Generate symbols before and after the placement. The generated symbols follow the naming
   _<name>_start and _<name>_end. For example, if name == sym1,

When adding flags, the specific section -> target in the scheme needs to be specified. For multiple section
-> target, use a comma as a separator. For example,

# Notes:
# A. semicolon after entity-scheme
# B. comma before section2 -> target2
# C. section1 -> target1 and section2 -> target2 should be defined in entries of
  # scheme1
entity1 (scheme1);
  section1 -> target1 KEEP() ALIGN(4, pre, post),
  section2 -> target2 SURROUND(sym) ALIGN(4, post) SORT()
Putting it all together, the following mapping fragment, for example,

```plaintext
[mapping:name]
archive: lib1.a
entries:
  obj1 (noflash);
      rodata -> dram0_data KEEP() SORT() ALIGN(8) SURROUND(my_sym)
```

generates an output on the linker script:

```plaintext
. = ALIGN(8)
_my_sym_start = ABSOLUTE(.)
KEEP(lib1.a:obj1.*( SORT(.rodata) SORT(.rodata.*) ))
_my_sym_end = ABSOLUTE(.)
```

Note that ALIGN and SURROUND, as mentioned in the flag descriptions, are order sensitive. Therefore, if for the same mapping fragment these two are switched, the following is generated instead:

```plaintext
_my_sym_start = ABSOLUTE(.)
. = ALIGN(8)
KEEP(lib1.a:obj1.*( SORT(.rodata) SORT(.rodata.*) ))
_my_sym_end = ABSOLUTE(.)
```

**On Symbol-Granularity Placements** Symbol granularity placements is possible due to compiler flags `-ffunction-sections` and `-fdata-sections`. ESP-IDF compiles with these flags by default. If the user opts to remove these flags, then the symbol-granularity placements will not work. Furthermore, even with the presence of these flags, there are still other limitations to keep in mind due to the dependence on the compiler’s emitted output sections.

For example, with `-ffunction-sections`, separate sections are emitted for each function; with section names predictably constructed i.e. `.text.{func_name}` and `.literal.{func_name}`. This is not the case for string literals within the function, as they go to pooled or generated section names.

With `-fdata-sections`, for global scope data the compiler predictably emits either `.data.{var_name}`, `.rodata.{var_name}` or `.bss.{var_name}`; and so Type I mapping entry works for these. However, this is not the case for static data declared in function scope, as the generated section name is a result of mangling the variable name with some other information.

**Linker Script Template**

The linker script template is the skeleton in which the generated placement rules are put into. It is an otherwise ordinary linker script, with a specific marker syntax that indicates where the generated placement rules are placed.

To reference the placement rules collected under a target token, the following syntax is used:

```plaintext
mapping[target]
```

**Example:**

The example below is an excerpt from a possible linker script template. It defines an output section `.iram0.text`, and inside is a marker referencing the target `.iram0_text`.

```
.iram0.text :
{
  /* Code marked as running out of IRAM */
  _iram_text_start = ABSOLUTE(.)

  /* Marker referencing irm0_text */
  mapping[iram0_text]
```

(continues on next page)
Suppose the generator collected the fragment definitions below:

```plaintext
[sections:text]
  .text+
  .literal+

[sections:iram]
  .iram1+

[scheme:default]
entries:
  text -> flash_text
  iram -> iram0_text

[scheme:noflash]
entries:
  text -> iram0_text

[mapping:freertos]
archive: libfreertos.a
entries:
  * (noflash)
```

Then the corresponding excerpt from the generated linker script will be as follows:

```plaintext
.iram0.text :
{
  /* Code marked as running out of IRAM */
  _iram_text_start = ABSOLUTE(.);

  /* Placement rules generated from the processed fragments, placed where the
     marker was in the template */
  "libfreertos.a:(.literal .text .literal.* .text.*)"
  _iram_text_end = ABSOLUTE(.);
}
```

*libfreertos.a:(.literal .text .literal.* .text.*)*

Rule generated from the entry * (noflash) of the freertos mapping fragment. All text sections of all object files under the archive libfreertos.a will be collected under the target iram0_text (as per the noflash scheme) and placed wherever in the template iram0_text is referenced by a marker.

* {.iram1 .iram1.*}*

Rule generated from the default scheme entry iram -> iram0_text. Since the default scheme specifies an iram -> iram0_text entry, it too is placed wherever iram0_text is referenced by a marker. Since it is a rule generated from the default scheme, it comes first among all other rules collected under the same target name.

The linker script template currently used is esp_system/ld/esp32/sections.ld.in; the generated output script sections.ld is put under its build directory.
Migrate to ESP-IDF v5.0 Linker Script Fragment Files Grammar

The old grammar supported in ESP-IDF v3.x would be dropped in ESP-IDF v5.0. Here are a few notes on how to migrate properly:

1. Now indentation is enforced and improperly indented fragment files would generate a runtime parse exception. This was not enforced in the old version but previous documentation and examples demonstrate properly indented grammar.
2. Migrate the old condition entry to the `if...elif...else` structure for conditionals. You can refer to the earlier chapter for detailed grammar.
3. Mapping fragments now requires a name like other fragment types.

4.20 lwIP

ESP-IDF uses the open source lwIP lightweight TCP/IP stack. The ESP-IDF version of lwIP (esp-lwip) has some modifications and additions compared to the upstream project.

4.20.1 Supported APIs

ESP-IDF supports the following lwIP TCP/IP stack functions:

- BSD Sockets API
- Netconn API is enabled but not officially supported for ESP-IDF applications

Adapted APIs

**Warning:** When using any lwIP API (other than BSD Sockets API), please make sure that it is thread safe. To check if a given API call is safe, enable `CONFIG_LWIP_CHECK_THREAD_SAFETY` and run the application. This way lwIP asserts the TCP/IP core functionality to be correctly accessed; the execution aborts if it is not locked properly or accessed from the correct task (lwIP FreeRTOS Task). The general recommendation is to use ESP-NETIF component to interact with lwIP.

Some common lwIP “app” APIs are supported indirectly by ESP-IDF:

- DHCP Server & Client are supported indirectly via the ESP-NETIF functionality
- Simple Network Time Protocol (SNTP) is also supported via the ESP-NETIF, or directly via the lwip/include/apps/esp_sntp.h functions that provide thread-safe API to lwip/lwip/src/include/lwip/apps/sntp.h functions (see also SNTP Time Synchronization)
- ICMP Ping is supported using a variation on the lwIP ping API. See ICMP Echo.
- NetBIOS lookup is available using the standard lwIP API, protocols/http_server/restful_server has an option to demonstrate using NetBIOS to look up a host on the LAN.
- mDNS uses a different implementation to the lwIP default mDNS (see mDNS Service), but lwIP can look up mDNS hosts using standard APIs such as `gethostbyname()` and the convention `hostname.local`, provided the `CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES` setting is enabled.
- The PPP implementation in lwIP can be used to create PPPoS (PPP over serial) interface in ESP-IDF. Please refer to the documentation of ESP-NETIF component to create and configure a PPP network interface, by means of the `ESP_NETIF_DEFAULT_PPP()` macro defined in esp_netif/include/esp_netif_defaults.h. Additional runtime settings are provided via the esp_netif/include/esp_netif_ppp.h. PPPoS interfaces are typically used to interact with NBioT/GSM/LTE modems; more application level friendly API is supported by esp_modem library, which uses this PPP lwIP module behind the scenes.
4.20.2 BSD Sockets API

The BSD Sockets API is a common cross-platform TCP/IP sockets API that originated in the Berkeley Standard Distribution of UNIX but is now standardized in a section of the POSIX specification. BSD Sockets are sometimes called POSIX Sockets or Berkeley Sockets.

As implemented in ESP-IDF, lwIP supports all of the common usages of the BSD Sockets API.

References

A wide range of BSD Sockets reference material is available, including:

- Single UNIX Specification BSD Sockets page
- Berkeley Sockets Wikipedia page

Examples

A number of ESP-IDF examples show how to use the BSD Sockets APIs:

- protocols/sockets/tcp_server
- protocols/sockets/tcp_client
- protocols/sockets/udp_server
- protocols/sockets/udp_client
- protocols/sockets/udp_multicast
- protocols/http_request (Note: this is a simplified example of using a TCP socket to send an HTTP request. The ESP HTTP Client is a much better option for sending HTTP requests.)

Supported functions

The following BSD socket API functions are supported. For full details see lwip/lwip/src/include/lwip/sockets.h.

- socket()
- bind()
- accept()
- shutdown()
- getpeername()
- getsockopt() & setsockopt() (see Socket Options)
- close() (via Virtual filesystem component)
- read(), readv(), write(), writev() (via Virtual filesystem component)
- recv(), recvmsg(), recvfrom()
- send(), sendmsg(), sendto()
- select() (via Virtual filesystem component)
- poll() (Note: on ESP-IDF, poll() is implemented by calling select internally, so using select() directly is recommended if a choice of methods is available.)
- fcntl() (see fcntl)

Non-standard functions:

- ioctl() (see ioctls)

Note: Some lwIP application sample code uses prefixed versions of BSD APIs, for example lwip_socket() instead of the standard socket(). Both forms can be used with ESP-IDF, but using standard names is recommended.
Socket Error Handling

BSD Socket error handling code is very important for robust socket applications. Normally the socket error handling involves the following aspects:

- Detecting the error.
- Getting the error reason code.
- Handle the error according to the reason code.

In lwIP, we have two different scenarios of handling socket errors:

- Socket API returns an error. For more information, see `Socket API Errors`.
- `select(int maxfdp1, fd_set *readset, fd_set *writeset, fd_set *exceptset, struct timeval *timeout)` has exception descriptor indicating that the socket has an error. For more information, see `select() Errors`.

Socket API Errors

The error detection

- We can know that the socket API fails according to its return value.

Get the error reason code

- When socket API fails, the return value doesn’t contain the failure reason and the application can get the error reason code by accessing errno. Different values indicate different meanings. For more information, see `<Socket Error Reason Code>`.

Example:

```c
int err;
int sockfd;

if (sockfd = socket(AF_INET, SOCK_STREAM, 0) < 0) {
    // the error code is obtained from errno
    err = errno;
    return err;
}
```

select() Errors

The error detection

- Socket error when `select()` has exception descriptor

Get the error reason code

- If the `select` indicates that the socket fails, we can’t get the error reason code by accessing errno, instead we should call `getsockopt()` to get the failure reason code. Because `select()` has exception descriptor, the error code will not be given to errno.

Note: `getsockopt` function prototype `int getsockopt(int s, int level, int optname, void *optval, socklen_t *optlen)`. Its function is to get the current value of the option of any type, any state socket, and store the result in optval. For example, when you get the error code on a socket, you can get it by `getsockopt(sockfd, SOL_SOCKET, SO_ERROR, &err, &optlen)`.

Example:

```c
int err;

if (select(sockfd + 1, NULL, NULL, &exfds, &tval) <= 0) {
    err = errno;
    return err;
} else {
    if (FD_ISSET(sockfd, &exfds)) {
```
// select() exception set using getsockopt()
int optlen = sizeof(int);
getsockopt(sockfd, SOL_SOCKET, SO_ERROR, &err, &optlen);
    return err;
}

**Socket Error Reason Code**  Below is a list of common error codes. For more detailed list of standard POSIX/C error codes, please see newlib errno.h and the platform-specific extensions newlib/platform_include/errno.h

<table>
<thead>
<tr>
<th>Error code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECONNREFUSED</td>
<td>Connection refused</td>
</tr>
<tr>
<td>EADDRINUSE</td>
<td>Address already in use</td>
</tr>
<tr>
<td>ECONNABORTED</td>
<td>Software caused connection abort</td>
</tr>
<tr>
<td>ENETUNREACH</td>
<td>Network is unreachable</td>
</tr>
<tr>
<td>ENETDOWN</td>
<td>Network interface is not configured</td>
</tr>
<tr>
<td>ETIMEDOUT</td>
<td>Connection timed out</td>
</tr>
<tr>
<td>EHOSTDOWN</td>
<td>Host is down</td>
</tr>
<tr>
<td>EHOSTUNREACH</td>
<td>Host is unreachable</td>
</tr>
<tr>
<td>EINPROGRESS</td>
<td>Connection already in progress</td>
</tr>
<tr>
<td>EALREADY</td>
<td>Socket already connected</td>
</tr>
<tr>
<td>EDESTADDRREQ</td>
<td>Destination address required</td>
</tr>
<tr>
<td>EPROTO</td>
<td>Unknown protocol</td>
</tr>
</tbody>
</table>

**Socket Options**

The `getsockopt()` and `setsockopt()` functions allow getting/setting per-socket options.

Not all standard socket options are supported by lwIP in ESP-IDF. The following socket options are supported:

**Common options**  Used with level argument SOL_SOCKET.

- SO_REUSEADDR (available if `CONFIG_LWIP_SO_REUSE` is set, behavior can be customized by setting `CONFIG_LWIP_SO_REUSE_RXTOALL`)
- SO_KEEPALIVE
- SO_BROADCAST
- SO_ACCEPTCONN
- SO_RCVBUF (available if `CONFIG_LWIP_SO_RCVBUF` is set)
- SO_SNDBUF / SO_RCVTIMEO
- SO_ERROR (this option is only used with `select()`, see [Socket Error Handling](#))
- SO_TYPE
- SO_NO_CHECK (for UDP sockets only)

**IP options**  Used with level argument IPPROTO_IP.

- IP_TOS
- IP_TTL
- IP_PKTINFO (available if `CONFIG_LWIP_NETBUF_RECVINFO` is set)

For multicast UDP sockets:

- IP_MULTICAST_IF
- IP_MULTICAST_LOOP
- IP_MULTICAST_TTL
- IP_ADD_MEMBERSHIP
- IP_DROP_MEMBERSHIP
TCP options  TCP sockets only. Used with level argument IPPROTO_TCP.

- TCP_NODELAY

Options relating to TCP keepalive probes:

- TCP_KEEPALIVE (int value, TCP keepalive period in milliseconds)
- TCP_KEEPIDLE (same as TCP_KEEPALIVE, but the value is in seconds)
- TCP_KEEPINTVL (int value, interval between keepalive probes in seconds)
- TCP_KEEPCNT (int value, number of keepalive probes before timing out)

IPv6 options  IPv6 sockets only. Used with level argument IPPROTO_IPV6

- IPV6_CHECKSUM
- IPV6_V6ONLY

For multicast IPv6 UDP sockets:

- IPV6_JOIN_GROUP / IPV6_ADD_MEMBERSHIP
- IPV6_LEAVE_GROUP / IPV6_DROP_MEMBERSHIP
- IPV6_MULTICAST_IF
- IPV6_MULTICAST_HOPS
- IPV6_MULTICAST_LOOP

fcntl

The fcntl() function is a standard API for manipulating options related to a file descriptor. In ESP-IDF, the Virtual filesystem component layer is used to implement this function.

When the file descriptor is a socket, only the following fcntl() values are supported:

- O_NONBLOCK to set/clear non-blocking I/O mode. Also supports O_NDELAY, which is identical to O_NONBLOCK.
- O_RDONLY, O_WRONLY, O_RDWR flags for different read/write modes. These can read via F_GETFL only, they cannot be set using F_SETFL. A TCP socket will return a different mode depending on whether the connection has been closed at either end or is still open at both ends. UDP sockets always return O_RDWR.

ioctl

The ioctl() function provides a semi-standard way to access some internal features of the TCP/IP stack. In ESP-IDF, the Virtual filesystem component layer is used to implement this function.

When the file descriptor is a socket, only the following ioctl() values are supported:

- FIONREAD returns the number of bytes of pending data already received in the socket’s network buffer.
- FIONBIO is an alternative way to set/clear non-blocking I/O status for a socket, equivalent to fcntl(fd, F_SETFL, O_NONBLOCK, ...).

4.20.3 Netconn API

lwIP supports two lower level APIs as well as the BSD Sockets API: the Netconn API and the Raw API.

The lwIP Raw API is designed for single threaded devices and is not supported in ESP-IDF.

The Netconn API is used to implement the BSD Sockets API inside lwIP, and it can also be called directly from ESP-IDF apps. This API has lower resource usage than the BSD Sockets API, in particular it can send and receive data without needing to first copy it into internal lwIP buffers.

Important:  Espressif does not test the Netconn API in ESP-IDF. As such, this functionality is enabled but not supported. Some functionality may only work correctly when used from the BSD Sockets API.
Chapter 4. API Guides

For more information about the Netconn API, consult lwip/lwip/src/include/lwip/api.h and this wiki page which is part of the unofficial lwIP Application Developers Manual.

4.20.4 lwIP FreeRTOS Task

lwIP creates a dedicated TCP/IP FreeRTOS task to handle socket API requests from other tasks. A number of configuration items are available to modify the task and the queues (“mailboxes”) used to send data to/from the TCP/IP task:

- `CONFIG_LWIP_TCPIP_RECMBOX_SIZE`
- `CONFIG_LWIP_TCPIP_TASK_STACK_SIZE`
- `CONFIG_LWIP_TCPIP_TASK_AFFINITY`

4.20.5 IPv6 Support

Both IPv4 and IPv6 are supported as a dual stack and are enabled by default. Both IPv6 and IPv4 may be disabled separately if they are not needed (see Minimum RAM usage). IPv6 support is limited to Stateless Autoconfiguration only. Stateful configuration is not supported in ESP-IDF (not in upstream lwip). IPv6 Address configuration is defined by means of these protocols or services:

- SLAAC IPv6 Stateless Address Autoconfiguration (RFC-2462)
- DHCPv6 Dynamic Host Configuration Protocol for IPv6 (RFC-8415)

None of these two types of address configuration is enabled by default, so the device uses only Link Local addresses or statically defined addresses.

Stateless Autoconfiguration Process

To enable address autoconfiguration using Router Advertisement protocol please enable:

- `CONFIG_LWIP_IPV6_AUTOCONFIG`

This configuration option enables IPv6 autoconfiguration for all network interfaces (in contrast to the upstream lwIP, where the autoconfiguration needs to be explicitly enabled for each netif with `netif->ip6_autoconfig_enabled=1`)

DHCPv6

DHCPv6 in lwIP is very simple and supports only stateless configuration. It could be enabled using:

- `CONFIG_LWIP_IPV6_DHCP6`

Since the DHCPv6 works only in its stateless configuration, the Stateless Autoconfiguration Process has to be enabled, too, by means of `CONFIG_LWIP_IPV6_AUTOCONFIG`. Moreover, the DHCPv6 needs to be explicitly enabled in the application code using

```
        dhcp6_enable_stateless(netif);
```

DNS servers in IPv6 autoconfiguration

In order to autoconfigure DNS server(s), especially in IPv6 only networks, we have these two options

- Recursive domain name system – this belongs to the Neighbor Discovery Protocol (NDP), uses Stateless Autoconfiguration Process. Number of servers must be set `CONFIG_LWIP_IPV6_RDNSS_MAX_DNS_SERVERS`, this is option is disabled (set to 0) by default.
- DHCPv6 stateless configuration – uses DHCPv6 to configure DNS servers. Note that the this configuration assumes IPv6 Router Advertisement Flags (RFC-5175) to be set to
  - Managed Address Configuration Flag = 0
– Other Configuration Flag = 1

4.20.6 esp-lwip custom modifications

Additions

The following code is added which is not present in the upstream lwIP release:

**Thread-safe sockets**  It is possible to `close()` a socket from a different thread to the one that created it. The `close()` call will block until any function calls currently using that socket from other tasks have returned.

It is, however, not possible to delete a task while it is actively waiting on `select()` or `poll()` APIs. It is always necessary that these APIs exit before destroying the task, as this might corrupt internal structures and cause subsequent crashes of the lwIP. (These APIs allocate globally referenced callback pointers on stack, so that when the task gets destroyed before unrolling the stack, the lwIP would still hold pointers to the deleted stack)

**On demand timers**  lwIP IGMP and MLD6 features both initialize a timer in order to trigger timeout events at certain times.

The default lwIP implementation is to have these timers enabled all the time, even if no timeout events are active. This increases CPU usage and power consumption when using automatic light sleep mode. esp-lwip default behaviour is to set each timer “on demand” so it is only enabled when an event is pending.

To return to the default lwIP behaviour (always-on timers), disable `CONFIG_LWIP_TIMERS_ONDEMAND`.

**Lwip timers API**  When users are not using WiFi, these APIs provide users with the ability to turn off lwIP timer to reduce power consumption.

The following API functions are supported. For full details see `lwip/lwip/src/include/lwip/timeouts.h`.

- `sys_timeouts_init()`
- `sys_timeouts_deinit()`

**Additional Socket Options**

- Some standard IPV4 and IPV6 multicast socket options are implemented (see **Socket Options**).
- Possible to set IPV6-only UDP and TCP sockets with `IPV6_V6ONLY` socket option (normal lwIP is TCP only).

**IP layer features**

- IPV4 source based routing implementation is different.
- IPV4 mapped IPV6 addresses are supported.

**Customized lwIP hooks**  The original lwIP supports implementing custom compile-time modifications via `LWIP_HOOK_FILENAME`. This file is already used by the IDF port layer, but IDF users could still include and implement any custom additions via a header file defined by the macro `ESP_IDF_LWIP_HOOK_FILENAME`. Here is an example of adding a custom hook file to the build process (the hook is called `my_hook.h` and located in the project’s main folder):

```c
idf_component_get_property(lwip lwip COMPONENT_LIB)
target_compile_options({$lwip} PRIVATE "-I${PROJECT_DIR}/main")
target_compile_definitions({$lwip} PRIVATE "-DESP_IDF_LWIP_HOOK_FILENAME="my_hook.h")
```
**Limitations**

Calling `send()` or `sendto()` repeatedly on a UDP socket may eventually fail with `errno` equal to `ENOMEM`. This is a limitation of buffer sizes in the lower layer network interface drivers. If all driver transmit buffers are full then UDP transmission will fail. Applications sending a high volume of UDP datagrams who don’t wish for any to be dropped by the sender should check for this error code and re-send the datagram after a short delay.

Increasing the number of TX buffers in the Wi-Fi or Ethernet project configuration (as applicable) may also help.

### 4.20.7 Performance Optimization

TCP/IP performance is a complex subject, and performance can be optimized towards multiple goals. The default settings of ESP-IDF are tuned for a compromise between throughput, latency, and moderate memory usage.

#### Maximum throughput

Espressif tests ESP-IDF TCP/IP throughput using the `wifi/iperf` example in an RF sealed enclosure.

The `wifi/iperf/sdkconfig.defaults` file for the `iperf` example contains settings known to maximize TCP/IP throughput, usually at the expense of higher RAM usage. To get maximum TCP/IP throughput in an application at the expense of other factors then suggest applying settings from this file into the project `sdkconfig`.

**Important:** Suggest applying changes a few at a time and checking the performance each time with a particular application workload.

- If a lot of tasks are competing for CPU time on the system, consider that the lwIP task has configurable CPU affinity (`CONFIG_LWIP_TCP_IP_TASK_AFFINITY`) and runs at fixed priority (18, `ESP_TASK_TCP_IP_PRIO`). Configure competing tasks to be pinned to a different core, or to run at a lower priority. See also [Built-in Task Priorities](https://docs.espressif.com/projects/espidf/en/latest/esp-idf/system_configuring.html#built-in-task-priorities).
- If using `select()` function with socket arguments only, disabling `CONFIG_VFS_SUPPORT_SELECT` will make `select()` calls faster.
- If there is enough free IRAM, select `CONFIG_LWIP_IRAM_OPTIMIZATION` and `CONFIG_LWIP_EXTRA_IRAM_OPTIMIZATION` to improve TX/RX throughput.

If using a Wi-Fi network interface, please also refer to [Wi-Fi Buffer Usage](https://docs.espressif.com/projects/espidf/en/latest/esp-idf/networking_set_up.html#buffer-usage).

#### Minimum latency

Except for increasing buffer sizes, most changes which increase throughput will also decrease latency by reducing the amount of CPU time spent in lwIP functions.

- For TCP sockets, lwIP supports setting the standard `TCP_NODELAY` flag to disable Nagle’s algorithm.

#### Minimum RAM usage

Most lwIP RAM usage is on-demand, as RAM is allocated from the heap as needed. Therefore, changing lwIP settings to reduce RAM usage may not change RAM usage at idle but can change it at peak.

- Reducing `CONFIG_LWIP_MAX_SOCKETS` reduces the maximum number of sockets in the system. This will also cause TCP sockets in the `WAIT_CLOSE` state to be closed and recycled more rapidly (if needed to open a new socket), further reducing peak RAM usage.
- Reducing `CONFIG_LWIP_TCP_PIPE_RECVMBX_SIZE`, `CONFIG_LWIP_TCP_RECVMBX_SIZE` and `CONFIG_LWIP_UDP_RECVMBX_SIZE` reduce memory usage at the expense of throughput, depending on usage.
- Reducing `CONFIG_LWIP_TCP_MSL`, `CONFIG_LWIP_TCP_FIN_WAIT_TIMEOUT` reduces the maximum segment lifetime in the system. This will also cause TCP sockets in the `TIME_WAIT, FIN_WAIT_2` state to be closed and recycled more rapidly.
• Disabling `CONFIG_LWIP_IPV6` can save about 39 KB for firmware size and 2KB RAM when the system is powered up and 7KB RAM when the TCP/IP stack is running. If there is no requirement for supporting IPV6 then it can be disabled to save flash and RAM footprint.
• Disabling `CONFIG_LWIP_IPV4` can save about 26 KB of firmware size and 600B RAM on power up and 6KB RAM when the TCP/IP stack is running. If the local network supports IPv6-only configuration then IPv4 can be disabled to save flash and RAM footprint.

If using Wi-Fi, please also refer to Wi-Fi Buffer Usage.

**Peak Buffer Usage**   The peak heap memory that lwIP consumes is the theoretically-maximum memory that the lwIP driver consumes. Generally, the peak heap memory that lwIP consumes depends on:

- the memory required to create a UDP connection: `lwip_udp_conn`
- the memory required to create a TCP connection: `lwip_tcp_conn`
- the number of UDP connections that the application has: `lwip_udp_con_num`
- the number of TCP connections that the application has: `lwip_tcp_con_num`
- the TCP TX window size: `lwip_tcp_tx_win_size`
- the TCP RX window size: `lwip_tcp_rx_win_size`

So, the peak heap memory that the LwIP consumes can be calculated with the following formula:

\[
lwip\_dynamic\_peek\_memory = (lwip\_udp\_con\_num \times lwip\_udp\_conn) + (lwip\_tcp\_con\_num \times (lwip\_tcp\_tx\_win\_size + lwip\_tcp\_rx\_win\_size + lwip\_tcp\_conn))\]

Some TCP-based applications need only one TCP connection. However, they may choose to close this TCP connection and create a new one when an error (such as a sending failure) occurs. This may result in multiple TCP connections existing in the system simultaneously, because it may take a long time for a TCP connection to close, according to the TCP state machine (refer to RFC793).

### 4.21 Memory Types

ESP32 chip has multiple memory types and flexible memory mapping features. This section describes how ESP-IDF uses these features by default.

ESP-IDF distinguishes between instruction memory bus (IRAM, IROM, RTC FAST memory) and data memory bus (DRAM, DROM). Instruction memory is executable, and can only be read or written via 4-byte aligned words. Data memory is not executable and can be accessed via individual byte operations. For more information about the different memory buses consult the ESP32 Technical Reference Manual > System and Memory [PDF].

#### 4.21.1 DRAM (Data RAM)

Non-constant static data (.data) and zero-initialized data (.bss) is placed by the linker into Internal SRAM as data memory. The remaining space in this region is used for the runtime heap.

By applying the `EXT_RAM_BSS_ATTR` macro, zero-initialized data can also be placed into external RAM. To use this macro, the `CONFIG_SPIRAM_ALLOW_BSS_SEG_EXTERNAL_MEMORY` needs to be enabled. See Allow .bss Segment to Be Placed in External Memory.

The available size of the internal DRAM region is reduced by 64 KB (by shifting start address to 0x3FFC0000) if Bluetooth stack is used. Length of this region is also reduced by 16 KB or 32 KB if trace memory is used. Due to some memory fragmentation issues caused by ROM, it is also not possible to use all available DRAM for static allocations - however the remaining DRAM is still available as heap at runtime.

**Note:** There is 520 KB of available SRAM (320 KB of DRAM and 200 KB of IRAM) on the ESP32. However, due to a technical limitation, the maximum statically allocated DRAM usage is 160 KB. The remaining 160 KB (for a total of 320 KB of DRAM) can only be allocated at runtime as heap.
Chapter 4. API Guides

Constant data may also be placed into DRAM, for example if it is used in a non-flash-safe ISR (see explanation under How to Place Code in IRAM).

“noinit” DRAM

The macro __NOINIT_ATTR can be used as attribute to place data into .noinit section. The values placed into this section will not be initialized at startup and should keep its value after software restart.

By applying the EXT_RAM_NOINIT_ATTR macro, non-initialized value could also be placed in external RAM. To do this, the CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY needs to be enabled. See Allow .noinit Segment to Be Placed in External Memory. If the CONFIG_SPIRAM_ALLOW_NOINIT_SEG_EXTERNAL_MEMORY is not enabled, EXT_RAM_NOINIT_ATTR will behave just as __NOINIT_ATTR, it will make data to be placed into .noinit segment in internal RAM.

Example:

```c
__NOINIT_ATTR uint32_t noinit_data;
```

4.21.2 IRAM (Instruction RAM)

ESP-IDF allocates part of the Internal SRAM0 region for instruction RAM. The region is defined in ESP32 Technical Reference Manual > System and Memory > Embedded Memory [PDF]. Except for the first 64 KB block which is used for PRO and APP MMU caches, the rest of this memory range (i.e. from 0x40080000 to 0x400A0000) is used to store parts of the application which need to run from RAM.

When to Place Code in IRAM

Cases when parts of the application should be placed into IRAM:

- Interrupt handlers must be placed into IRAM if ESP_INTR_FLAG_IRAM is used when registering the interrupt handler. For more information, see IRAM-Safe Interrupt Handlers.
- Some timing critical code may be placed into IRAM to reduce the penalty associated with loading the code from flash. ESP32 reads code and data from flash via the MMU cache. In some cases, placing a function into IRAM may reduce delays caused by a cache miss and significantly improve that function’s performance.

How to Place Code in IRAM

Some code is automatically placed into the IRAM region using the linker script.

If some specific application code needs to be placed into IRAM, it can be done by using the Linker Script Generation feature and adding a linker script fragment file to your component that targets at the entire source files or functions with the noflash placement. See the Linker Script Generation docs for more information.

Alternatively, it’s possible to specify IRAM placement in the source code using the IRAM_ATTR macro:

```c
#include "esp_attr.h"

void IRAM_ATTR gpio_isr_handler(void* arg) {
    // ...
}
```

There are some possible issues with placement in IRAM, that may cause problems with IRAM-safe interrupt handlers:

- Strings or constants inside an IRAM_ATTR function may not be placed in RAM automatically. It’s possible to use DRAM_ATTR attributes to mark these, or using the linker script method will cause these to be automatically placed correctly.
void IRAM_ATTR gpio_isr_handler(void * arg)
{
    const static DRAM_ATTR uint8_t INDEX_DATA[] = { 45, 33, 12, 0 };  
    const static char * MSG = DRAM_STR("I am a string stored in RAM");
}

Note that knowing which data should be marked with DRAM_ATTR can be hard, the compiler will sometimes recognize that a variable or expression is constant (even if it is not marked const) and optimize it into flash, unless it is marked with DRAM_ATTR.

- GCC optimizations that automatically generate jump tables or switch/case lookup tables place these tables in flash. IDF by default builds all files with -fno-jump-tables -fno-tree-switch-conversion flags to avoid this.

Jump table optimizations can be re-enabled for individual source files that don’t need to be placed in IRAM. For instructions on how to add the -fno-jump-tables -fno-tree-switch-conversion options when compiling individual source files, see Controlling Component Compilation.

### 4.21.3 IROM (code executed from flash)

If a function is not explicitly placed into IRAM (Instruction RAM) or RTC memory, it is placed into flash. As IRAM is limited, most of an application’s binary code must be placed into IROM instead.

The mechanism by which Flash MMU is used to allow code execution from flash is described in ESP32 Technical Reference Manual > Memory Management and Protection Units (MMU, MPU) [PDF].

During Application Startup Flow, the bootloader (which runs from IRAM) configures the MMU flash cache to map the app’s instruction code region to the instruction space. Flash accessed via the MMU is cached using some internal SRAM and accessing cached flash data is as fast as accessing other types of internal memory.

### 4.21.4 DROM (data stored in flash)

By default, constant data is placed by the linker into a region mapped to the MMU flash cache. This is the same as the IROM (code executed from flash) section, but is for read-only data not executable code.

The only constant data not placed into this memory type by default are literal constants which are embedded by the compiler into application code. These are placed as the surrounding function’s executable instructions.

The DRAM_ATTR attribute can be used to force constants from DROM into the DRAM (Data RAM) section (see above).

### 4.21.5 RTC Slow memory

Global and static variables used by code which runs from RTC memory must be placed into RTC Slow memory. For example deep sleep variables can be placed here instead of RTC FAST memory, or code and variables accessed by the ULP Coprocessor programming.

The attribute macro named RTC_NOINIT_ATTR can be used to place data into this type of memory. The values placed into this section keep their value after waking from deep sleep.

Example:

```
RTC_NOINIT_ATTR uint32_t rtc_noinit_data;
```
4.21.6 RTC FAST memory

The same region of RTC FAST memory can be accessed as both instruction and data memory. Code which has to run after wake-up from deep sleep mode has to be placed into RTC memory. Please check detailed description in deep sleep documentation.

RTC FAST memory can only be accessed by the PRO CPU.

In single core mode, remaining RTC FAST memory is added to the heap unless the option CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP is disabled. This memory can be used interchangeably with DRAM (Data RAM), but is slightly slower to access and not DMA capable.

4.21.7 DMA Capable Requirement

Most peripheral DMA controllers (e.g. SPI, sdmmc, etc.) have requirements that sending/receiving buffers should be placed in DRAM and word-aligned. We suggest to place DMA buffers in static variables rather than in the stack.

Use macro DMA_ATTR to declare global/local static variables like:

```c
DMA_ATTR uint8_t buffer[] = "I want to send something";

void app_main()
{
    // initialization code...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8 * sizeof(buffer),
    };
    spi_device_transmit(spi, &temp);
    // other stuff
}
```

Or:

```c
void app_main()
{
    DMA_ATTR static uint8_t buffer[] = "I want to send something";
    // initialization code...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8 * sizeof(buffer),
    };
    spi_device_transmit(spi, &temp);
    // other stuff
}
```

It is also possible to allocate DMA-capable memory buffers dynamically by using the MALLOC_CAP_DMA capabilities flag.

4.21.8 DMA Buffer in the Stack

Placing DMA buffers in the stack is possible but discouraged. If doing so, pay attention to the following:

- Placing DRAM buffers on the stack is not recommended if the stack may be in PSRAM. If the stack of a task is placed in the PSRAM, several steps have to be taken as described in Support for External RAM.
- Use macro WORD_ALIGNED_ATTR in functions before variables to place them in proper positions like:
4.22 OpenThread

OpenThread is an IP stack running on the 802.15.4 MAC layer which features mesh network and low power consumption.

4.22.1 Modes of the OpenThread stack

OpenThread can run under the following modes on Espressif chips:

**Standalone Node**

The full OpenThread stack and the application layer run on the same chip. This mode is available on chips with 15.4 radio such as ESP32-H2 and ESP32-C6.

**Radio Co-Processor (RCP)**

The chip is connected to another host running the OpenThread IP stack. It sends and receives 15.4 packets on behalf of the host. This mode is available on chips with 15.4 radio such as ESP32-H2 and ESP32-C6. The underlying transport between the chip and the host can be SPI or UART. For the sake of latency, we recommend using SPI as the underlying transport.

**OpenThread Host**

For chips without a 15.4 radio, it can be connected to an RCP and run OpenThread under host mode. This mode enables OpenThread on Wi-Fi chips such as ESP32, ESP32-S2, ESP32-S3, and ESP32-C3. The following diagram shows how devices work under different modes:

4.22.2 How to Write an OpenThread Application

The OpenThread `openthread/ot_cli` example is a good place to start at. It demonstrates basic OpenThread initialization and simple socket-based server and client.
Before OpenThread Initialization

- s1.1: The main task calls `esp_vfs_eventfd_register()` to initialize the eventfd virtual file system. The eventfd file system is used for task notification in the OpenThread driver.
- s1.2: The main task calls `nvs_flash_init()` to initialize the NVS where the Thread network data is stored.
- s1.3: Optional. The main task calls `esp_netif_init()` only when it wants to create the network interface for Thread.
- s1.4: The main task calls `esp_event_loop_create()` to create the system Event task and initialize an application event’s callback function.

OpenThread Stack Initialization

- s2.1: Call `esp_openthread_init()` to initialize the OpenThread stack.

OpenThread Network Interface Initialization

The whole stage is optional and only required if the application wants to create the network interface for Thread.

- s3.1: Call `esp_netif_new()` with `ESP_NETIF_DEFAULT_OPENTHREAD` to create the interface.
- s3.2: Call `esp_openthread_netif_glue_init()` to create the OpenThread interface handlers.
- s3.3: Call `esp_netif_attach()` to attach the handlers to the interface.

The OpenThread Main Loop

- s4.3: Call `esp_openthread_launch_mainloop()` to launch the OpenThread main loop. Note that this is a busy loop and does not return until the OpenThread stack is terminated.

Calling OpenThread APIs

The OpenThread APIs are not thread-safe. When calling OpenThread APIs from other tasks, make sure to hold the lock with `esp_openthread_lock_acquire()` and release the lock with `esp_openthread_lock_release()` afterwards.
Deinitialization

The following steps are required to deinitialize the OpenThread stack:

- Call `esp_netif_destroy()` and `esp_openthread_netif_glue_deinit()` to deinitialize the OpenThread network interface if you have created one.
- Call `esp_openthread_deinit()` to deinitialize the OpenThread stack.

### 4.22.3 The OpenThread Border Router

The OpenThread border router connects the Thread network with other IP networks. It provides IPv6 connectivity, service registration, and commission functionality.

To launch an OpenThread border router on an ESP chip, you need to connect an RCP to a Wi-Fi capable chip such as ESP32.

Calling `esp_openthread_border_router_init()` during the initialization launches all the border routing functionalities.

You may refer to the `openthread/ot_br` example and the README for further border router details.

### 4.23 Partition Tables

#### 4.23.1 Overview

A single ESP32’s flash can contain multiple apps, as well as many different kinds of data (calibration data, filesystems, parameter storage, etc). For this reason a partition table is flashed to (default offset) 0x8000 in the flash.

The partition table length is 0xC00 bytes, as we allow a maximum of 95 entries. An MD5 checksum, used for checking the integrity of the partition table at runtime, is appended after the table data. Thus, the partition table occupies an entire flash sector, which size is 0x1000 (4 KB). As a result, any partition following it must be at least located at (default offset) + 0x1000.

Each entry in the partition table has a name (label), type (app, data, or something else), subtype and the offset in flash where the partition is loaded.

The simplest way to use the partition table is to open the project configuration menu (`idf.py menuconfig`) and choose one of the simple predefined partition tables under `CONFIG_PARTITION_TABLE_TYPE`:

- “Single factory app, no OTA”
- “Factory app, two OTA definitions”

In both cases the factory app is flashed at offset 0x10000. If you execute `idf.py partition-table` then it will print a summary of the partition table.

#### 4.23.2 Built-in Partition Tables

Here is the summary printed for the “Single factory app, no OTA” configuration:

```plaintext
# ESP-IDF Partition Table
# Name, Type, SubType, Offset, Size, Flags
nvs, data, nvs, 0x9000, 0x6000,
phy_init, data, phy, 0xf000, 0x1000,
factory, app, factory, 0x10000, 1M,
```

- At a 0x10000 (64 KB) offset in the flash is the app labelled “factory”. The bootloader will run this app by default.
There are also two data regions defined in the partition table for storing NVS library partition and PHY init data.

Here is the summary printed for the “Factory app, two OTA definitions” configuration:

```
<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Type</th>
<th>SubType</th>
<th>Offset</th>
<th>Size</th>
<th>Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td>nvs</td>
<td>data</td>
<td>nvs</td>
<td></td>
<td>0x9000</td>
<td>0x4000</td>
<td></td>
</tr>
<tr>
<td>ota_data</td>
<td>data</td>
<td>ota</td>
<td></td>
<td>0xd000</td>
<td>0x2000</td>
<td></td>
</tr>
<tr>
<td>phy_init</td>
<td>data</td>
<td>phy</td>
<td></td>
<td>0xf000</td>
<td>0x1000</td>
<td></td>
</tr>
<tr>
<td>factory</td>
<td>app</td>
<td>factory</td>
<td></td>
<td>0x10000</td>
<td>1M</td>
<td></td>
</tr>
<tr>
<td>ota_0</td>
<td>app</td>
<td>ota_0</td>
<td></td>
<td>0x11000</td>
<td>1M</td>
<td></td>
</tr>
<tr>
<td>ota_1</td>
<td>app</td>
<td>ota_1</td>
<td></td>
<td>0x21000</td>
<td>1M</td>
<td></td>
</tr>
</tbody>
</table>
```

- There are now three app partition definitions. The type of the factory app (at 0x10000) and the next two “OTA” apps are all set to “app”, but their subtypes are different.
- There is also a new “otadata” slot, which holds the data for OTA updates. The bootloader consults this data in order to know which app to execute. If “ota data” is empty, it will execute the factory app.

### 4.23.3 Creating Custom Tables

If you choose “Custom partition table CSV” in menuconfig then you can also enter the name of a CSV file (in the project directory) to use for your partition table. The CSV file can describe any number of definitions for the table you need.

The CSV format is the same format as printed in the summaries shown above. However, not all fields are required in the CSV. For example, here is the “input” CSV for the OTA partition table:

```
<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Type</th>
<th>SubType</th>
<th>Offset</th>
<th>Size</th>
<th>Flags</th>
</tr>
</thead>
<tbody>
<tr>
<td>nvs</td>
<td>data</td>
<td>nvs</td>
<td></td>
<td>0x9000</td>
<td>0x4000</td>
<td></td>
</tr>
<tr>
<td>ota_data</td>
<td>data</td>
<td>ota</td>
<td></td>
<td>0xd000</td>
<td>0x2000</td>
<td></td>
</tr>
<tr>
<td>phy_init</td>
<td>data</td>
<td>phy</td>
<td></td>
<td>0xf000</td>
<td>0x1000</td>
<td></td>
</tr>
<tr>
<td>factory</td>
<td>app</td>
<td>factory</td>
<td></td>
<td>0x10000</td>
<td>1M</td>
<td></td>
</tr>
<tr>
<td>ota_0</td>
<td>app</td>
<td>ota_0</td>
<td></td>
<td></td>
<td>1M</td>
<td></td>
</tr>
<tr>
<td>ota_1</td>
<td>app</td>
<td>ota_1</td>
<td></td>
<td></td>
<td>1M</td>
<td></td>
</tr>
<tr>
<td>nvs_key</td>
<td>data</td>
<td>nvs_keys</td>
<td></td>
<td>0x1000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

- Whitespace between fields is ignored, and so is any line starting with # (comments).
- Each non-comment line in the CSV file is a partition definition.
- The “Offset” field for each partition is empty. The gen.esp32part.py tool fills in each blank offset, starting after the partition table and making sure each partition is aligned correctly.

#### Name Field

Name field can be any meaningful name. It is not significant to the ESP32. The maximum length of names is 16 bytes, including one null terminator. Names longer than the maximum length will be truncated.

#### Type Field

Partition type field can be specified as `app` (0x00) or `data` (0x01). Or it can be a number 0-254 (or as hex 0x00-0xFE). Types 0x00-0x3F are reserved for ESP-IDF core functions.

If your app needs to store data in a format not already supported by ESP-IDF, then please add a custom partition type value in the range 0x40-0xFE.

See `esp_partition_type_t` for the enum definitions for `app` and `data` partitions.

If writing in C++ then specifying a application-defined partition type requires casting an integer to `esp_partition_type_t` in order to use it with the `partition API`. For example:
static const esp_partition_type_t APP_PARTITION_TYPE_A = (esp_partition_type_t)0x40;

The ESP-IDF bootloader ignores any partition types other than app (0x00) and data (0x01).

**SubType**

The 8-bit SubType field is specific to a given partition type. ESP-IDF currently only specifies the meaning of the subtype field for app and data partition types.

See enum `esp_partition_subtype_t` for the full list of subtypes defined by ESP-IDF, including the following:

- **When type is app**, the SubType field can be specified as `factory` (0x00), `ota_0` (0x10) … `ota_15` (0x1F) or `test` (0x20).
  - `factory` (0x00) is the default app partition. The bootloader will execute the factory app unless there it sees a partition of type data/ota, in which case it reads this partition to determine which OTA image to boot.
    - OTA never updates the factory partition.
    - If you want to conserve flash usage in an OTA project, you can remove the factory partition and use `ota_0` instead.
  - `ota_0` (0x10) … `ota_15` (0x1F) are the OTA app slots. When OTA is in use, the OTA data partition configures which app slot the bootloader should boot. When using OTA, an application should have at least two OTA application slots (`ota_0` & `ota_1`). Refer to the OTA documentation for more details.
  - `test` (0x20) is a reserved subtype for factory test procedures. It will be used as the fallback boot partition if no other valid app partition is found. It is also possible to configure the bootloader to read a GPIO input during each boot, and boot this partition if the GPIO is held low, see *Boot from Test Firmware*.

- **When type is data**, the subtype field can be specified as `ota` (0x00), `phy` (0x01), `nvs` (0x02), `nvs_keys` (0x04), or a range of other component-specific subtypes (see `subtype enum`).
  - `ota` (0) is the **OTA data partition** which stores information about the currently selected OTA app slot. This partition should be 0x2000 bytes in size. Refer to the OTA documentation for more details.
  - `phy` (1) is for storing PHY initialisation data. This allows PHY to be configured per-device, instead of in firmware.
    - In the default configuration, the phy partition is not used and PHY initialisation data is compiled into the app itself. As such, this partition can be removed from the partition table to save space.
    - To load PHY data from this partition, open the project configuration menu (`idf.py menuconfig`) and enable `CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION` option. You will also need to flash your devices with phy init data as the esp-idf build system does not do this automatically.
  - `nvs` (2) is for the **Non-Volatile Storage (NVS) API**.
    - NVS is used to store per-device PHY calibration data (different to initialisation data).
    - NVS is used to store Wi-Fi data if the `esp_wifi_set_storage(WIFI_STORAGE_FLASH)` initialization function is used.
    - The NVS API can also be used for other application data.
    - It is strongly recommended that you include an NVS partition of at least 0x3000 bytes in your project.
    - If using NVS API to store a lot of data, increase the NVS partition size from the default 0x6000 bytes.
  - `nvs_keys` (4) is for the NVS key partition. See Non-Volatile Storage (NVS) API for more details.
    - It is used to store NVS encryption keys when NVS Encryption feature is enabled.
    - The size of this partition should be 4096 bytes (minimum partition size).
  - There are other predefined data subtypes for data storage supported by ESP-IDF. These include **FAT filesystem** (`ESP_PARTITION_SUBTYPE_DATA_FAT`), **SPIFFS** (`ESP_PARTITION_SUBTYPE_DATA_SPIFFS`), etc.

Other subtypes of data type are reserved for future ESP-IDF uses.

- If the partition type is any application-defined value (range 0x40-0xFE), then subtype field can be any value chosen by the application (range 0x00-0x0FE).

Note that when writing in C++, an application-defined subtype value requires casting to type `esp_partition_subtype_t` in order to use it with the `partition API`.

Espressif Systems 2511 Release v5.1.2

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Chapter 4. API Guides

Extra Partition SubTypes

A component can define a new partition subtype by setting the EXTRA_PARTITION_SUBTYPES property. This property is a CMake list, each entry of which is a comma separated string with <type>, <subtype>, <value> format. The build system uses this property to add extra subtypes and creates fields named ESP_PARTITION_SUBTYPE_<type>_<subtype> in esp_partition_subtype_t. The project can use this subtype to define partitions in the partitions table CSV file and use the new fields in esp_partition_subtype_t.

Offset & Size

The offset represents the partition address in the SPI flash, which sector size is 0x1000 (4 KB). Thus, the offset must be a multiple of 4 KB.

Partitions with blank offsets in the CSV file will start after the previous partition, or after the partition table in the case of the first partition.

Partitions of type app have to be placed at offsets aligned to 0x10000 (64 K). If you leave the offset field blank, gen_esp32part.py will automatically align the partition. If you specify an unaligned offset for an app partition, the tool will return an error.

Sizes and offsets can be specified as decimal numbers, hex numbers with the prefix 0x, or size multipliers K or M (1024 and 1024*1024 bytes).

If you want the partitions in the partition table to work relative to any placement (CONFIG_PARTITION_TABLE_OFFSET) of the table itself, leave the offset field (in CSV file) for all partitions blank. Similarly, if changing the partition table offset then be aware that all blank partition offsets may change to match, and that any fixed offsets may now collide with the partition table (causing an error).

Flags

Only one flag is currently supported, encrypted. If this field is set to encrypted, this partition will be encrypted if Flash Encryption is enabled.

Note: app type partitions will always be encrypted, regardless of whether this flag is set or not.

4.23.4 Generating Binary Partition Table

The partition table which is flashed to the ESP32 is in a binary format, not CSV. The tool partition_table/gen_esp32part.py is used to convert between CSV and binary formats.

If you configure the partition table CSV name in the project configuration (idf.py menuconfig) and then build the project or run idf.py partition-table, this conversion is done as part of the build process.

To convert CSV to Binary manually:

```
python gen_esp32part.py input_partitions.csv binary_partitions.bin
```

To convert binary format back to CSV manually:

```
python gen_esp32part.py binary_partitions.bin input_partitions.csv
```

To display the contents of a binary partition table on stdout (this is how the summaries displayed when running idf.py partition-table are generated):

```
python gen_esp32part.py binary_partitions.bin
```


### 4.23.5 Partition Size Checks

The ESP-IDF build system will automatically check if generated binaries fit in the available partition space, and will fail with an error if a binary is too large.

Currently these checks are performed for the following binaries:

- Bootloader binary must fit in space before partition table (see [Bootloader Size](#)).
- App binary should fit in at least one partition of type “app”. If the app binary doesn’t fit in any app partition, the build will fail. If it only fits in some of the app partitions, a warning is printed about this.

**Note:** Although the build process will fail if the size check returns an error, the binary files are still generated and can be flashed (although they may not work if they are too large for the available space.)

### MD5 Checksum

The binary format of the partition table contains an MD5 checksum computed based on the partition table. This checksum is used for checking the integrity of the partition table during the boot.

The MD5 checksum generation can be disabled by the `--disable-md5sum` option of `gen_esp32part.py` or by the `CONFIG_PARTITION_TABLE_MD5` option. This is useful for example when one uses a bootloader from ESP-IDF before v3.1 which cannot process MD5 checksums and the boot fails with the error message `invalid magic number 0xebeb`.

### 4.23.6 Flashing the Partition Table

- `idf.py partition-table-flash`: will flash the partition table with `esptool.py`.
- `idf.py flash`: Will flash everything including the partition table.

A manual flashing command is also printed as part of `idf.py partition-table` output.

**Note:** Note that updating the partition table doesn’t erase data that may have been stored according to the old partition table. You can use `idf.py erase-flash` (or `esptool.py erase_flash`) to erase the entire flash contents.

### 4.23.7 Partition Tool (parttool.py)

The component `partition_table` provides a tool `parttool.py` for performing partition-related operations on a target device. The following operations can be performed using the tool:

- reading a partition and saving the contents to a file (`read_partition`)
- writing the contents of a file to a partition (`write_partition`)
- erasing a partition (`erase_partition`)
- retrieving info such as name, offset, size and flag ( “encrypted” ) of a given partition (`get_partition_info`)

The tool can either be imported and used from another Python script or invoked from shell script for users wanting to perform operation programmatically. This is facilitated by the tool’s Python API and command-line interface, respectively.

**Python API**

Before anything else, make sure that the `parttool` module is imported.
import sys
import os

idf_path = os.environ['IDF_PATH']  # get value of IDF_PATH from environment
parttool_dir = os.path.join(idf_path, "components", "partition_table")  # parttool.py lives in $IDF_PATH/components/partition_table
sys.path.append(parttool_dir)  # this enables Python to find parttool module

from parttool import *  # import all names inside parttool module

The starting point for using the tool’s Python API to do is create a ParttoolTarget object:

```python
# Create a partool.py target device connected on serial port /dev/ttyUSB1
target = ParttoolTarget("/dev/ttyUSB1")
```

The created object can now be used to perform operations on the target device:

```python
# Erase partition with name ‘storage’
target.erase_partition(PartitionName("storage"))

# Read partition with type ‘data’ and subtype ‘spiffs’ and save to file ‘spiffs.bin’
target.read_partition(PartitionType("data", "spiffs"), "spiffs.bin")

# Write to partition ‘factory’ the contents of a file named ‘factory.bin’
target.write_partition(PartitionName("factory"), "factory.bin")

# Print the size of default boot partition
storage = target.get_partition_info(PARTITION_BOOT_DEFAULT)
print(storage.size)
```

The partition to operate on is specified using PartitionName or PartitionType or PARTITION_BOOT_DEFAULT. As the name implies, these can be used to refer to partitions of a particular name, type-subtype combination, or the default boot partition.

More information on the Python API is available in the docstrings for the tool.

**Command-line Interface**

The command-line interface of parttool.py has the following structure:

```bash
parttool.py [command-args] [subcommand] [subcommand-args]
```

- command-args - These are arguments that are needed for executing the main...
- command - (parttool.py), mostly pertaining to the target device
- subcommand - This is the operation to be performed
- subcommand-args - These are arguments that are specific to the chosen operation

```bash
# Erase partition with name 'storage'
parttool.py --port "/dev/ttyUSB1" erase_partition --partition-name=storage

# Read partition with type 'data' and subtype 'spiffs' and save to file 'spiffs.bin'
parttool.py --port "/dev/ttyUSB1" read_partition --partition-type=data --partition-subtype=spiffs --output "spiffs.bin"

# Write to partition 'factory' the contents of a file named 'factory.bin'
parttool.py --port "/dev/ttyUSB1" write_partition --partition-name=factory --input "factory.bin"
```

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Chapter 4. API Guides

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```bash
# Print the size of default boot partition
parttool.py --port "/dev/ttyUSB1" get_partition_info --partition=boot-default --
--info size
```

More information can be obtained by specifying `--help` as argument:

```bash
# Display possible subcommands and show main command argument descriptions
parttool.py --help

# Show descriptions for specific subcommand arguments
parttool.py [subcommand] --help
```

4.24 Performance

ESP-IDF ships with default settings that are designed for a trade-off between performance, resource usage, and available functionality.

These guides describe how to optimize a firmware application for a particular aspect of performance. Usually this involves some trade-off in terms of limiting available functions, or swapping one aspect of performance (such as execution speed) for another (such as RAM usage).

4.24.1 How to Optimize Performance

1. Decide what the performance-critical aspects of your application are (for example: a particular response time to a certain network operation, a particular startup time limit, particular peripheral data throughput, etc.).
2. Find a way to measure this performance (some methods are outlined in the guides below).
3. Modify the code and project configuration and compare the new measurement to the old measurement.
4. Repeat step 3 until the performance meets the requirements set out in step 1.

4.24.2 Guides

Speed Optimization

**Overview** Optimizing execution speed is a key element of software performance. Code that executes faster can also have other positive effects, e.g., reducing overall power consumption. However, improving execution speed may have trade-offs with other aspects of performance such as *Minimizing Binary Size*.

**Choose What to Optimize** If a function in the application firmware is executed once per week in the background, it may not matter if that function takes 10 ms or 100 ms to execute. If a function is executed constantly at 10 Hz, it matters greatly if it takes 10 ms or 100 ms to execute.

Most kinds of application firmware only have a small set of functions that require optimal performance. Perhaps those functions are executed very often, or have to meet some application requirements for latency or throughput. Optimization efforts should be targeted at these particular functions.

**Measuring Performance** The first step to improving something is to measure it.
Basic Performance Measurements  You may be able to measure directly the performance relative to an external interaction with the world, e.g., see the examples wifi/iperf and ethernet/iperf for measuring general network performance. Or you can use an oscilloscope or logic analyzer to measure the timing of an interaction with a device peripheral.

Otherwise, one way to measure performance is to augment the code to take timing measurements:

```c
#include "esp_timer.h"

void measure_important_function(void) {
    const unsigned MEASUREMENTS = 5000;
    uint64_t start = esp_timer_get_time();
    for (int retries = 0; retries < MEASUREMENTS; retries++) {
        important_function(); // This is the thing you need to measure
    }
    uint64_t end = esp_timer_get_time();
    printf("%u iterations took %llu milliseconds (%llu microseconds per...
        -invocation)\n", MEASUREMENTS, (end - start)/1000, (end - start)/MEASUREMENTS);
}
```

Executing the target multiple times can help average out factors, e.g., RTOS context switches, overhead of measurements, etc.

- Using `esp_timer_get_time()` generates “wall clock” timestamps with microsecond precision, but has moderate overhead each time the timing functions are called.
- It is also possible to use the standard Unix `gettimeofday()` and `utime()` functions, although the overhead is slightly higher.
- Otherwise, including `hal/cpu_hal.h` and calling the HAL function `cpu_hal_get_cycle_count()` returns the number of CPU cycles executed. This function has lower overhead than the others, which is good for measuring very short execution times with high precision.

The CPU cycles are counted per-core, so only use this method from an interrupt handler, or a task that is pinned to a single core.

- While performing “microbenchmarks” (i.e., benchmarking only a very small routine of code that runs in less than 1-2 milliseconds), the flash cache performance can sometimes cause big variations in timing measurements depending on the binary. This happens because binary layout can cause different patterns of cache misses in a particular sequence of execution. If the test code is larger, then this effect usually averages out. Executing a small function multiple times when benchmarking can help reduce the impact of flash cache misses. Alternatively, move this code to IRAM (see Targeted Optimizations).

External Tracing  The Application Level Tracing library allows measuring code execution with minimal impact on the code itself.

Tasks  If the option `CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS` is enabled, then the FreeRTOS API `vTaskGetRunTimeStats()` can be used to retrieve runtime information about the processor time used by each FreeRTOS task.

SEGGER SystemView is an excellent tool for visualizing task execution and looking for performance issues or improvements in the system as a whole.

Improving Overall Speed  The following optimizations improve the execution of nearly all code, including boot times, throughput, latency, etc:

- Set `CONFIG_ESPTOOLPY_FLASHFREQ` to 80 MHz. This is double the 40 MHz default value and doubles the speed at which code is loaded or executed from flash. You should verify that the board or module that connects
the ESP32 to the flash chip is rated for 80 MHz operation at the relevant temperature ranges before changing this setting. This information is contained in the hardware datasheet(s).

- Set `CONFIG_ESPTOOLPY_FLASHMODE` to QIO or QOUT mode (Quad I/O). Both almost double the speed at which code is loaded or executed from flash compared to the default DIO mode. QIO is slightly faster than QOUT if both are supported. Note that both the flash chip model, and the electrical connections between the ESP32 and the flash chip must support quad I/O modes or the SoC will not work correctly.

- Set `CONFIG_COMPILER_OPTIMIZATION` to `Optimize for performance (-O2)`. This may slightly increase binary size compared to the default setting, but almost certainly increases the performance of some code. Note that if your code contains C or C++ Undefined Behavior, then increasing the compiler optimization level may expose bugs that otherwise are not seen.

- If the application uses PSRAM and is based on ESP32 rev. 3 (ECO3), setting `CONFIG_ESP32_REV_MIN` to 3 disables PSRAM bug workarounds, reducing the code size and improving overall performance.

- Avoid using floating point arithmetic `float`. Even though ESP32 has a single precision hardware floating point unit, floating point calculations are always slower than integer calculations. If possible then use fixed point representations, a different method of integer representation, or convert part of the calculation to be integer only before switching to floating point.

- Avoid using double precision floating point arithmetic `double`. These calculations are emulated in software and are very slow. If possible then use an integer-based representation, or single-precision floating point.

### Reduce Logging Overhead

Although standard output is buffered, it is possible for an application to be limited by the rate at which it can print data to log output once buffers are full. This is particularly relevant for startup time if a lot of output is logged, but such problem can happen at other times as well. There are multiple ways to solve this problem:

- Reduce the volume of log output by lowering the app `CONFIG_LOG_DEFAULT_LEVEL` (the equivalent bootloader setting is `CONFIG_BOOTLOADER_LOG_LEVEL`). This also reduces the binary size, and saves some CPU time spent on string formatting.

- Increase the speed of logging output by increasing the `CONFIG_ESP_CONSOLE_UART_BAUDRATE`.

### Not Recommended

The following options also increase execution speed, but are not recommended as they also reduce the debuggability of the firmware application and may increase the severity of any bugs:

- Set `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL` to disabled. This also reduces firmware binary size by a small amount. However, it may increase the severity of bugs in the firmware including security-related bugs. If it is necessary to do this to optimize a particular function, consider adding `#define NDEBUG` at the top of that single source file instead.

### Targeted Optimizations

The following changes increase the speed of a chosen part of the firmware application:

- Move frequently executed code to IRAM. By default, all code in the app is executed from flash cache. This means that it is possible for the CPU to have to wait on a “cache miss” while the next instructions are loaded from flash. Functions which are copied into IRAM are loaded once at boot time, and then always execute at full speed.

- IRAM is a limited resource, and using more IRAM may reduce available DRAM, so a strategic approach is needed when moving code to IRAM. See IRAM (Instruction RAM) for more information.

- Jump table optimizations can be re-enabled for individual source files that do not need to be placed in IRAM. For hot paths in large switch cases, this improves performance. For instructions on how to add the `-fjump-tables` and `-ftree-switch-conversion` options when compiling individual source files, see Controlling Component Compilation

### Improving Startup Time

In addition to the overall performance improvements shown above, the following options can be tweaked to specifically reduce startup time:
Minimizing the `CONFIG_LOG_DEFAULT_LEVEL` and `CONFIG_BOOTLOADER_LOG_LEVEL` has a large impact on startup time. To enable more logging after the app starts up, set the `CONFIG_LOG_MAXIMUM_LEVEL` as well, and then call `esp_log_level_set()` to restore higher level logs. The `system/startup_time` main function shows how to do this.

If using Deep-sleep mode, setting `CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP` allows a faster wake from sleep. Note that if using Secure Boot, this represents a security compromise, as Secure Boot validation are not be performed on wake.

Setting `CONFIG_BOOTLOADER_SKIP_VALIDATE_ON_POWER_ON` skips verifying the binary on every boot from the power-on reset. How much time this saves depends on the binary size and the flash settings. Note that this setting carries some risk if the flash becomes corrupt unexpectedly. Read the help text of the `config` item for an explanation and recommendations if using this option.

It is possible to save a small amount of time during boot by disabling RTC slow clock calibration. To do so, set `CONFIG_RTC_CLK_CAL_CYCLES` to 0. Any part of the firmware that uses RTC slow clock as a timing source will be less accurate as a result.

The example project `system/startup_time` is pre-configured to optimize startup time. The file `system/startup_time/sdkconfig.defaults` contain all of these settings. You can append these to the end of your project’s own `sdkconfig` file to merge the settings, but please read the documentation for each setting first.

**Task Priorities**

As ESP-IDF FreeRTOS is a real-time operating system, it is necessary to ensure that high-throughput or low-latency tasks are granted a high priority in order to run immediately. Priority is set when calling `xTaskCreate()` or `xTaskCreatePinnedToCore()` and can be changed at runtime by calling `vTaskPrioritySet()`.

It is also necessary to ensure that tasks yield CPU (by calling `vTaskDelay()`, `sleep()`, or by blocking on semaphores, queues, task notifications, etc) in order to not starve lower-priority tasks and cause problems for the overall system. The **Task Watchdog Timer (TWDT)** provides a mechanism to automatically detect if task starvation happens. However, note that a TWDT timeout does not always indicate a problem, because sometimes the correct operation of the firmware requires some long-running computation. In these cases, tweaking the TWDT timeout or even disabling the TWDT may be necessary.

**Built-in Task Priorities**

ESP-IDF starts a number of system tasks at fixed priority levels. Some are automatically started during the boot process, while some are started only if the application firmware initializes a particular feature. To optimize performance, structure the task priorities of your application properly to ensure the tasks are not delayed by the system tasks, while also not starving system tasks and impacting other functions of the system.

This may require splitting up a particular task. For example, perform a time-critical operation in a high-priority task or an interrupt handler and do the non-time-critical part in a lower-priority task.

Header `components/esp_system/include/esp_task.h` contains macros for the priority levels used for built-in ESP-IDF tasks system. See **Background Tasks** for more details about the system tasks.

Common priorities are:

- **Running the main task** that executes `app_main` function has minimum priority (1). This task is pinned to Core 0 by default (configurable).
- **High Resolution Timer (ESP Timer)** system task to manage high precision timer events and execute callbacks has high priority (22, `ESP_TASK_TIMER_PRIO`). This task is pinned to Core 0.
- FreeRTOS Timer Task to handle FreeRTOS timer callbacks is created when the scheduler initializes and has minimum task priority (1, configurable). This task is pinned to Core 0.
- **Event Loop Library** system task to manage the default system event loop and execute callbacks has high priority (20, `ESP_TASK_EVENT_PRIO`) and it is pinned to Core 0. This configuration is only used if the application calls `esp_event_loop_create_default()`, it is possible to call `esp_event_loop_create()` with a custom task configuration instead.
- **lwIP** TCP/IP task has high priority (18, `ESP_TASK_TCPIP_PRIO`) and is not pinned to any core (configurable).
- **Wi-Fi Driver** task has high priority (23) and is pinned to Core 0 by default (configurable).

Submit Document Feedback
• Wi-Fi wpa_supplicant component may create dedicated tasks while the Wi-Fi Protected Setup (WPS), WPA2 EAP-TLS, Device Provisioning Protocol (DPP) or BSS Transition Management (BTM) features are in use. These tasks all have low priority (2) and are not pinned to any core.

• **Controller & VHCI** task has high priority (23, ESP_TASK_BT_CONTROLLER_PRIO) and is pinned to Core 0 by default (configurable). The Bluetooth Controller needs to respond to requests with low latency, so it should always be among the highest priority task assigned to a single CPU.

• **NimBLE-based host APIs** task has high priority (21) and is pinned to Core 0 by default (configurable).

• **Bluetooth API** creates multiple tasks when used:
  - Stack event callback task (“BTC”) has high priority (19).
  - Stack BTU layer task has high priority (20).
  - Host HCI host task has high priority (22).

    All Bluedroid Tasks are pinned to the same core, which is Core 0 by default (configurable).

• The Ethernet driver creates a task for the MAC to receive Ethernet frames. If using the default config ETH_MAC_DEFAULT_CONFIG then the priority is medium-high (15) and the task is not pinned to any core. These settings can be changed by passing a custom eth_mac_config_t struct when initializing the Ethernet MAC.

• If using the MQTT component, it creates a task with default priority 5 (configurable, depends on CONFIG_MQTT_USE_CUSTOM_CONFIG) and not pinned to any core (configurable).

• To see what is the task priority for mDNS service, please check Performance Optimization.

**Choosing Task Priorities of the Application** With a few exceptions, most importantly the lwIP TCP/IP task, in the default configuration most built-in tasks are pinned to Core 0. This makes it quite easy for the application to place high priority tasks on Core 1. Using priority 19 or higher guarantees that an application task can run on Core 1 without being preempted by any built-in task. To further isolate the tasks running on each CPU, configure the lwIP task to only run on Core 0 instead of either core, which may reduce total TCP/IP throughput depending on what other tasks are running.

In general, it is not recommended to set task priorities on Core 0 higher than the built-in Wi-Fi/Bluetooth operations as starving them of CPU may make the system unstable. Choosing priority 19 and Core 0 allows lower-layer Wi-Fi/Bluetooth functionality to run without delays, but still pre-empts the lwIP TCP/IP stack and other less time-critical internal functionality. This is an option for time-critical tasks that do not perform network operations. Any task that does TCP/IP network operations should run at lower priority than the lwIP TCP/IP task (18) to avoid priority-inversion issues.

**Note:** Setting a task to always run in preference to built-in ESP-IDF tasks does not require pinning the task to Core 1. Instead, the task can be left unpinned and assigned a priority of 17 or lower. This allows the task to optionally run on Core 0 if there are no higher-priority built-in tasks running on that core. Using unpinned tasks can improve the overall CPU utilization, however it makes reasoning about task scheduling more complex.

**Note:** Task execution is always completely suspended when writing to the built-in SPI flash chip. Only **IRAM-Safe Interrupt Handlers** continues executing.

**Improving Interrupt Performance** ESP-IDF supports dynamic Interrupt allocation with interrupt preemption. Each interrupt in the system has a priority, and higher-priority interrupts preempts lower priority ones.

Interrupt handlers execute in preference to any task, provided the task is not inside a critical section. For this reason, it is important to minimize the amount of time spent in executing an interrupt handler.

To obtain the best performance for a particular interrupt handler:

• Assign more important interrupts a higher priority using a flag such as ESP_INTR_FLAG_LEVEL2 or ESP_INTR_FLAG_LEVEL3 when calling esp_intr_alloc().
• Assign the interrupt on a CPU where built-in Wi-Fi/Bluetooth tasks are not configured to run, which means assigning the interrupt on Core 1 by default, see Built-in Task Priorities. Interrupts are assigned on the same CPU where the esp_intr_alloc() function call is made.
• If you are sure the entire interrupt handler can run from IRAM (see IRAM-Safe Interrupt Handlers) then set the ESP_INTR_FLAG_IRAM flag when calling esp_intr_alloc() to assign the interrupt. This prevents it being temporarily disabled if the application firmware writes to the internal SPI flash.
• Even if the interrupt handler is not IRAM-safe, if it is going to be executed frequently then consider moving the handler function to IRAM anyhow. This minimizes the chance of a flash cache miss when the interrupt code is executed (see Targeted Optimizations). It is possible to do this without adding the ESP_INTR_FLAG_IRAM flag to mark the interrupt as IRAM-safe, if only part of the handler is guaranteed to be in IRAM.

Improving Network Speed
• For Wi-Fi, see How to Improve Wi-Fi Performance and Wi-Fi Buffer Usage
• For lwIP TCP/IP (Wi-Fi and Ethernet), see Performance Optimization
  The wifi/iperf example contains a configuration that is heavily optimized for Wi-Fi TCP/IP throughput. Append the contents of the files wifi/iperf/sdkconfig.defaults, wifi/iperf/sdkconfig.defaults.esp32 and wifi/iperf/sdkconfig.ci.99 to the sdkconfig file in your project in order to add all of these options. Note that some of these options may have trade-offs in terms of reduced debuggability, increased firmware size, increased memory usage, or reduced performance of other features. To get the best result, read the documentation pages linked above and use related information to determine exactly which options are best suited for your app.
  The ethernet/iperf example contains a configuration that is heavily optimized for Ethernet TCP/IP throughput. Examine ethernet/iperf/sdkconfig.defaults for more details. Note that some of these options may have trade-offs in terms of reduced debuggability, increased firmware size, increased memory usage, or reduced performance of other features. To get the best result, read the documentation pages linked above and use related information to determine exactly which options are best suited for your app.

Improving I/O Performance
  Using standard C library functions like fread and fwrite instead of platform specific unbuffered syscalls such as read and write can be slow. These functions are designed to be portable, so they are not necessarily optimized for speed, have a certain overhead and are buffered.

FAT Filesystem Support specific information and tips:

• Maximum size of the R/W request = FatFS cluster size (allocation unit size).
• Use read and write instead of fread and fwrite.
• To increase speed of buffered reading functions like fread and fgets, you can increase a size of the file buffer (Newlib’s default is 128 bytes) to a higher number like 4096, 8192 or 16384. This can be done locally via the setvbuf function used on a certain file pointer or globally applied to all files via modifying CONFIG_FATFS_VFS_FSTAT_BLKSIZE.

  Note: Setting a bigger buffer size also increases the heap memory usage.

Minimizing Binary Size

The ESP-IDF build system compiles all source files in the project and ESP-IDF, but only functions and variables that are actually referenced by the program are linked into the final binary. In some cases, it is necessary to reduce the total size of the firmware binary (for example, in order to fit it into the available flash partition size).

The first step to reducing the total firmware binary size is measuring what is causing the size to increase.

Measuring Static Sizes
  To optimize both firmware binary size and memory usage it’s necessary to measure statically allocated RAM ( “data”, “bss” ), code ( “text” ) and read-only data ( “rodata” ) in your project.
Using the `idf.py` sub-commands `size`, `size-components` and `size-files` provides a summary of memory used by the project:

**Note:** It is possible to add `-DOUTPUT_FORMAT=csv` or `-DOUTPUT_FORMAT=json` to get the output in CSV or JSON format.

### Size Summary (idf.py size)

```
$ idf.py size
 [...]  
Total sizes:
  DRAM .data size: 14956 bytes
  DRAM .bss size: 15808 bytes
  Used static DRAM: 30764 bytes (149972 available, 17.0% used)
  Used static IRAM: 83918 bytes (47154 available, 64.0% used)
  Flash code: 559943 bytes
  Flash rodata: 176736 bytes
Total image size: ~835553 bytes (.bin may be padded larger)
```

This output breaks down the size of all static memory regions in the firmware binary:

- **DRAM .data size** is statically allocated RAM that is assigned to non-zero values at startup. This uses RAM (DRAM) at runtime and also uses space in the binary file.
- **DRAM .bss size** is statically allocated RAM that is assigned zero at startup. This uses RAM (DRAM) at runtime but doesn’t use any space in the binary file.
- **Used static DRAM** is the total DRAM used by .data + .bss. The available size is the estimated amount of DRAM which will be available as heap memory at runtime (due to metadata overhead and implementation constraints, and heap allocations done by ESP-IDF during startup, the actual free heap at startup will be lower than this).
- **Used static IRAM** is the total size of executable code executed from IRAM. This uses space in the binary file and also reduces IRAM and/or DRAM (depending on sizes) available as heap memory at runtime. See [Optimizing IRAM Usage](#).
- **Flash code** is the total size of executable code executed from flash cache (IROM). This uses space in the binary file.
- **Flash rodata** is the total size of read-only data loaded from flash cache (DROM). This uses space in the binary file.
- **Total image size** is the estimated total binary file size, which is the total of all the used memory types except for .bss.

### Component Usage Summary (idf.py size-components)

The summary output provided by `idf.py size` does not give enough detail to find the main contributor to excessive binary size. To analyze in more detail, use `idf.py size-components`:

```
$ idf.py size-components
 [...]  
Total sizes:
  DRAM .data size: 14956 bytes
  DRAM .bss size: 15808 bytes
  Used static DRAM: 30764 bytes (149972 available, 17.0% used)
  Used static IRAM: 83918 bytes (47154 available, 64.0% used)
  Flash code: 559943 bytes
  Flash rodata: 176736 bytes
Total image size: ~835553 bytes (.bin may be padded larger)
Per-archive contributions to ELF file:
  Archive File  DRAM .data & .bss & other  IRAM  D/IRAM Flash code &...
  ...rodata  Total
```

(continues on next page)
The first lines of output from `idf.py size-components` are the same as `idf.py size`. After this a table is printed of “per-archive contributions to ELF file”. This means how much each static library archive has contributed to the final binary size.

Generally, one static library archive is built per component, although some are binary libraries included by a particular component (for example, `libnet80211.a` is included by `esp_wifi` component). There are also toolchain libraries such as `libc.a` and `libgcc.a` listed here, these provide Standard C/C++ Library and toolchain built-in functionality.

If your project is simple and only has a “main” component, then all of the project’s code will be shown under `libmain.a`. If your project includes its own components (see Build System), then they will each be shown on a separate line.

The table is sorted in descending order of the total contribution to the binary size.

The columns are as follows:

- **DRAM .data & .bss & other** - .data and .bss are the same as for the totals shown above (static variables, these both reduce total available RAM at runtime but .bss doesn’t contribute to the binary file size). “other” is a column for any custom section types that also contribute to RAM size (usually this value is 0).

<table>
<thead>
<tr>
<th>Library</th>
<th>.text</th>
<th>.data</th>
<th>.bss</th>
<th>.rodata</th>
<th>.text.rel</th>
</tr>
</thead>
<tbody>
<tr>
<td>libnet80211.a</td>
<td>1267</td>
<td>6044</td>
<td>0</td>
<td>5490</td>
<td>0</td>
</tr>
<tr>
<td>liblwip.a</td>
<td>21</td>
<td>3838</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libmbedtls.a</td>
<td>60</td>
<td>524</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libmbedtlscrypto.a</td>
<td>64</td>
<td>81</td>
<td>0</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>libnvs_flash.a</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libmain.a</td>
<td>12</td>
<td>848</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libfreertos.a</td>
<td>3104</td>
<td>740</td>
<td>0</td>
<td>15711</td>
<td>0</td>
</tr>
<tr>
<td>libnvs_flash.a</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libspi_flash.a</td>
<td>1562</td>
<td>294</td>
<td>0</td>
<td>8851</td>
<td>0</td>
</tr>
<tr>
<td>libesp_system.a</td>
<td>245</td>
<td>206</td>
<td>0</td>
<td>3078</td>
<td>0</td>
</tr>
<tr>
<td>libesp_tls.a</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libesp_rom.a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>112</td>
<td>0</td>
</tr>
<tr>
<td>libcxx.a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(exe)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libesp_pm.a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libesp_eth.a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libmesh.a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libwpa_supplicant.a</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libphy.a</td>
<td>1439</td>
<td>715</td>
<td>0</td>
<td>7798</td>
<td>0</td>
</tr>
<tr>
<td>libpp.a</td>
<td>2427</td>
<td>1292</td>
<td>0</td>
<td>20851</td>
<td>0</td>
</tr>
<tr>
<td>liblibc.a</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libphy.a</td>
<td>1439</td>
<td>715</td>
<td>0</td>
<td>7798</td>
<td>0</td>
</tr>
<tr>
<td>libphy.a</td>
<td>1439</td>
<td>715</td>
<td>0</td>
<td>7798</td>
<td>0</td>
</tr>
<tr>
<td>libfreertos.a</td>
<td>3104</td>
<td>740</td>
<td>0</td>
<td>15711</td>
<td>0</td>
</tr>
<tr>
<td>libnvs_flash.a</td>
<td>0</td>
<td>24</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>libspi_flash.a</td>
<td>1562</td>
<td>294</td>
<td>0</td>
<td>8851</td>
<td>0</td>
</tr>
<tr>
<td>libesp_system.a</td>
<td>245</td>
<td>206</td>
<td>0</td>
<td>3078</td>
<td>0</td>
</tr>
<tr>
<td>libesp_tls.a</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>[... removed some lines here ...]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The first lines of output from `idf.py size-components` are the same as `idf.py size`. After this a table is printed of “per-archive contributions to ELF file”. This means how much each static library archive has contributed to the final binary size.

Generally, one static library archive is built per component, although some are binary libraries included by a particular component (for example, `libnet80211.a` is included by `esp_wifi` component). There are also toolchain libraries such as `libc.a` and `libgcc.a` listed here, these provide Standard C/C++ Library and toolchain built-in functionality.

If your project is simple and only has a “main” component, then all of the project’s code will be shown under `libmain.a`. If your project includes its own components (see Build System), then they will each be shown on a separate line.

The table is sorted in descending order of the total contribution to the binary size.

The columns are as follows:

- **DRAM .data & .bss & other** - .data and .bss are the same as for the totals shown above (static variables, these both reduce total available RAM at runtime but .bss doesn’t contribute to the binary file size). “other” is a column for any custom section types that also contribute to RAM size (usually this value is 0).
• IRAM - is the same as for the totals shown above (code linked to execute from IRAM, uses space in the binary file and also reduces IRAM that can be dynamically allocated at runtime using HEAP_CAP_32BIT.
• D/IRAM - Shows IRAM space which, due to occupying D/IRAM space, is also reducing available DRAM available as heap at runtime.
• Flash code & rodata - these are the same as the totals above, IROM and DROM space accessed from flash cache that contribute to the binary size.

Source File Usage Summary (idf.py size-files) For even more detail, run idf.py size-files to get a summary of the contribution each object file has made to the final binary size. Each object file corresponds to a single source file.

```
$ idf.py size-files
[...]
Total sizes:
DRAM .data size: 14956 bytes
DRAM .bss size: 15808 bytes
Used static DRAM: 30764 bytes (149972 available, 17.0% used)
Used static IRAM: 83918 bytes (47154 available, 64.0% used)
Flash code: 559943 bytes
Flash rodata: 176736 bytes
Total image size:~ 835553 bytes (.bin may be padded larger)
```

Per-file contributions to ELF file:

```
<table>
<thead>
<tr>
<th>Object File</th>
<th>DRAM .data &amp; .bss &amp; other</th>
<th>IRAM</th>
<th>D/IRAM</th>
<th>Flash code &amp; rodata</th>
</tr>
</thead>
<tbody>
<tr>
<td>x509_crt_bundle.S.o</td>
<td>0 0 0 0 0 0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wi_cnx.o</td>
<td>2 3183 0 221 0 13119</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>phy_chip_v7.o</td>
<td>721 614 0 1642 0 16820</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ieee80211_iocctl.o</td>
<td>740 96 0 437 0 15325</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pp.o</td>
<td>1142 45 0 8871 0 5030</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ieee80211_output.o</td>
<td>2 20 0 2118 0 11617</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ieee80211_sta.o</td>
<td>1 41 0 1498 0 10858</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lib-a-vfprintf.o</td>
<td>0 0 0 13829</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lib-a-svfprintf.o</td>
<td>0 0 0 0 0 13251</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ssl_tls.c.o</td>
<td>60 0 0 0 0 12769</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sockets.c.o</td>
<td>0 648 0 0 0 11096</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nd6.c.o</td>
<td>8 932 0 0 0 11515</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>phy_chip_v7_cal.o</td>
<td>477 53 0 3499 0 8561</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pm.o</td>
<td>32 364 0 2673 0 7788</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ieee80211_scan.o</td>
<td>18 288 0 0 0 8889</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lib-a-svfprintf.o</td>
<td>0 0 0 0 0 9654</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lib-a-vfprintf.o</td>
<td>0 0 0 0 0 10069</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ieee80211_ht.o</td>
<td>0 4 0 1186 0 8628</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>phy_chip_v7_ana.o</td>
<td>241 48 0 2657 0 7677</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```
(continues on next page)
<table>
<thead>
<tr>
<th>Source File</th>
<th>Size (bytes)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>bignum.c.o</td>
<td>09652</td>
<td></td>
</tr>
<tr>
<td>tcp_in.c.o</td>
<td>8750</td>
<td></td>
</tr>
<tr>
<td>trc.o</td>
<td>6245</td>
<td></td>
</tr>
<tr>
<td>tasks.c.o</td>
<td>7384</td>
<td></td>
</tr>
<tr>
<td>ecp_curves.c.o</td>
<td>8864</td>
<td></td>
</tr>
<tr>
<td>ecp.c.o</td>
<td>9788</td>
<td></td>
</tr>
<tr>
<td>ieee80211_hostap.o</td>
<td>8578</td>
<td></td>
</tr>
<tr>
<td>wdev.o</td>
<td>3684</td>
<td></td>
</tr>
<tr>
<td>tcp_out.c.o</td>
<td>5686</td>
<td></td>
</tr>
<tr>
<td>tcp.c.o</td>
<td>6161</td>
<td></td>
</tr>
<tr>
<td>ieee80211_input.o</td>
<td>8578</td>
<td></td>
</tr>
<tr>
<td>wpa.c.o</td>
<td>8864</td>
<td></td>
</tr>
<tr>
<td>[... additional lines removed ...]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After the summary of total sizes, a table of “Per-file contributions to ELF file” is printed. The columns are the same as shown above for `idy.py size-components`, but this time the granularity is the contribution of each individual object file to the binary size.

For example, we can see that the file `x509_crt_bundle.S.o` contributed 64212 bytes to the total firmware size, all as `.rodata` in flash. Therefore we can guess that this application is using the ESP x509 Certificate Bundle feature and not using this feature would save at last this many bytes from the firmware size.

Some of the object files are linked from binary libraries and therefore you won’t find a corresponding source file. To locate which component a source file belongs to, it’s generally possible to search in the ESP-IDF source tree or look in the Linker Map File for the full path.

**Comparing Two Binaries** If making some changes that affect binary size, it’s possible to use an ESP-IDF tool to break down the exact differences in size. This operation isn’t part of `idy.py`, it’s necessary to run the `esp_idf_size` Python tool directly.

To do so, first locate the linker map file in the build directory. It will have the name `PROJECTNAME.map`. The `esp_idf_size` tool performs its analysis based on the output of the linker map file.

To compare with another binary, you will also need its corresponding `.map` file saved from the build directory.

For example, to compare two builds: one with the default `CONFIG_COMPILER_OPTIMIZATION` setting “Debug (-Og)” configuration and one with “Optimize for size (-Os)”:  

```bash
$ python -m esp_idf_size --diff build_Og/https_request.map build_Os/https_request.map
```

```
<CURRENT> MAP file: build_Og/https_request.map
<REFERENCE> MAP file: build_Os/https_request.map
Difference is counted as <CURRENT> - <REFERENCE>, i.e. a positive number means...
that <CURRENT> is larger.
Total sizes of <CURRENT>:
-<REFERENCE> Difference
DRAM .data size: 14516 bytes
-14956 -440
```

(continues on next page)
We can see from the “Difference” column that changing this one setting caused the whole binary to be over 60 KB smaller and over 5 KB more RAM is available.

It’s also possible to use the “diff” mode to output a table of component-level (static library archive) differences:

**Note:** To get the output in JSON or CSV format using `esp_idf_size` it is possible to use the `--format` option.

```
python -m esp_idf_size --archives --diff build_Og/https_request.map build_Oshttps_request.map
```

Also at the individual source file level:

```
python -m esp_idf_size --files --diff build_Og/https_request.map build_Oshttps_request.map
```

Other options (like writing the output to a file) are available, pass `--help` to see the full list.

**Showing Size When Linker Fails** If too much static memory is used, then the linker will fail with an error such as DRAM segment data does not fit, region `iram0_0_seg' overflowed by 44 bytes, or similar.

In these cases, `idf.py size` will not succeed either. However it is possible to run `esp_idf_size` manually in order to view the partial static memory usage (the memory usage will miss the variables which could not be linked, so there still appears to be some free space.)

The map file argument is `<projectname>.map` in the build directory

```
python -m esp_idf_size build/project_name.map
```

It is also possible to view the equivalent of `size-components` or `size-files` output:

```
python -m esp_idf_size --archives build/project_name.map
python -m esp_idf_size --files build/project_name.map
```

**Linker Map File** This is an advanced analysis method, but it can be very useful. Feel free to skip ahead to `:ref:`reducing-overall-size` and possibly come back to this later.

The `idf.py size` analysis tools all work by parsing the GNU binutils “linker map file”, which is a summary of everything the linker did when it created ( “linked” ) the final firmware binary file

Linker map files themselves are plain text files, so it’s possible to read them and find out exactly what the linker did. However, they are also very complex and long - often 100,000 or more lines!

The map file itself is broken into parts and each part has a heading. The parts are:
• Archive member included to satisfy reference by file (symbol). This shows you: for each object file included in the link, what symbol (function or variable) was the linker searching for when it included that object file. If you’re wondering why some object file in particular was included in the binary, this part may give a clue. This part can be used in conjunction with the Cross Reference Table at the end of the file. Note that not every object file shown in this list ends up included in the final binary, some end up in the Discarded input sections list instead.

• Allocating common symbols - This is a list of (some) global variables along with their sizes. Common symbols have a particular meaning in ELF binary files, but ESP-IDF doesn’t make much use of them.

• Discarded input sections - These sections were read by the linker as part of an object file to be linked into the final binary, but then nothing else referred to them so they were discarded from the final binary. For ESP-IDF this list can be very long, as we compile each function and static variable to a unique section in order to minimize the final binary size (specifically ESP-IDF uses compiler options -ffunction-sections -fdata-sections and linker option --gc-sections). Items mentioned in this list do not contribute to the final binary.

• Memory Configuration, Linker script and memory map - These two parts go together. Some of the output comes directly from the linker command line and the Linker Script, both provided by the Build System. The linker script is partially generated from the ESP-IDF project using the Linker Script Generation feature.

As the output of the Linker script and memory map part of the map unfolds, you can see each symbol (function or static variable) linked into the final binary along with its address (as a 16 digit hex number), its length (also in hex), and the library and object file it was linked from (which can be used to determine the component and the source file). Following all of the output sections that take up space in the final .bin file, the memory map also includes some sections in the ELF file that are only used for debugging (ELF sections .debug_*, etc.). These don’t contribute to the final binary size. You’ll notice the address of these symbols is a very low number (starting from 0x0000000000000000 and counting up).

• Cross Reference Table. This table shows for each symbol (function or static variable), the list of object file(s) that referred to it. If you’re wondering why a particular thing is included in the binary, this will help determine what included it.

**Note:** Unfortunately, the Cross Reference Table doesn’t only include symbols that made it into the final binary. It also includes symbols in discarded sections. Therefore, just because something is shown here doesn’t mean that it was included in the final binary - this needs to be checked separately.

---

**Note:** Linker map files are generated by the GNU binutils linker “ld”, not ESP-IDF. You can find additional information online about the linker map file format. This quick summary is written from the perspective of ESP-IDF build system in particular.

---

**Reducing Overall Size** The following configuration options will reduce the final binary size of almost any ESP-IDF project:

• Set `CONFIG_COMPILER_OPTIMIZATION` to “Optimize for size (-Os)”. In some cases, “Optimize for performance (-O2)” will also reduce the binary size compared to the default. Note that if your code contains C or C++ Undefined Behaviour then increasing the compiler optimization level may expose bugs that otherwise don’t happen.

• Reduce the compiled-in log output by lowering the app `CONFIG_LOG_DEFAULT_LEVEL`. If the `CONFIG_LOG_MAXIMUM_LEVEL` is changed from the default then this setting controls the binary size instead. Reducing compiled-in logging reduces the number of strings in the binary, and also the code size of the calls to logging functions.

• Set the `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL` to “Silent”. This avoids compiling in a dedicated assertion string and source file name for each assert that may fail. It’s still possible to find the failed assert in the code by looking at the memory address where the assertion failed.

• Besides the `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL`, you can disable or silent the assertion for HAL component separately by setting `CONFIG_HAL_DEFAULT_ASSERTION_LEVEL`. It
is to notice that ESP-IDF lowers HAL assertion level in bootloader to be silent even if `CONFIG_HAL_DEFAULT_ASSERTION_LEVEL` is set to full-assertion level. This is to reduce the bootloader size.

- Set `CONFIG_COMPILER_OPTIMIZATION_CHECKS_SILENT`. This removes specific error messages for particular internal ESP-IDF error check macros. This may make it harder to debug some error conditions by reading the log output.
- If the binary needs to run on only certain revision(s) of ESP32, increasing `CONFIG_ESP32_REV_MIN` to match can result in a reduced binary size. This will make a large difference if setting ESP32 minimum revision 3, and PSRAM is enabled.
- Don’t enable `CONFIG_COMPILER_CXX_EXCEPTIONS`, `CONFIG_COMPILER_CXX_RTTI`, or set the `CONFIG_COMPILER_STACK_CHECK_MODE` to Overall. All of these options are already disabled by default, but they have a large impact on binary size.
- Disabling `CONFIG_ESP_ERR_TO_NAME_LOOKUP` will remove the lookup table to translate user-friendly names for error values (see Error Handling) in error logs, etc. This saves some binary size, but error values will be printed as integers only.
- Setting `CONFIG_ESP_SYSTEM_PANIC` to “Silent reboot” will save a small amount of binary size, however this is only recommended if no one will use UART output to debug the device.
- If the application binary uses only one of the security versions of the protocomm component, then the support for others can be disabled to save some code size. The support can be disabled through `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_0`, `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_1`, or `CONFIG_ESP_PROTOCOMM_SUPPORT_SECURITY_VERSION_2` respectively.

**Note:** In addition to the many configuration items shown here, there are a number of configuration options where changing the option from the default will increase binary size. These are not noted here. Where the increase is significant, this is usually noted in the configuration item help text.

### Targeted Optimizations

The following binary size optimizations apply to a particular component or a function:

#### Wi-Fi

- Disabling `CONFIG_ESP_WIFI_ENABLE_WPA3_SAE` will save some Wi-Fi binary size if WPA3 support is not needed. (Note that WPA3 is mandatory for new Wi-Fi device certifications.)
- Disabling `CONFIG_ESP_WIFI_SOFTAP_SUPPORT` will save some Wi-Fi binary size if soft-AP support is not needed.
- Disabling `CONFIG_ESP_WIFI_ENTERPRISE_SUPPORT` will save some Wi-Fi binary size if enterprise support is not needed.

#### ADC

- Disabling ADC calibration features `CONFIG_ADC_CAL_EFUSE_TP_ENABLE`, `CONFIG_ADC_CAL_EFUSE_VREF_ENABLE`, `CONFIG_ADC_CAL_LUT_ENABLE` will save a small amount of binary size if ADC driver is used, at expense of accuracy.

#### Bluetooth NimBLE

If using NimBLE Bluetooth Host then the following modifications can reduce binary size:

- Set `CONFIG_BTDM_CTRL_BLE_MAX_CONN` to 1 if only one BLE connection is needed.
- `CONFIG_BT_NIMBLE_MAX_CONNECTIONS` to 1 if only one BLE connection is needed.
- Disable either `CONFIG_BT_NIMBLE_ROLE_CENTRAL` or `CONFIG_BT_NIMBLE_ROLE_OBSERVER` if these roles are not needed.
- Reducing `CONFIG_BT_NIMBLE_LOG_LEVEL` can reduce binary size. Note that if the overall log level has been reduced as described above in Reducing Overall Size then this also reduces the NimBLE log level.
lwIP IPv6

• Setting `CONFIG_LWIP_IPV6` to false will reduce the size of the lwIP TCP/IP stack, at the cost of only supporting IPv4.

**Note:** IPv6 is required by some components such as coap and ASIO port. These components will not be available if IPv6 is disabled.

lwIP IPv4

• If IPv4 connectivity is not required, setting `CONFIG_LWIP_IPV4` to false will reduce the size of the lwIP, supporting IPv6 only TCP/IP stack.

**Note:** Before disabling IPv4 support, please note that IPv6 only network environments are not ubiquitous and must be supported in the local network, e.g. by your internet service provider or using constrained local network settings.

Newlib nano formatting   By default, ESP-IDF uses newlib “full” formatting for I/O (printf, scanf, etc.)

Enabling the config option `CONFIG_NEWLIB_NANO_FORMAT` will switch newlib to the “nano” formatting mode. This both smaller in code size and a large part of the implementation is compiled into the ESP32 ROM, so it doesn’t need to be included in the binary at all.

The exact difference in binary size depends on which features the firmware uses, but 25 KB ~ 50 KB is typical.

Enabling Nano formatting reduces the stack usage of each function that calls printf() or another string formatting function, see Reducing Stack Sizes.

“Nano” formatting doesn’t support 64-bit integers, or C99 formatting features. For a full list of restrictions, search for `--enable-newlib-nano-formatted-io` in the Newlib README file.

mbedTLS features   Under Component Config -> mbedTLS there are multiple mbedTLS features which are enabled by default but can be disabled if not needed to save code size.

These include:

• `CONFIG_MBEDTLS_HAVE_TIME`
• `CONFIG_MBEDTLS_ECDSA_DETERMINISTIC`
• `CONFIG_MBEDTLS_SHA512_C`
• `CONFIG_MBEDTLS_CLIENT_SSL_SESSION_TICKETS`
• `CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS`
• `CONFIG_MBEDTLS_SSL_CONTEXT.Serialization`
• `CONFIG_MBEDTLS_SSL_ALPN`
• `CONFIG_MBEDTLS_SSL_Renegotiation`
• `CONFIG_MBEDTLS_CCM_C`
• `CONFIG_MBEDTLS_GCM_C`
• `CONFIG_MBEDTLS_ECP_C` (Alternatively: Leave this option enabled but disable some of the elliptic curves listed in the sub-menu.)
• `CONFIG_MBEDTLS_ECP_NIST_OPTIM`
• `CONFIG_MBEDTLS_ECP_FIXED_POINT_OPTIM`
• Change `CONFIG_MBEDTLS_TLS_MODE` if both server & client functionalities are not needed
• Consider disabling some cipher suites listed in the “TLS Key Exchange Methods” sub-menu (i.e. `CONFIG_MBEDTLS_KEY_EXCHANGE_RSA`)

The help text for each option has some more information.

**Important:** It is strongly not recommended to disable all these mbedTLS options. Only disable options where you understand the functionality and are certain that it is not needed in the application. In particular:
• Ensure that any TLS server(s) the device connects to can still be used. If the server is controlled by a third party or a cloud service, recommend ensuring that the firmware supports at least two of the supported cipher suites in case one is disabled in a future update.
• Ensure that any TLS client(s) that connect to the device can still connect with supported/recommended cipher suites. Note that future versions of client operating systems may remove support for some features, so it is recommended to enable multiple supported cipher suites or algorithms for redundancy.

If depending on third party clients or servers, always pay attention to announcements about future changes to supported TLS features. If not, the ESP32 device may become inaccessible if support changes.

Note: Not every combination of mbedtls TLS compile-time config is tested in ESP-IDF. If you find a combination that fails to compile or function as expected, please report the details on GitHub.

VFS  Virtual filesystem feature in ESP-IDF allows multiple filesystem drivers and file-like peripheral drivers to be accessed using standard I/O functions (open, read, write, etc.) and C library functions (fopen, fread, fwrite, etc.). When filesystem or file-like peripheral driver functionality is not used in the application this feature can be fully or partially disabled. VFS component provides the following configuration options:

• CONFIG_VFS_SUPPORT_TERMIOS — can be disabled if the application doesn’t use termios family of functions. Currently, these functions are implemented only for UART VFS driver. Most applications can disable this option. Disabling this option reduces the code size by about 1.8 kB.
• CONFIG_VFS_SUPPORT_SELECT — can be disabled if the application doesn’t use select function with file descriptors. Currently, only the UART and eventfd VFS drivers implement select support. Note that when this option is disabled, select can still be used for socket file descriptors. Disabling this option reduces the code size by about 2.7 kB.
• CONFIG_VFS_SUPPORT_DIR — can be disabled if the application doesn’t use directory related functions, such as readdir (see the description of this option for the complete list). Applications which only open, read and write specific files and don’t need to enumerate or create directories can disable this option, reducing the code size by 0.5 kB or more, depending on the filesystem drivers in use.
• CONFIG_VFS_SUPPORT_IO — can be disabled if the application doesn’t use filesystems or file-like peripheral drivers. This disables all VFS functionality, including the three options mentioned above. When this option is disabled, console can’t be used. Note that the application can still use standard I/O functions with socket file descriptors when this option is disabled. Compared to the default configuration, disabling this option reduces code size by about 9.4 kB.

Bootsloader Size  This document deals with the size of an ESP-IDF app binary only, and not the ESP-IDF Second stage bootloader.

For a discussion of ESP-IDF bootloader binary size, see Booteoader Size.

IRAM Binary Size  If the IRAM section of a binary is too large, this issue can be resolved by reducing IRAM memory usage. See Optimizing IRAM Usage.

Minimizing RAM Usage

In some cases, a firmware application’s available RAM may run low or run out entirely. In these cases, it is necessary to tune the memory usage of the firmware application.

In general, firmware should aim to leave some headroom of free internal RAM to deal with extraordinary situations or changes in RAM usage in future updates.
Background  Before optimizing ESP-IDF RAM usage, it is necessary to understand the basics of ESP32 memory types, the difference between static and dynamic memory usage in C, and the way ESP-IDF uses stack and heap. This information can all be found in Heap Memory Allocation.

Measuring Static Memory Usage  The idf.py tool can be used to generate reports about the static memory usage of an application, see Measuring Static Sizes.

Measuring Dynamic Memory Usage  ESP-IDF contains a range of heap APIs for measuring free heap at runtime, see Heap Memory Debugging.

Note:  In embedded systems, heap fragmentation can be a significant issue alongside total RAM usage. The heap measurement APIs provide ways to measure the largest free block. Monitoring this value along with the total number of free bytes can give a quick indication of whether heap fragmentation is becoming an issue.

Reducing Static Memory Usage

• Reducing the static memory usage of the application increases the amount of RAM available for heap at runtime, and vice versa.
• Generally speaking, minimizing static memory usage requires monitoring the .data and .bss sizes. For tools to do this, see Measuring Static Sizes.
• Internal ESP-IDF functions do not make heavy use of static RAM in C. In many instances (such as Wi-Fi library, Bluetooth controller), static buffers are still allocated from the heap. However, the allocation is performed only once during feature initialization and will be freed if the feature is deinitialized. This approach is adopted to optimize the availability of free memory at various stages of the application’s life cycle.

To minimize static memory use:

• Constant data can be stored in flash memory instead of RAM, thus it is recommended to declare structures, buffers, or other variables as const. This approach may require modifying firmware functions to accept const * arguments instead of mutable pointer arguments. These changes can also help reduce the stack usage of certain functions.
• If using Bluedroid, setting the option CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY will cause Bluedroid to allocate memory on initialization and free it on deinitialization. This does not necessarily reduce the peak memory usage, but changes it from static memory usage to runtime memory usage.
• If using OpenThread, enabling the option CONFIG_OPENTHREAD_PLATFORM_MSGPOOL_MANAGEMENT will cause OpenThread to allocate message pool buffers from PSRAM, which will reduce static memory use.

Reducing Stack Sizes  In FreeRTOS, task stacks are usually allocated from the heap. The stack size for each task is fixed and passed as an argument to xTaskCreate(). Each task can use up to its allocated stack size, but using more than this will cause an otherwise valid program to crash, with a stack overflow or heap corruption.

Therefore, determining the optimum sizes of each task stack, minimizing the required size of each task stack, and minimizing the number of task stacks as whole, can all substantially reduce RAM usage.

To determine the optimum size for a particular task stack, users can consider the following methods:

• At runtime, call the function uxTaskGetStackHighWaterMark() with the handle of any task where you think there is unused stack memory. This function returns the minimum lifetime free stack memory in bytes.
  – The easiest time to call uxTaskGetStackHighWaterMark() is from the task itself; call uxTaskGetStackHighWaterMark(NULL) to get the current task’s high water mark after the time that the task has achieved its peak stack usage, i.e., if there is a main loop, execute the main loop a number of times with all possible states, and then call uxTaskGetStackHighWaterMark().
  – Often, it is possible to subtract almost the entire value returned here from the total stack size of a task, but allow some safety margin to account for unexpected small increases in stack usage at runtime.
• Call `uxTaskGetSystemState()` at runtime to get a summary of all tasks in the system. This includes their individual stack high watermark values.

• When debugger watchpoints are not being used, users can set the `CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK` option. This will cause one of the watchpoints to watch the last word of the task’s stack. If that word is overwritten (such as in a stack overflow), a panic is triggered immediately. This is slightly more reliable than the default `CONFIG_FREERTOS_CHECK_STACKOVERFLOW` option of Check using canary bytes, because the panic happens immediately, rather than on the next RTOS context switch. Neither option is perfect. In some cases, it is possible that the stack pointer skips the watchpoint or canary bytes and corrupts another region of RAM instead.

To reduce the required size of a particular task stack, users can consider the following methods:

• Avoid stack heavy functions. String formatting functions (like `printf()`) are particularly heavy users of the stack, so any task which does not ever call these can usually have its stack size reduced.
  – Enabling Newlib nano formatting reduces the stack usage of any task that calls `printf()` or other C string formatting functions.

• Avoid allocating large variables on the stack. In C, any large structures or arrays allocated as an automatic variable (i.e., default scope of a C declaration) uses space on the stack. To minimize the sizes of these, allocate them statically and/or see if you can save memory by dynamically allocating them from the heap only when they are needed.

• Avoid deep recursive function calls. Individual recursive function calls do not always add a lot of stack usage each time they are called, but if each function includes large stack-based variables then the overhead can get quite high.

To reduce the total number of tasks, users can consider the following method:

• Combine tasks. If a particular task is never created, the task’s stack is never allocated, thus reducing RAM usage significantly. Unnecessary tasks can typically be removed if those tasks can be combined with another task. In an application, tasks can typically be combined or removed if:
  – The work done by the tasks can be structured into multiple functions that are called sequentially.
  – The work done by the tasks can be structured into smaller jobs that are serialized (via a FreeRTOS queue or similar) for execution by a worker task.

Internal Task Stack Sizes ESP-IDF allocates a number of internal tasks for housekeeping purposes or operating system functions. Some are created during the startup process, and some are created at runtime when particular features are initialized.

The default stack sizes for these tasks are usually set conservatively high to allow all common usage patterns. Many of the stack sizes are configurable, and it may be possible to reduce them to match the real runtime stack usage of the task.

Important: If internal task stack sizes are set too small, ESP-IDF will crash unpredictably. Even if the root cause is task stack overflow, this is not always clear when debugging. It is recommended that internal stack sizes are only reduced carefully (if at all), with close attention to high water mark free space under load. If reporting an issue that occurs when internal task stack sizes have been reduced, please always include the following information and the specific configuration that is being used.

• Running the main task has stack size `CONFIG_ESP_MAIN_TASK_STACK_SIZE`.
• High Resolution Timer (ESP Timer) system task which executes callbacks has stack size `CONFIG_ESP_TIMER_TASK_STACK_SIZE`.
• FreeRTOS Timer Task to handle FreeRTOS timer callbacks has stack size `CONFIG_FREERTOS_TIMER_TASK_STACK_SIZE`.
• Event Loop Library system task to execute callbacks for the default system event loop has stack size `CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE`.
• lwIP TCP/IP task has stack size `CONFIG_LWIP_TCPIP_TASK_STACK_SIZE`.
• Bluetooth API have task stack sizes `CONFIG_BT_BTCL_TASK_STACK_SIZE`, `CONFIG_BT_BTU_TASK_STACK_SIZE`.
• **NimBLE-based host APIs** has task stack size `CONFIG_BT_NIMBLE_HOST_TASK_STACK_SIZE`.

• The Ethernet driver creates a task for the MAC to receive Ethernet frames. If using the default config `ETH_MAC_DEFAULT_CONFIG` then the task stack size is 4 KB. This setting can be changed by passing a custom `eth_mac_config_t` struct when initializing the Ethernet MAC.

• FreeRTOS idle task stack size is configured by `CONFIG_FREERTOS_IDLE_TASK_STACK_SIZE`.

• If using the **ESP-MQTT** component, it creates a task with stack size configured by `CONFIG_MQTT_TASK_STACK_SIZE`. MQTT stack size can also be configured using `task_stack` field of `esp_mqtt_client_config_t`.

• To see how to optimize RAM usage when using mDNS, please check Minimizing RAM Usage.

**Note:** Aside from built-in system features such as ESP-timer, if an ESP-IDF feature is not initialized by the firmware, then no associated task is created. In those cases, the stack usage is zero, and the stack-size configuration for the task is not relevant.

**Reducing Heap Usage** For functions that assist in analyzing heap usage at runtime, see Heap Memory Debugging.

Normally, optimizing heap usage consists of analyzing the usage and removing calls to `malloc()` that are not being used, reducing the corresponding sizes, or freeing previously allocated buffers earlier.

There are some ESP-IDF configuration options that can reduce heap usage at runtime:

• lwIP documentation has a section to configure Minimum RAM usage.

• **Wi-Fi Buffer Usage** describes options to either reduce the number of static buffers or reduce the maximum number of dynamic buffers in use, so as to minimize memory usage at a possible cost of performance. Note that static Wi-Fi buffers are still allocated from the heap when Wi-Fi is initialized, and will be freed if Wi-Fi is deinitialized.

• The Ethernet driver allocates DMA buffers for the internal Ethernet MAC when it is initialized - configuration options are `CONFIG_ETH_DMA_BUFFER_SIZE`, `CONFIG_ETH_DMA_RX_BUFFER_NUM`, `CONFIG_ETH_DMA_TX_BUFFER_NUM`.

• Several Mbed TLS configuration options can be used to reduce heap memory usage. See the Reducing Heap Usage docs for details.

• In single-core mode only, it is possible to use IRAM as byte-accessible memory added to the regular heap by enabling `CONFIG_ESP32_IRAM_AS_8BIT_ACCESSIBLE_MEMORY`. Note that this option carries a performance penalty, and the risk of security issues caused by executable data. If this option is enabled, then it is possible to set other options to prefer certain buffers allocated from this memory: `CONFIG_MBEDTLS_MEM_ALLOC_MODE`, `NimBLE`.

• Reduce `CONFIG_BTDM_CTRL_BLE_MAX_CONN` if using Bluetooth LE.

• Reduce `CONFIG_BTDM_CTRL_BR_EDR_MAX_ACL_CONN` if using Bluetooth Classic.

**Note:** There are other configuration options that increases heap usage at runtime if changed from the defaults. These options are not listed above, but the help text for the configuration item will mention if there is some memory impact.

**Optimizing IRAM Usage** If the app allocates more static IRAM than available, then the app will fail to build, and linker errors such as section ".iram0.text" will not fit in region "iram0_0_seg", IRAM0 segment data does not fit, and region "iram0_0_seg" overflowed by 84-bytes will be seen. If this happens, it is necessary to find ways to reduce static IRAM usage in order to link the application.

To analyze the IRAM usage in the firmware binary, use Measuring Static Sizes. If the firmware failed to link, steps to analyze are shown at Showing Size When Linker Fails.

The following options will reduce IRAM usage of some ESP-IDF features:

• Enable `CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH`. Provided these functions are not incorrectly used from ISRs, this option is safe to enable in all configurations.
Chapter 4. API Guides

- Enable `CONFIG_FREERTOS_PLACE_SNAPSHOT_FUNS_INTO_FLASH`. Enabling this option places snapshot-related functions, such as `vTaskGetSnapshot` or `uxTaskGetSnapshotAll`, in flash.
- Enable `CONFIG_RINGBUF_PLACE_FUNCTIONS_INTO_FLASH`. Provided these functions are not incorrectly used from ISRs, this option is safe to enable in all configurations.
- Enable `CONFIG_RINGBUF_PLACE_ISR_FUNCTIONS_INTO_FLASH`. This option is not safe to use if the ISR ringbuf functions are used from an IRAM interrupt context, e.g., if `CONFIG_UART_ISR_IN_IRAM` is enabled. For the ESP-IDF drivers where this is the case, you can get an error at run-time when installing the driver in question.
- Disabling Wi-Fi options `CONFIG_ESP_WIFI_IRAM_OPT` and/or `CONFIG_ESP_WIFI_RX_IRAM_OPT` options frees available IRAM at the cost of Wi-Fi performance.
- Disabling `CONFIG_SPI_FLASH_ROM_DRIVER_PATCH` frees some IRAM but is only available in some flash configurations, see the configuration item help text.
- If the application uses PSRAM and is based on ESP32 rev. 3 (ECO3), setting `CONFIG_ESP32_REVMIN` to 3 disables PSRAM bug workarounds, saving 10 KB or more of IRAM.
- Disabling `CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR` prevents posting `esp_event` events from IRAM-Safe Interrupt Handlers but saves some IRAM.
- Disabling `CONFIG_SPI_MASTER_ISR_IN_IRAM` prevents spi_master interrupts from being serviced while writing to flash, and may otherwise reduce spi_master performance, but saves some IRAM.
- Disabling `CONFIG_SPI_SLAVE_ISR_IN_IRAM` prevents spi_slave interrupts from being serviced while writing to flash, which saves some IRAM.
- Setting `CONFIG_HAL_DEFAULT_ASSERTION_LEVEL` to disable assertion for HAL component saves some IRAM, especially for HAL code who calls `HAL_ASSERT` a lot and resides in IRAM.
- Refer to the sdkconfig menu `Auto-detect Flash chips`, and you can disable flash drivers which you do not need to save some IRAM.
- Enable `CONFIG_HEAP_PLACE_FUNCTION_INTO_FLASH`. Provided that `CONFIG_SPI_MASTER_ISR_IN_IRAM` is not enabled and the heap functions are not incorrectly used from ISRs, this option is safe to enable in all configurations.

**Using SRAM1 for IRAM** The SRAM1 memory area is normally used for DRAM, but it is possible to use parts of it for IRAM with `CONFIG_ESP_SYSTEM_ESP32_SRAM1_REGION_AS_IRAM`. This memory would previously be reserved for DRAM data usage (e.g., `.bss`) by the software bootloader and later added to the heap. After this option was introduced, the bootloader DRAM size was reduced to a value closer to what it normally actually needs.

To use this option, ESP-IDF should be able to recognize that the new SRAM1 area is also a valid load address for an image segment. If the software bootloader was compiled before this option existed, then the bootloader will not be able to load the app that has code placed in this new extended IRAM area. This would typically happen if you are doing an OTA update, where only the app would be updated.

If the IRAM section were to be placed in an invalid area, then this would be detected during the bootup process, and result in a failed boot:

```
E (204) esp_image: Segment 5 0x400845f8-0x400a126c invalid: bad load address range
```

**Warning:** Apps compiled with `CONFIG_ESP_SYSTEM_ESP32_SRAM1_REGION_AS_IRAM` may fail to boot, if used together with a software bootloader that was compiled before this config option was introduced. If you are using an older bootloader and updating over OTA, please test carefully before pushing any updates.

Any memory that ends up unused for static IRAM will be added to the heap.

**Putting C Library in Flash** When compiling for ESP32 revisions older than ECO3 (`CONFIG_ESP32_REVMIN`), the PSRAM Cache bug workaround (`CONFIG_SPIRAM_CACHE_WORKAROUND`) option is enabled, and the C library functions normally located in ROM are recompiled with the workaround and placed into IRAM instead. For most applications, it is safe to move many of the C library functions into flash, reclaiming some IRAM. Corresponding options include:
• `CONFIG_SPIRAM_CACHE_LIBJMP_IN_IRAM`: affects the functions `longjmp` and `setjmp`.
• `CONFIG_SPIRAM_CACHE_LIBMATH_IN_IRAM`: affects the functions `abs`, `div`, `labs`, `ldiv`, `quorem`, `fpclassify` and `nan`.
• `CONFIG_SPIRAM_CACHE_LIBNUMPARSER_IN_IRAM`: affects the functions `utoa`, `itoa`, `atoi`, `atol`, `strtol`, and `strtof`.
• `CONFIG_SPIRAM_CACHE_LIBIO_IN_IRAM`: affects the functions `wcrthost`, `fwrite`, `wbuf`, `wsetup`, `fpread`, `memchr`, `memcpy`, `memmove`, `strftime`, `strchr`, `strcoll`, `strcspn`, `strdup`, `strndup`, `strlcat`, `strlcpy`, `strlstr`, `strncasecmp`, `strncpy`, `strndup`, `strchr`, `strstr`, `strrchr`, `strspn`, `strtok`, and \`\`strtok\`.
• `CONFIG_SPIRAM_CACHE_LIBTIME_IN_IRAM`: affects the functions `asctime`, `asctime_r`, `ctime`, `ctime_r`, `lcltime`, `lcltime_r`, `gmtime`, `gmtime_r`, `strftime`, `mktime`, `tzone`, `tzone_r`, `tzset`, `time`, `getztime`, `systimes`, `month_lengths`, `timelocal`, `tzvars`, `tzlock`, `tzaux`, and `strptime`.
• `CONFIG_SPIRAM_CACHE_LIBCHAR_IN_IRAM`: affects the functions `ctype_`, `toupper`, `tolower`, `tolower`, `toascii`, `strcpyp`, `bzero`, `isalnum`, `isalpha`, `isblank`, `iscntrl`, `isdigit`, `isspace`, `isgraph`, `islower`, `ispunct`, `isspace`, and `isupper`.
• `CONFIG_SPIRAM_CACHE_LIBMEM_IN_IRAM`: affects the functions `memccpy`, `memchr`, `memmove`, and `memrchr`.
• `CONFIG_SPIRAM_CACHE_LIBSTR_IN_IRAM`: affects the functions `strcasestr`, `strchr`, `strcoll`, `strcspn`, `strdup`, `strndup`, `strlcat`, `strlcpy`, `strlstr`, `strncasecmp`, `strncmp`, `strncpy`, `strndup`, `strlup`, `strlstr`, `strsep`, `strspn`, `strstr`, `strtok`, `strtok_r`, and \`\`strtok\`.
• `CONFIG_SPIRAM_CACHE_LIBBRAND_IN_IRAM`: affects the functions `srand`, `rand`, and `rand_r`.
• `CONFIG_SPIRAM_CACHE_LIBENV_IN_IRAM`: affects the functions `environ`, `envlock`, and `getenv`.
• `CONFIG_SPIRAM_CACHE_LIBFILE_IN_IRAM`: affects the functions `lock`, `isatty`, `fcntl`, `open`, `close`, `creat`, `read`, `rshift`, `sbbrk`, `stdio`, `sysssbrk`, `sysclclose`, `sysopen`, `create`, `sysread`, `syswrite`, `impure`, `fwalk`, and `findfp`.
• `CONFIG_SPIRAM_CACHE_LIBMISC_IN_IRAM`: affects the functions `raise` and `system`.

The exact amount of IRAM saved will depend on how much C library code is actually used by the application. In addition, the following options may be used to move more of the C library code into flash, however note that this may result in reduced performance. Be careful not to use the C library function allocated with `ESP_INTR_FLAG_IRAM` flag from interrupts when cache is disabled, refer to `IRAM-Safe Interrupt Handlers` for more details. For these reasons, the functions `itoa`, `memccpy`, `memcpy`, `memset`, `strcat`, `strchr`, and `strlen` are always put in IRAM.

**Note:** Moving frequently-called functions from IRAM to flash may increase their execution time.

**Note:** Other configuration options exist that will increase IRAM usage by moving some functionality into IRAM, usually for performance, but the default option is not to do this. These are not listed here. The IRAM size impact of enabling these options is usually noted in the configuration item help text.

### 4.25 Reproducible Builds

#### 4.25.1 Introduction

ESP-IDF build system supports for reproducible builds.

When reproducible builds are enabled, the application built with ESP-IDF doesn’t depend on the build environment. Both the .elf file and .bin file of the application remains exactly the same, even if the following variables change:

- Directory where the project is located
- Directory where ESP-IDF is located (IDF\_PATH)
- Build time
4.25.2 Reasons for non-reproducible builds

There are several reasons why an application may depend on the build environment, even when the same source code and tools versions are used.

- In C code, `__FILE__` preprocessor macro is expanded to the full path of the source file.
- `__DATE__` and `__TIME__` preprocessor macros are expanded to compilation date and time.
- When the compiler generates object files, it adds sections with debug information. These sections help debuggers, like GDB, to locate the source code which corresponds to a particular location in the machine code. These sections typically contain paths of relevant source files. These paths may be absolute, and will include the path to ESP-IDF or to the project.

There are also other possible reasons, such as unstable order of inputs and non-determinism in the build system.

4.25.3 Enabling reproducible builds in ESP-IDF

Reproducible builds can be enabled in ESP-IDF using `CONFIG_APP_REPRODUCIBLE_BUILD` option. This option is disabled by default. It can be enabled in `menuconfig`.

The option may also be added into `sdkconfig.defaults`. If adding the option into `sdkconfig.defaults`, delete the `sdkconfig` file and run the build again. See Custom Sdkconfig Defaults for more information.

4.25.4 How reproducible builds are achieved

ESP-IDF achieves reproducible builds using the following measures:

- In ESP-IDF source code, `__DATE__` and `__TIME__` macros are not used when reproducible builds are enabled. Note, if the application source code uses these macros, the build will not be reproducible.
- ESP-IDF build system passes a set of `-fmacro-prefix-map` and `-fdebug-prefix-map` flags to replace base paths with placeholders:
  - Path to ESP-IDF is replaced with `/IDF`
  - Path to the project is replaced with `/IDF_PROJECT`
  - Path to the build directory is replaced with `/IDF_BUILD`
  - Paths to components are replaced with `/COMPONENT_NAME_DIR` (where `NAME` is the name of the component)
- Build date and time are not included into the application metadata structure if `CONFIG_APP_REPRODUCIBLE_BUILD` is enabled.
- ESP-IDF build system ensures that source file lists, component lists and other sequences are sorted before passing them to CMake. Various other parts of the build system, such as the linker script generator also perform sorting to ensure that same output is produced regardless of the environment.

4.25.5 Reproducible builds and debugging

When reproducible builds are enabled, file names included in debug information sections are altered as shown in the previous section. Due to this fact, the debugger (GDB) is not able to locate the source files for the given code location.

This issue can be solved using GDB `set substitute-path` command. For example, by adding the following command to GDB init script, the altered paths can be reverted to the original ones:

```
set substitute-path /COMPONENT_FREERTOS_DIR /home/user/esp/esp-idf/components/...freertos
```

ESP-IDF build system generates a file with the list of such `set substitute-path` commands automatically during the build process. The file is called `prefix_map_gdbinit` and is located in the project build directory.

When `idf.py gdb` is used to start debugging, this additional gdbinit file is automatically passed to GDB. When launching GDB manually or from and IDE, please pass this additional gdbinit script to GDB using `-x build/prefix_map_gdbinit` argument.
4.25.6 Factors which still affect reproducible builds

Note that the built application still depends on:

- ESP-IDF version
- Versions of the build tools (CMake, Ninja) and the cross-compiler

_IDF Docker Image can be used to ensure that these factors do not affect the build.

4.26 RF Calibration

ESP32 supports three RF calibration methods during RF initialization:

1. Partial calibration
2. Full calibration
3. No calibration

4.26.1 Partial Calibration

During RF initialization, the partial calibration method is used by default for RF calibration. It is done based on the full calibration data which is stored in the NVS. To use this method, please go to menuconfig and enable _CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE_.

4.26.2 Full Calibration

Full calibration is triggered in the following conditions:

1. NVS does not exist.
2. The NVS partition to store calibration data has been erased.
3. Hardware MAC address has changed.
4. PHY library version has changed.
5. The RF calibration data loaded from the NVS partition is broken.

Full calibration takes 100 ms longer than the partial calibration method. If boot duration is not of critical importance to the application, the full calibration method is recommended. To switch to the full calibration method, go to menuconfig and disable _CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE_. If you use the default method of RF calibration, there are two ways to add the function of triggering full calibration as a last-resort remedy.

1. Erase the NVS partition if you do not mind all of the data stored in the NVS partition is erased. That is indeed the easiest way.
2. Call API _esp_phy_erase_cal_data_in_nvs()_ before initializing Wi-Fi and Bluetooth®/Bluetooth Low Energy based on some conditions (e.g., an option provided in some diagnostic mode). In this case, only the PHY namespace of the NVS partition is erased.

4.26.3 No Calibration

The no calibration method is only used when the device wakes up from Deep-sleep mode.

4.26.4 PHY Initialization Data

The PHY initialization data is used for RF calibration. There are two ways to get the PHY initialization data.

One is to use the default initialization data which is located in the header file components/esp_phy/esp32/include/phy_init_data.h. It is embedded into the application binary after compiling and
then stored into read-only memory (DROM). To use the default initialization data, please go to menuconfig and disable CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION.

An alternative is to store the initialization data in a PHY data partition. A PHY data partition is included in the default partition table. However, when using a custom partition table, please ensure that a PHY data partition (type: data, subtype: phy) is included in the custom partition table. Whether you are using a custom partition table or the default partition table, if initialization data is stored in a partition, it has to be flashed there, otherwise a runtime error occurs. If you want to use initialization data stored in a partition, go to menuconfig and enable the option CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION.

### 4.26.5 API Reference

#### Header File

- components/esp_phy/include/esp_phy_init.h

#### Functions

```c
const esp_phy_init_data_t *esp_phy_get_init_data(void)
```

Get PHY init data.

* If “Use a partition to store PHY init data” option is set in menuconfig, This function will load PHY init data from a partition. Otherwise, PHY init data will be compiled into the application itself, and this function will return a pointer to PHY init data located in read-only memory (DROM).

* If “Use a partition to store PHY init data” option is enabled, this function may return NULL if the data loaded from flash is not valid.

**Note:** Call esp_phy_release_init_data to release the pointer obtained using this function after the call to esp_wifi_init.

```c
void esp_phy_release_init_data(const esp_phy_init_data_t *data)
```

Release PHY init data.

* Parameters `data` — pointer to PHY init data structure obtained from esp_phy_get_init_data function

```c
esp_err_t esp_phy_load_cal_data_from_nvs(esp_phy_calibration_data_t *out_cal_data)
```

Function called by esp_phy_load_cal_and_init to load PHY calibration data.

* This is a convenience function which can be used to load PHY calibration data from NVS. Data can be stored to NVS using esp_phy_store_cal_data_to_nvs function.

* If calibration data is not present in the NVS, or data is not valid (was obtained for a chip with a different MAC address, or obtained for a different version of software), this function will return an error.

* Parameters `out_cal_data` — pointer to calibration data structure to be filled with loaded data.

* Returns ESP_OK on success

```c
esp_err_t esp_phy_store_cal_data_to_nvs(const esp_phy_calibration_data_t *cal_data)
```

Function called by esp_phy_load_cal_and_init to store PHY calibration data.

* This is a convenience function which can be used to store PHY calibration data to the NVS. Calibration data is returned by esp_phy_load_cal_and_init function. Data saved using this function to the NVS can later be loaded using esp_phy_store_cal_data_to_nvs function.

* Parameters `cal_data` — pointer to calibration data which has to be saved.
### Chapter 4. API Guides

**Returns** ESP_OK on success

`esp_err_t esp_phy_erase_cal_data_in_nvs(void)`

Erase PHY calibration data which is stored in the NVS.

This is a function which can be used to trigger full calibration as a last-resort remedy if partial calibration is used. It can be called in the application based on some conditions (e.g. an option provided in some diagnostic mode).

**Returns** ESP_OK on success
**Returns** others on fail. Please refer to NVS API return value error number.

```c
void esp_phy_enable (esp_phy_modem_t modem)
```

Enable PHY and RF module.

PHY and RF module should be enabled in order to use WiFi or BT. Now PHY and RF enabling job is done automatically when start WiFi or BT. Users should not call this API in their application.

**Parameters**
- `modem` - the modem to call the phy enable.

```c
void esp_phy_disable (esp_phy_modem_t modem)
```

Disable PHY and RF module.

PHY module should be disabled in order to shutdown WiFi or BT. Now PHY and RF disabling job is done automatically when stop WiFi or BT. Users should not call this API in their application.

**Parameters**
- `modem` - the modem to call the phy disable.

```c
void esp_phy_load_cal_and_init (void)
```

Load calibration data from NVS and initialize PHY and RF module.

```c
void esp_phy_modem_init (void)
```

Initialize backup memory for Phy power up/down.

```c
void esp_phy_modem_deinit (void)
```

Deinitialize backup memory for Phy power up/down Set phy_init_flag if all modems deinit on ESP32C3.

```c
void esp_phy_common_clock_enable (void)
```

Enable WiFi/BT common clock.

```c
void esp_phy_common_clock_disable (void)
```

Disable WiFi/BT common clock.

```c
int64_t esp_phy_rf_get_on_ts (void)
```

Get the time stamp when PHY/RF was switched on.

**Returns**
- return 0 if PHY/RF is never switched on.
- Otherwise return time in microsecond since boot when phy/RF was last switched on

```c
esp_err_t esp_phy_update_country_info (const char *country)
```

Update the corresponding PHY init type according to the country code of Wi-Fi.

**Parameters**
- `country` - country code

**Returns**
- ESP_OK on success.
- esp_err_t code describing the error on fail
Chapter 4. API Guides

char *get_phy_version_str (void)
    Get PHY lib version.

    Returns PHY lib version.

void phy_init_param_set (uint8_t param)
    Set PHY init parameters.

    Parameters param -- is 1 means combo module

void phy_wifi_enable_set (uint8_t enable)
    Wi-Fi RX enable.

    Parameters enable -- True for enable wifi receiving mode as default, false for closing wifi receiving mode as default.

Structures

struct esp_phy_init_data_t
    Structure holding PHY init parameters.

    Public Members

    uint8_t params[128]
        opaque PHY initialization parameters

struct esp_phy_calibration_data_t
    Opaque PHY calibration data.

    Public Members

    uint8_t version[4]
        PHY version

    uint8_t mac[6]
        The MAC address of the station

    uint8_t opaque[1894]
        calibration data

Enumerations

enum esp_phy_modem_t
    PHY enable or disable modem.

    Values:

    enumerator PHY_MODEM_WIFI
        PHY modem WIFI
enumerator **PHY_MODEM_BT**

PHY modem BT

enumerator **PHY_MODEM_IEEE802154**

PHY modem IEEE802154

**enum esp_phy_calibration_mode_t**

PHY calibration mode.

**Values:**

enumerator **PHY_RF_CAL_PARTIAL**

Do part of RF calibration. This should be used after power-on reset.

enumerator **PHY_RF_CAL_NONE**

Don’t do any RF calibration. This mode is only suggested to be used after deep sleep reset.

enumerator **PHY_RF_CAL_FULL**

Do full RF calibration. Produces best results, but also consumes a lot of time and current. Suggested to be used once.

**Header File**

- components/esp_phy/include/esp_phy_cert_test.h

**Functions**

void **esp_wifi_power_domain_on** (void)

Wifi power domain power on.

void **esp_wifi_power_domain_off** (void)

Wifi power domain power off.

void **esp_phy_rftest_config** (uint8_t conf)

Environment variable configuration.

**Parameters**

- **conf** – Set to 1 to enter RF test mode.

void **esp_phy_rftest_init** (void)

RF initialization configuration.

void **esp_phy_tx_contin_en** (bool contin_en)

TX Continuous mode.

**Parameters**

- **contin_en** – Set to true for continuous packet sending, which can be used for certification testing; Set to false to cancel continuous mode, which is the default mode and can be used for WLAN tester.

void **esp_phy_cbw40m_en** (bool en)

HT40/HT20 mode selection.

**Parameters**

- **en** – Set to false to enter 11n HT20 mode; Set to true to enter 11n HT40 mode;
void esp_phy_wifi_tx (uint32_t chan, esp_phy_wifi_rate_t rate, int8_t backoff, uint32_t length_byte, uint32_t packet_delay, uint32_t packet_num)

Wi-Fi TX command.

Parameters
- **chan** – channel setting, 1~14;
- **rate** – rate setting;
- **backoff** – Transmit power attenuation, unit is 0.25dB. For example, 4 means that the power is attenuated by 1dB;
- **length_byte** – TX packet length configuration, indicating PSDU Length, unit is byte;
- **packet_delay** – TX packet interval configuration, unit is us;
- **packet_num** – The number of packets sent, 0 means sending packets continuously, other values represent the number of packets to send.

void esp_phy_test_start_stop (uint8_t value)

Test start/stop command, used to stop transmitting or reciving state.

Parameters **value** – Value should be set to 3 before TX/RX. Set value to 0 to end TX/RX state.

void esp_phy_wifi_rx (uint32_t chan, esp_phy_wifi_rate_t rate)

Wi-Fi RX command.

Parameters
- **chan** – channel setting, 1~14;
- **rate** – rate setting;

void esp_phy_wifi_tx_tone (uint32_t start, uint32_t chan, uint32_t backoff)

Wi-Fi Carrier Wave(CW) TX command.

Parameters
- **start** – enable CW, 1 means transmit, 0 means stop transmitting;
- **chan** – CW channel setting, 1~14;
- **backoff** – CW power attenuation parameter, unit is 0.25dB. 4 indicates the power is attenuated by 1dB.

void esp_phy_ble_tx (uint32_t txpwr, uint32_t chan, uint32_t len, esp_phy_ble_type_t data_type, uint32_t syncw, esp_phy_ble_rate_t rate, uint32_t tx_num_in)

BLE TX command.

Parameters
- **txpwr** – Transmit power level. Tx power is about (level-8)*3 dBm, step is 3dB. Level 8 is around 0 dBm;
- **chan** – channel setting, range is 0~39, corresponding frequency = 2402+chan*2;
- **len** – Payload length setting, range is 0-255, unit is byte, 37 bytes is employed generally;
- **data_type** – Data type setting;
- **syncw** – Packet identification (need to be provided by the packet generator or instrument manufacturer), 0x71764129 is employed generally;
- **rate** – rate setting;
- **tx_num_in** – The number of packets sent, 0 means sending packets continuously, other values represent the number of packets to send.

void esp_phy_ble_rx (uint32_t chan, uint32_t syncw, esp_phy_ble_rate_t rate)

BLE RX command.

Parameters
- **chan** – channel selection, range is 0-39; Channels 0, 1, 2~10 correspond to 2404MHz, 2406MHz, 2408MHz~2424MHz respectively; Channels 11, 12, 13~36 correspond to 2428MHz, 2430MHz, 2432MHz~2478MHz respectively; Channel 37: 2402MHz, Channel 38: 2426MHz, Channel 39: 2480MHz;
- **syncw** – Packet identification (need to be provided by the packet generator or instrument manufacturer), 0x71764129 is employed generally;
- **rate** – rate setting;
void esp_phy_bt_tx_tone (uint32_t start, uint32_t chan, uint32_t power)
BLE Carrier Wave(CW) TX command.

Parameters
• start – enable CW. 1 means transmit, 0 means stop transmitting;
• chan – Single carrier transmission channel selection, range is 0~39, corresponding frequency freq = 2402+chan*2;
• power – CW power attenuation parameter, unit is 0.25dB. 4 indicates the power is attenuated by 1dB.

void esp_phy_get_rx_result (esp_phy_rx_result_t *rx_result)
Get some RX information.

Parameters rx_result – This struct for storing RX information;

Structures

struct esp_phy_rx_result_t
Structure holding PHY RX result.

Public Members

uint32_t phy_rx_correct_count
The number of desired packets received

int phy_rx_rssi
Average RSSI of desired packets

uint32_t phy_rx_total_count
The number of total packets received

uint32_t phy_rx_result_flag
0 means no RX info; 1 means the lastest Wi-Fi RX info; 2 means the lastest BLE RX info.

Enumerations

enum esp_phy_wifi_rate_t
Values:

enumerator PHY_RATE_1M

tenumerator PHY_RATE_2M

tenumerator PHY_RATE_5M

tenumerator PHY_RATE_11M

tenumerator PHY_RATE_6M
enumerator PHY_RATE_9M
enumerator PHY_RATE_12M
enumerator PHY_RATE_18M
enumerator PHY_RATE_24M
enumerator PHY_RATE_36M
enumerator PHY_RATE_48M
enumerator PHY_RATE_54M
enumerator PHY_RATE_MCS0
enumerator PHY_RATE_MCS1
enumerator PHY_RATE_MCS2
enumerator PHY_RATE_MCS3
enumerator PHY_RATE_MCS4
enumerator PHY_RATE_MCS5
enumerator PHY_RATE_MCS6
enumerator PHY_RATE_MCS7
enumerator PHY_WIFI_RATE_MAX

enum esp_phy_ble_rate_t
  Values:
  enumerator PHY_BLE_RATE_1M
  enumerator PHY_BLE_RATE_2M
  enumerator PHY_BLE_RATE_125K
  enumerator PHY_BLE_RATE_500k
  enumerator PHY_BLE_RATE_MAX
enum esp_phy_ble_type_t

Values:

enumerator PHY_BLE_TYPE_1010
enumerator PHY_BLE_TYPE_00001111
enumerator PHY_BLE_TYPE_prbs9
enumerator PHY_BLE_TYPE_00111100
enumerator PHY_BLE_TYPE_MAX

4.27 Security

This guide provides an overview of the overall security features available in Espressif solutions. It is highly recommended to consider this guide while designing the products with Espressif platform and ESP-IDF software stack from the “security” perspective.

4.27.1 Goals

High level security goals are as follows:

1. Preventing untrusted code execution
2. Protecting the identity and integrity of the code stored in the off-chip flash memory
3. Securing device identity
4. Secure storage for confidential data
5. Authenticated and encrypted communication from the device

4.27.2 Platform Security

Secure Boot

Secure Boot feature ensures that only authenticated software can execute on the device. Secure boot process forms chain of trust by verifying all mutable software entities involved in the ESP-IDF boot process. Signature verification happens during both boot-up as well as OTA updates.

Please refer to the Secure Boot (v2) Guide for detailed documentation about this feature.

For ESP32 before ECO3, please refer to Secure Boot (v1) Guide.

Important: It is highly recommended that a secure boot feature be enabled on all production devices.

Secure Boot Best Practices

• Generate the signing key on a system with a quality source of entropy.
• Always keep the signing key private. A leak of this key will compromise the Secure Boot system.
• Do not allow any third party to observe any aspects of the key generation or signing process using espsecure.py. Both processes are vulnerable to timing or other side-channel attacks.
• Ensure that all security eFuses have been correctly programmed, includes disabling of the debug interfaces, non-required boot mediums (e.g., UART DL mode) etc.
Chapter 4. API Guides

Flash Encryption

Flash Encryption feature helps to encrypt the contents on the off-chip flash memory and thus provides the "confidentiality" aspect to the software or data stored in the flash memory.

Please refer to the Flash Encryption Guide for detailed documentation about this feature.

Flash Encryption Best Practices

- It is recommended to use Flash Encryption release mode for the production use-cases.
- It is recommended to have a unique flash encryption key per device.
- Enable Secure Boot as an extra layer of protection, and to prevent an attacker from selectively corrupting any part of the flash before boot.

Debug Interfaces

JTAG

- JTAG interfaces stays disabled if any of the security features are enabled, please refer to JTAG with Flash Encryption or Secure Boot for more information.
- JTAG interface can also be disabled in the absence of any other security features using eFuse API.

UART DL Mode

For ESP32 ECO3 case, UART Download mode stays disabled if any of the security features are enabled in their release configuration. Alternatively, it can also be disabled by calling esp_efuse_disable_rom_download_mode() at runtime.

Important: If UART Download mode is disabled then esptool cannot work on the device.

4.27.3 Network Security

Wi-Fi

In addition to the traditional security methods (WEP/WPA-TKIP/WPA2-CCMP), Wi-Fi driver in ESP-IDF also supports additional state-of-the-art security protocols. Please refer to the Wi-Fi Security for detailed documentation.

TLS (Transport Layer Security)

It is recommended to use TLS (Transport Layer Security) in all external communications, e.g., cloud communication, OTA updates etc. from the ESP device. ESP-IDF supports mbedTLS as the official TLS stack.

TLS is default integrated in ESP HTTP Client, ESP HTTPS Server and several other components that ship with ESP-IDF.

Note: It is recommended to use ESP-IDF protocol components in their default configuration which has been ensured to be secure. Disabling HTTPS and similar security critical configurations should be avoided.

ESP-TLS Abstraction

ESP-IDF provides an abstraction layer for most used TLS functionalities and hence it is recommended that an application makes use of the API exposed by ESP-TLS.

TLS Server verification section highlights diverse ways in which the identity of server could be established on the device side.
Chapter 4. API Guides

ESP Certificate Bundle  The ESP x509 Certificate Bundle API provides an easy way to include a bundle of custom x509 root certificates for TLS server verification. The certificate bundle is the easiest way to verify the identity of almost all standard TLS servers.

**Important:** It is highly recommended to verify the identity of the server (based on X.509 certificates) to avoid establishing communication with the fake server.

4.27.4 Product Security

Secure Provisioning

Secure Provisioning refers to a process of secure on-boarding of the ESP device on to the Wi-Fi network. This mechanism also allows provision of additional custom configuration data during the initial provisioning phase from the provisioning entity (e.g., Smartphone).

ESP-IDF provides various security schemes to establish a secure session between ESP and the provisioning entity, they are highlighted at Security Schemes.

Please refer to the Wi-Fi Provisioning documentation for details and example code for this feature.

**Note:** Espressif provides Android and iOS Phone Apps along with their sources so that it could be easy to further customize them as per the product requirement.

Secure OTA (Over-the-air) Updates

- OTA Updates must happen over secure transport, e.g., HTTPS.
- ESP-IDF provides a simplified abstraction layer ESP HTTPS OTA for this.
- If Secure Boot is enabled then server should host the signed application image.
- If Flash Encryption is enabled then no additional steps are required on the server side, encryption shall be taken care on the device itself during flash write.
- OTA update Rollback Process can help to switch the application as active only after its functionality has been verified.

Anti-Rollback Protection  Anti-rollback protection feature ensures that device only executes application that meets the security version criteria as stored in its eFuse. So even though the application is trusted and signed by legitimate key it may contain some revoked security feature or credential and hence device must reject any such application.

ESP-IDF allows this feature for the application only and it’s managed through 2nd stage bootloader. The security version is stored in the device eFuse and it’s compared against the application image header during both bootup and over-the-air updates.

Please see more information to enable this feature in the Anti-rollback guide.

Encrypted Firmware Distribution  Encrypted firmware distribution during over-the-air updates ensure that the application stays encrypted in transit from server to the the device. This can act as an additional layer of protection on top of the TLS communication during OTA updates and protect the identity of the application.

Please see working example for this documented in OTA Upgrades with Pre-Encrypted Firmware section.

Secure Storage

Secure storage refers to the application specific data that can be stored in a secure manner on the device (off-chip flash memory). This is typically read-write flash partition and holds device specific configuration data e.g., Wi-Fi credentials.
ESP-IDF provides “NVS (Non-volatile Storage)” management component which allows encrypted data partitions. This feature is tied with the platform Flash Encryption feature described earlier.

Please refer to the NVS Encryption for detailed documentation on the working and instructions to enable this feature.

**Important:** By default, ESP-IDF components writes the device specific data into the default NVS partition (includes Wi-Fi credentials too) and it is recommended to protect this data using “NVS Encryption” feature.

### Secure Device Control

ESP-IDF provides capability to control an ESP device over Wi-Fi + HTTP or BLE in a secure manner using ESP Local Control component.

Please refer to the ESP Local Control for detailed documentation about this feature.

#### 4.27.5 Security Policy

ESP-IDF GitHub repository has attached Security Policy Brief.

**Advisories**

- Espressif publishes critical Security Advisories on the website, this includes both hardware and software related.
- ESP-IDF software components specific advisories are published through the GitHub repository.

**Software Updates**

Critical security issues in the ESP-IDF components, 3rd party libraries are fixed as and when we find them or when they are reported to us. Gradually, we make the fixes available in all applicable release branches in ESP-IDF.

Applicable security issues and CVEs for the ESP-IDF components, 3rd party libraries are mentioned in the ESP-IDF release notes.

**Important:** We recommend periodically updating to the latest bugfix version of the ESP-IDF release to have all critical security fixes available.

### 4.28 Secure Boot

**Important:** All references in this document are related to Secure Boot V1 (The AES based Secure Boot Scheme). ESP32 Revision 3 onwards, the preferred secure boot scheme is Secure Boot V2. Please refer to Secure Boot V2 document for ESP32 Revision 3 or ESP32-S2.

Secure Boot is a feature for ensuring only your code can run on the chip. Data loaded from flash is verified on each reset.

Secure Boot is separate from the Flash Encryption feature, and you can use secure boot without encrypting the flash contents. However, for a secure environment both should be used simultaneously. See Secure Boot & Flash Encryption for more details.
**Important:** Enabling secure boot limits your options for further updates of your ESP32. Make sure to read this document thoroughly and understand the implications of enabling secure boot.

### 4.28.1 Background

- Most data is stored in flash. Flash access does not need to be protected from physical access in order for secure boot to function, because critical data is stored (non-software-accessible) in Efuses internal to the chip.
- Efuses are used to store the secure bootloader key (in efuse BLOCK2), and also a single Efuse bit (ABS_DONE_0) is burned (written to 1) to permanently enable secure boot on the chip. For more details on efuses, see [ESP32 Technical Reference Manual > eFuse Controller (eFuse)](ESP32 Technical Reference Manual).
- To understand the secure boot process, first familiarise yourself with the standard [ESP-IDF boot process](ESP-IDF boot process).
- Both stages of the boot process (initial software bootloader load, and subsequent partition & app loading) are verified by the secure boot process, in a “chain of trust” relationship.

### 4.28.2 Secure Boot Process Overview

This is a high level overview of the secure boot process. Step by step instructions are supplied under How To Enable Secure Boot. Further in-depth details are supplied under Technical Details:

1. The options to enable secure boot are provided in the Project Configuration Menu, under “Secure Boot Configuration”.
2. Secure Boot defaults to signing images and partition table data during the build process. The “Secure boot private signing key” config item is a file path to an ECDSA public/private key pair in a PEM format file.
3. The software bootloader image is built by esp-idf with secure boot support enabled and the public key (signature verification) portion of the secure boot signing key compiled in. This software bootloader image is flashed at offset 0x1000.
4. On first boot, the software bootloader follows the following process to enable secure boot:
   - Hardware secure boot support generates a device secure bootloader key (generated via hardware RNG, then stored read/write protected in efuse), and a secure digest. The digest is derived from the key, an IV, and the bootloader image contents.
   - The secure digest is flashed at offset 0x0 in the flash.
   - Depending on Secure Boot Configuration, efuses are burned to disable JTAG and the ROM BASIC interpreter (it is strongly recommended these options are turned on.)
   - Bootloader permanently enables secure boot by burning the ABS_DONE_0 efuse. The software bootloader then becomes protected (the chip will only boot a bootloader image if the digest matches.)
5. On subsequent boots the ROM bootloader sees that the secure boot efuse is burned, reads the saved digest at 0x0 and uses hardware secure boot support to compare it with a newly calculated digest. If the digest does not match then booting will not continue. The digest and comparison are performed entirely by hardware, and the calculated digest is not readable by software. For technical details see [Secure Boot Hardware Support](Secure Boot Hardware Support).
6. When running in secure boot mode, the software bootloader uses the secure boot signing key (the public key of which is embedded in the bootloader itself, and therefore validated as part of the bootloader) to verify the signature appended to all subsequent partition tables and app images before they are booted.

### 4.28.3 Keys

The following keys are used by the secure boot process:

- “secure bootloader key” is a 256-bit AES key that is stored in Efuse block 2. The bootloader can generate this key itself from the internal hardware random number generator, the user does not need to supply it (it is optionally possible to supply this key, see [Re-Flashable Software Bootloader](Re-Flashable Software Bootloader)). The Efuse holding this key is read & write protected (preventing software access) before secure boot is enabled.
  - By default, the Efuse Block 2 Coding Scheme is “None” and a 256 bit key is stored in this block. On some ESP32s, the Coding Scheme is set to 3/4 Encoding (CODING_SCHEME efuse has value 1) and a 192 bit key must be stored in this block.
For more details, see ESP32 Technical Reference Manual > eFuse Controller (eFuse) > System Parameter coding_scheme [PDF].

The algorithm operates on a 256 bit key in all cases, 192 bit keys are extended by repeating some bits (details).
- “secure boot signing key” is a standard ECDSA public/private key pair (see Image Signing Algorithm) in PEM format.
  - The public key from this key pair (for signature verification but not signature creation) is compiled into the software bootloader and used to verify the second stage of booting (partition table, app image) before booting continues. The public key can be freely distributed, it does not need to be kept secret.
  - The private key from this key pair must be securely kept private, as anyone who has this key can authenticate to any bootloader that is configured with secure boot and the matching public key.

### 4.28.4 Bootloader Size

Enabling Secure boot and/or flash encryption will increase the size of bootloader, which might require updating partition table offset. See **Bootloader Size**.

### 4.28.5 How To Enable Secure Boot

1. Open the Project Configuration Menu, navigate to “Secure Boot Configuration” and select the option “One-time Flash”. (To understand the alternative “Reflashable” choice, see Re-Flashable Software Bootloader.)
2. Select a name for the secure boot signing key. This option will appear after secure boot is enabled. The file can be anywhere on your system. A relative path will be evaluated from the project directory. The file does not need to exist yet.
3. Set other menuconfig options (as desired). Pay particular attention to the “Bootloader Config” options, as you can only flash the bootloader once. Then exit menuconfig and save your configuration
4. The first time you run make, if the signing key is not found then an error message will be printed with a command to generate a signing key via espsecure.py generate_signing_key.

**Important:** A signing key generated this way will use the best random number source available to the OS and its Python installation (/dev/urandom on OSX/Linux and CryptGenRandom() on Windows). If this random number source is weak, then the private key will be weak.

**Important:** For production environments, we recommend generating the keypair using openssl or another industry standard encryption program. See **Generating Secure Boot Signing Key** for more details.

5. Run idf.py bootloader to build a secure boot enabled bootloader. The build output will include a prompt for a flashing command, using esptool.py write_flash.
6. When you’re ready to flash the bootloader, run the specified command (you have to enter it yourself, this step is not performed by make) and then wait for flashing to complete. **Remember this is a one time flash, you can’t change the bootloader after this!**
7. Run idf.py flash to build and flash the partition table and the just-built app image. The app image will be signed using the signing key you generated in step 4.

**Note:** idf.py flash doesn’t flash the bootloader if secure boot is enabled.

8. Reset the ESP32 and it will boot the software bootloader you flashed. The software bootloader will enable secure boot on the chip, and then it verifies the app image signature and boots the app. You should watch the serial console output from the ESP32 to verify that secure boot is enabled and no errors have occurred due to the build configuration.
**Note:** Secure boot won’t be enabled until after a valid partition table and app image have been flashed. This is to prevent accidents before the system is fully configured.

**Note:** If the ESP32 is reset or powered down during the first boot, it will start the process again on the next boot.

9. On subsequent boots, the secure boot hardware will verify the software bootloader has not changed (using the secure bootloader key) and then the software bootloader will verify the signed partition table and app image (using the public key portion of the secure boot signing key).

### 4.28.6 Re-Flashable Software Bootloader

Configuration “Secure Boot: One-Time Flash” is the recommended configuration for production devices. In this mode, each device gets a unique key that is never stored outside the device.

However, an alternative mode *Secure Boot: Reflashable* is also available. This mode allows you to supply a binary key file that is used for the secure bootloader key. As you have the key file, you can generate new bootloader images and secure boot digests for them.

In the esp-idf build process, this 256-bit key file is derived from the ECDSA app signing key generated by the user (see the *Generating Secure Boot Signing Key* step below). This private key’s SHA-256 digest is used as the secure bootloader key in efuse (as-is for Coding Scheme None, or truncate to 192 bytes for 3/4 Encoding). This is a convenience so you only need to generate/protect a single private key.

**Note:** Although it’s possible, we strongly recommend not generating one secure boot key and flashing it to every device in a production environment. The “One-Time Flash” option is recommended for production environments.

To enable a reflashable bootloader:

1. In the *Project Configuration Menu*, select “Bootloader Config” -> CONFIG_SECURE_BOOT -> CONFIG_SECURE_BOOT_V1_ENABLED -> CONFIG_SECURE_BOOTLOADER_MODE -> Reflashable.
2. If necessary, set the CONFIG_SECURE_BOOTLOADER_KEY_ENCODING based on the coding scheme used by the device. The coding scheme is shown in the Features line when esptool.py connects to the chip, or in the espefuse.py summary output.
3. Please follow the steps shown in *Generating Secure Boot Signing Key* to generate signing key. Path of the generated key file must be specified in “Secure Boot Configuration” menu.
4. Run idf.py bootloader. A binary key file will be created, derived from the private key that is used for signing. Two sets of flashing steps will be printed - the first set of steps includes an espefuse.py burn_key secure_boot_v1 path_to/secure-bootloader-key-xxx.bin command which is used to write the bootloader key to efuse. (Flashing this key is a one-time-only process.) The second set of steps can be used to reflash the bootloader with a pre-calculated digest (generated during the build process).
5. Resume from *Step 6 of the one-time flashing process*, to flash the bootloader and enable secure boot. Watch the console log output closely to ensure there were no errors in the secure boot configuration.

### 4.28.7 Generating Secure Boot Signing Key

The build system will prompt you with a command to generate a new signing key via espsecure.py generate_signing_key. This uses the python-ecdsa library, which in turn uses Python’s os.urandom() as a random number source.

The strength of the signing key is proportional to (a) the random number source of the system, and (b) the correctness of the algorithm used. For production devices, we recommend generating signing keys from a system with a quality entropy source, and using the best available EC key generation utilities.

For example, to generate a signing key using the openssl command line:
Chapter 4. API Guides

```
openssl ecparam -name prime256v1 -genkey -noout -out my_secure_boot_signing_key.pem
```

Remember that the strength of the secure boot system depends on keeping the signing key private.

### 4.28.8 Remote Signing of Images

For production builds, it can be good practice to use a remote signing server rather than have the signing key on the build machine (which is the default esp-idf secure boot configuration). The espsecure.py command line program can be used to sign app images & partition table data for secure boot, on a remote system.

To use remote signing, disable the option “Sign binaries during build”. The private signing key does not need to be present on the build system. However, the public (signature verification) key is required because it is compiled into the bootloader (and can be used to verify image signatures during OTA updates.

To extract the public key from the private key:

```
espsecure.py extract_public_key --keyfile PRIVATE_SIGNING_KEY PUBLIC_VERIFICATION_KEY
```

The path to the public signature verification key needs to be specified in the menuconfig under “Secure boot public signature verification key” in order to build the secure bootloader.

After the app image and partition table are built, the build system will print signing steps using espsecure.py:

```
espsecure.py sign_data --keyfile PRIVATE_SIGNING_KEY BINARY_FILE
```

The above command appends the image signature to the existing binary. You can use the -output argument to write the signed binary to a separate file:

```
espsecure.py sign_data --keyfile PRIVATE_SIGNING_KEY --output SIGNED_BINARY_FILE
```

### 4.28.9 Secure Boot Best Practices

- Generate the signing key on a system with a quality source of entropy.
- Keep the signing key private at all times. A leak of this key will compromise the secure boot system.
- Do not allow any third party to observe any aspects of the key generation or signing process using espsecure.py. Both processes are vulnerable to timing or other side-channel attacks.
- Enable all secure boot options in the Secure Boot Configuration. These include flash encryption, disabling of JTAG, disabling BASIC ROM interpreter, and disabling the UART bootloader encrypted flash access.
- Use secure boot in combination with flash encryption to prevent local readout of the flash contents.

### 4.28.10 Technical Details

The following sections contain low-level reference descriptions of various secure boot elements:

**Secure Boot Hardware Support**

The first stage of secure boot verification (checking the software bootloader) is done via hardware. The ESP32’s Secure Boot support hardware can perform three basic operations:

1. Generate a random sequence of bytes from a hardware random number generator.
2. Generate a digest from data (usually the bootloader image from flash) using a key stored in Efuse block 2. The key in Efuse can (& should) be read/write protected, which prevents software access. For full details of this algorithm see Secure Bootloader Digest Algorithm. The digest can only be read back by software if Efuse ABS_DONE_0 is not burned (ie still 0).
3. Generate a digest from data (usually the bootloader image from flash) using the same algorithm as step 2 and compare it to a pre-calculated digest supplied in a buffer (usually read from flash offset 0x0). The hardware returns a true/false comparison without making the digest available to software. This function is available even when Efuse ABS_DONE_0 is burned.

**Secure Bootloader Digest Algorithm**

Starting with an “image” of binary data as input, this algorithm generates a digest as output. The digest is sometimes referred to as an “abstract” in hardware documentation.

For a Python version of this algorithm, see the espsecure.py tool in the components/esptool_py directory (specifically, the `digest_secure_bootloader` command).

Items marked with (*) are to fulfill hardware restrictions, as opposed to cryptographic restrictions.

1. Read the AES key from efuse block 2, in reversed byte order. If Coding Scheme is set to 3/4 Encoding, extend the 192 bit key to 256 bits using the same algorithm described in Flash Encryption Algorithm.
2. Prefix the image with a 128 byte randomly generated IV.
3. If the image length is not modulo 128, pad the image to a 128 byte boundary with 0xFF. (*)
4. For each 16 byte plaintext block of the input image:
   - Reverse the byte order of the plaintext input block (*)
   - Apply AES256 in ECB mode to the plaintext block. - Reverse the byte order of the ciphertext output block. (*)
   - Append to the overall ciphertext output.
5. Byte-swap each 4 byte word of the ciphertext (*)
6. Calculate SHA-512 of the ciphertext.

Output digest is 192 bytes of data: The 128 byte IV, followed by the 64 byte SHA-512 digest.

**Image Signing Algorithm**

Deterministic ECDSA as specified by RFC 6979.

- Curve is NIST256p (openssl calls this curve “prime256v1”, it is also sometimes called secp256r1).
- Hash function is SHA256.
- Key format used for storage is PEM.
  - In the bootloader, the public key (for signature verification) is flashed as 64 raw bytes.
- Image signature is 68 bytes - a 4 byte version word (currently zero), followed by a 64 bytes of signature data. These 68 bytes are appended to an app image or partition table data.

**Manual Commands**

Secure boot is integrated into the esp-idf build system, so `make` will automatically sign an app image if secure boot is enabled. `idf.py bootloader` will produce a bootloader digest if menuconfig is configured for it.

However, it is possible to use the `espsecure.py` tool to make standalone signatures and digests.

To sign a binary image:

```
espsecure.py sign_data --keyfile ./my_signing_key.pem --output ./image_signed.bin
```

Keyfile is the PEM file containing an ECDSA private signing key.

To generate a bootloader digest:

```
espsecure.py digest_secure_bootloader --keyfile ./securebootkey.bin --output ./bootloader-digest.bin build/bootloader/bootloader.bin
```

Keyfile is the 32 byte raw secure boot key for the device.

The output of the `espsecure.py digest_secure_bootloader` command is a single file which contains both the digest and the bootloader appended to it. To flash the combined digest plus bootloader to the device:
4.28.11 Secure Boot & Flash Encryption

If secure boot is used without Flash Encryption, it is possible to launch “time-of-check to time-of-use” attack, where flash contents are swapped after the image is verified and running. Therefore, it is recommended to use both the features together.

4.28.12 Signed App Verification Without Hardware Secure Boot

The integrity of apps can be checked even without enabling the hardware secure boot option. This option uses the same app signature scheme as hardware secure boot, but unlike hardware secure boot it does not prevent the bootloader from being physically updated. This means that the device can be secured against remote network access, but not physical access. Compared to using hardware Secure Boot this option is much simpler to implement. See How To Enable Signed App Verification for step by step instructions.

An app can be verified on update and, optionally, be verified on boot.

- Verification on update: When enabled, the signature is automatically checked whenever the esp_ota_ops.h APIs are used for OTA updates. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option still adds significant security against network-based attackers by preventing spoofing of OTA updates.
- Verification on boot: When enabled, the bootloader will be compiled with code to verify that an app is signed before booting it. If hardware secure boot is enabled, this option is always enabled and cannot be disabled. If hardware secure boot is not enabled, this option doesn’t add significant security by itself so most users will want to leave it disabled.

How To Enable Signed App Verification

1. Open Project Configuration Menu -> Security features -> Enable CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
2. Bootloader verifies app signatures can be enabled, which verifies app on boot.
3. By default, “Sign binaries during build” will be enabled on selecting “Require signed app images” option, which will sign binary files as a part of build process. The file named in “Secure boot private signing key” will be used to sign the image.
4. If you disable “Sign binaries during build” option then you’ll have to enter path of a public key file used to verify signed images in “Secure boot public signature verification key”. In this case, private signing key should be generated by following instructions in Generating Secure Boot Signing Key; public verification key and signed image should be generated by following instructions in Remote Signing of Images.

4.28.13 Advanced Features

JTAG Debugging

By default, when Secure Boot is enabled then JTAG debugging is disabled via eFuse. The bootloader does this on first boot, at the same time it enables Secure Boot.

See JTAG with Flash Encryption or Secure Boot for more information about using JTAG Debugging with either Secure Boot or signed app verification enabled.

4.29 Secure Boot V2

Important: This document is about Secure Boot V2, supported on ESP32 (ECO 3 onwards)
For ESP32 before ECO3, refer to Secure Boot. It is recommended that users use Secure Boot V2 if they have a chip version that supports it. Secure Boot V2 is safer and more flexible than Secure Boot V1.

Secure Boot V2 uses RSA-PSS based app and bootloader verification. This document can also be used as a reference for signing apps using the RSA-PSS scheme without signing the bootloader.

Secure Boot V2 and RSA scheme (App Signing Scheme) options are available for ESP32 from ECO3 onwards. To use these options in menuconfig, set CONFIG_ESP32_REV_MIN greater than or equal to Rev 3.

### 4.29.1 Background

Secure Boot protects a device from running any unauthorized (i.e., unsigned) code by checking that each piece of software that is being booted is signed. On an ESP32, these pieces of software include the second stage bootloader and each application binary. Note that the first stage bootloader does not require signing as it is ROM code thus cannot be changed.

A RSA based Secure Boot verification scheme (Secure Boot V2) is implemented on ESP32 (ECO 3 onwards).

The Secure Boot process on the ESP32 involves the following steps:

1. When the first stage bootloader loads the second stage bootloader, the second stage bootloader’s RSA-PSS signature is verified. If the verification is successful, the second stage bootloader is executed.
2. When the second stage bootloader loads a particular application image, the application’s RSA-PSS signature is verified. If the verification is successful, the application image is executed.

### 4.29.2 Advantages

- The RSA-PSS public key is stored on the device. The corresponding RSA-PSS private key is kept at a secret place and is never accessed by the device.
- Only one public key can be generated and stored in the chip during manufacturing.
- Same image format and signature verification method is applied for applications and software bootloader.
- No secrets are stored on the device. Therefore, it is immune to passive side-channel attacks (timing or power analysis, etc.)

### 4.29.3 Secure Boot V2 Process

This is an overview of the Secure Boot V2 Process. Instructions how to enable Secure Boot are supplied in section How To Enable Secure Boot V2.

Secure Boot V2 verifies the bootloader image and application binary images using a dedicated signature block. Each image has a separately generated signature block which is appended to the end of the image.

Only one signature block can be appended to the bootloader or application image in ESP32 ECO3.

Each signature block contains a signature of the preceding image as well as the corresponding RSA-3072 public key. For more details about the format, refer to Signature Block Format. A digest of the RSA-3072 public key is stored in the eFuse.

The application image is not only verified on every boot but also on each over the air (OTA) update. If the currently selected OTA app image cannot be verified, the bootloader will fall back and look for another correctly signed application image.

The Secure Boot V2 process follows these steps:

1. On startup, the ROM code checks the Secure Boot V2 bit in the eFuse. If Secure Boot is disabled, a normal boot will be executed. If Secure Boot is enabled, the boot will proceed according to the following steps.
2. The ROM code verifies the bootloader’s signature block (Verifying a Signature Block). If this fails, the boot process will be aborted.
3. The ROM code verifies the bootloader image using the raw image data, its corresponding signature block(s), and the eFuse (Verifying an Image). If this fails, the boot process will be aborted.
4. The ROM code executes the bootloader.
5. The bootloader verifies the application image’s signature block (Verifying a Signature Block). If this fails, the boot process will be aborted.
6. The bootloader verifies the application image using the raw image data, its corresponding signature blocks and the eFuse (Verifying an Image). If this fails, the boot process will be aborted. If the verification fails but another application image is found, the bootloader will then try to verify that other image using steps 5 to 7. This repeats until a valid image is found or no other images are found.
7. The bootloader executes the verified application image.

4.29.4 Signature Block Format

The signature block starts on a 4KB aligned boundary and has a flash sector of its own. The signature is calculated over all bytes in the image including the padding bytes (Secure Padding).

The content of each signature block is shown in the following table:

<table>
<thead>
<tr>
<th>Offset</th>
<th>Size (bytes)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>Magic byte</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Version number byte (currently 0x02), 0x01 is for Secure Boot V1.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Padding bytes, Reserved. Should be zero.</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>SHA-256 hash of only the image content, not including the signature block.</td>
</tr>
<tr>
<td>36</td>
<td>384</td>
<td>RSA Public Modulus used for signature verification. (value ‘n’ in RFC8017).</td>
</tr>
<tr>
<td>420</td>
<td>4</td>
<td>RSA Public Exponent used for signature verification (value ‘e’ in RFC8017).</td>
</tr>
<tr>
<td>424</td>
<td>384</td>
<td>Pre-calculated R, derived from ‘n’.</td>
</tr>
<tr>
<td>808</td>
<td>4</td>
<td>Pre-calculated M*, derived from ‘n’.</td>
</tr>
<tr>
<td>812</td>
<td>384</td>
<td>RSA-PSS Signature result (section 8.1.1 of RFC8017) of image content, computed using following PSS parameters: SHA256 hash, MGF1 function, salt length 32 bytes, default trailer field (0xBC).</td>
</tr>
<tr>
<td>1196</td>
<td>4</td>
<td>CRC32 of the preceding 1196 bytes.</td>
</tr>
<tr>
<td>1200</td>
<td>16</td>
<td>Zero padding to length 1216 bytes.</td>
</tr>
</tbody>
</table>

Note: R and M* are used for hardware-assisted Montgomery Multiplication.

The remainder of the signature sector is erased flash (0xFF) which allows writing other signature blocks after previous signature block.

4.29.5 Secure Padding

In Secure Boot V2 scheme, the application image is padded to the flash MMU page size boundary to ensure that only verified contents are mapped in the internal address space. This is known as secure padding. Signature of the image is calculated after padding and then signature block (4KB) gets appended to the image.

- Default flash MMU page size is 64KB
- Secure padding is applied through the option `--secure-pad-v2` in the `elf2image` conversion using `esptool.py`

Following table explains the Secure Boot V2 signed image with secure padding and signature block appended:
Table 31: Contents of a signed application

<table>
<thead>
<tr>
<th>Offset</th>
<th>Size (KB)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>580</td>
<td>Unsigned application size (as an example)</td>
</tr>
<tr>
<td>580</td>
<td>60</td>
<td>Secure padding (aligned to next 64KB boundary)</td>
</tr>
<tr>
<td>640</td>
<td>4</td>
<td>Signature block</td>
</tr>
</tbody>
</table>

**Note:** Please note that the application image always starts on the next flash MMU page size boundary (default 64KB) and hence the space left over after the signature block shown above can be utilized to store any other data partitions (e.g., nvs).

### 4.29.6 Verifying a Signature Block

A signature block is “valid” if the first byte is 0xe7 and a valid CRC32 is stored at offset 1196. Otherwise it’s invalid.

### 4.29.7 Verifying an Image

An image is “verified” if the public key stored in any signature block is valid for this device, and if the stored signature is valid for the image data read from flash.

1. Compare the SHA-256 hash digest of the public key embedded in the bootloader’s signature block with the digest(s) saved in the eFuses. If public key’s hash doesn’t match any of the hashes from the eFuses, the verification fails.
2. Generate the application image digest and match it with the image digest in the signature block. If the digests don’t match, the verification fails.
3. Use the public key to verify the signature of the bootloader image, using RSA-PSS (section 8.1.2 of RFC8017) with the image digest calculated in step (2) for comparison.

### 4.29.8 Bootloader Size

Enabling Secure boot and/or flash encryption will increase the size of bootloader, which might require updating partition table offset. See Bootloader Size.

In the case when `CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES` is disabled, the bootloader is sector padded (4KB) using the `--pad-to-size` option in `elf2image` command of `esptool`.

### 4.29.9 eFuse usage

ESP32-ECO3:

- ABS_DONE_1 - Enables Secure Boot protection on boot.
- BLK2 - Stores the SHA-256 digest of the public key. SHA-256 hash of public key modulus, exponent, pre-calculated R & M’ values (represented as 776 bytes – offsets 36 to 812 – as per the Signature Block Format) is written to an eFuse key block. The write-protection bit must be set, but the read-protection bit must not.

The key(s) must be readable in order to give software access to it. If the key(s) is read-protected then the software reads the key(s) as all zeros and the signature verification process will fail, and the boot process will be aborted.

Submit Document Feedback
4.29.10 How To Enable Secure Boot V2

1. Open the Project Configuration Menu, in “Security features” set “Enable hardware Secure Boot in bootloader” to enable Secure Boot.

2. For ESP32, Secure Boot V2 is available only ESP32 ECO3 onwards. To view the “Secure Boot V2” option the chip revision should be changed to revision 3 (ESP32- ECO3). To change the chip revision, set “Minimum Supported ESP32 Revision” to Rev 3 in “Component Config” -> “ESP32- Specific”.

3. Specify the path to Secure Boot signing key, relative to the project directory.

4. Select the desired UART ROM download mode in “UART ROM download mode”. By default the UART ROM download mode has been kept enabled in order to prevent permanently disabling it in the development phase, this option is a potentially insecure option. It is recommended to disable the UART download mode for better security.

5. Set other menuconfig options (as desired). Then exit menuconfig and save your configuration.

6. The first time you run idf.py build, if the signing key is not found then an error message will be printed with a command to generate a signing key via espsecure.py generate_signing_key.

Important: A signing key generated this way will use the best random number source available to the OS and its Python installation (/dev/urandom on OSX/Linux and CryptGenRandom() on Windows). If this random number source is weak, then the private key will be weak.

Important: For production environments, we recommend generating the key pair using openssl or another industry standard encryption program. See Generating Secure Boot Signing Key for more details.

7. Run idf.py bootloader to build a Secure Boot enabled bootloader. The build output will include a prompt for a flashing command, using esptool.py write_flash.

8. When you’re ready to flash the bootloader, run the specified command (you have to enter it yourself, this step is not performed by the build system) and then wait for flashing to complete.

9. Run idf.py flash to build and flash the partition table and the just-built app image. The app image will be signed using the signing key you generated in step 6.

Note: idf.py flash doesn’t flash the bootloader if Secure Boot is enabled.

10. Reset the ESP32 and it will boot the software bootloader you flashed. The software bootloader will enable Secure Boot on the chip, and then it verifies the app image signature and boots the app. You should watch the serial console output from the ESP32 to verify that Secure Boot is enabled and no errors have occurred due to the build configuration.

Note: Secure boot won’t be enabled until after a valid partition table and app image have been flashed. This is to prevent accidents before the system is fully configured.

Note: If the ESP32 is reset or powered down during the first boot, it will start the process again on the next boot.

11. On subsequent boots, the Secure Boot hardware will verify the software bootloader has not changed and the software bootloader will verify the signed app image (using the validated public key portion of its appended signature block).

4.29.11 Restrictions after Secure Boot is enabled

- Any updated bootloader or app will need to be signed with a key matching the digest already stored in eFuse.
Chapter 4. API Guides

- After Secure Boot is enabled, no further eFuses can be read protected. *(If Flash Encryption is enabled then the bootloader will ensure that any flash encryption key generated on first boot will already be read protected.)* If `CONFIG_SECURE_BOOT_INSECURE` is enabled then this behavior can be disabled, but this is not recommended.

- Please note that enabling Secure Boot or flash encryption disables the USB-OTG USB stack in the ROM, disallowing updates via the serial emulation or Device Firmware Update (DFU) on that port.

### 4.29.12 Generating Secure Boot Signing Key

The build system will prompt you with a command to generate a new signing key via `espsecure.py generate_signing_key`.

The `--version 2` parameter will generate the RSA 3072 private key for Secure Boot V2. Additionally `--scheme rsa3072` can be passed as well to generate RSA 3072 private key.

The strength of the signing key is proportional to (a) the random number source of the system, and (b) the correctness of the algorithm used. For production devices, we recommend generating signing keys from a system with a quality entropy source, and using the best available RSA-PSS key generation utilities.

For example, to generate a signing key using the openssl command line:

For RSA 3072

```
openssl genrsa -out my_secure_boot_signing_key.pem 3072
```

Remember that the strength of the Secure Boot system depends on keeping the signing key private.

### 4.29.13 Remote Signing of Images

**Signing using espsecure.py**

For production builds, it can be good practice to use a remote signing server rather than have the signing key on the build machine (which is the default esp-idf Secure Boot configuration). The espsecure.py command line program can be used to sign app images & partition table data for Secure Boot, on a remote system.

To use remote signing, disable the option `CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES` and build the firmware. The private signing key does not need to be present on the build system.

After the app image and partition table are built, the build system will print signing steps using espsecure.py:

```
espsecure.py sign_data BINARY_FILE --version 2 --keyfile PRIVATE_SIGNING_KEY
```

The above command appends the image signature to the existing binary. You can use the `--output` argument to write the signed binary to a separate file:

```
espsecure.py sign_data --version 2 --keyfile PRIVATE_SIGNING_KEY --output SIGNED_BINARY_FILE BINARY_FILE
```

**Signing using Pre-calculated Signatures**

If you have valid pre-calculated signatures generated for an image and their corresponding public keys, you can use these signatures to generate a signature sector and append it to the image. Note that the pre-calculated signature should be calculated over all bytes in the image including the secure-padding bytes.

In such cases, the firmware image should be built by disabling the option `CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES`. This image will be secure-padded and to generate a signed binary use the following command:

```
espsecure.py sign_data --version 2 --pub-key PUBLIC_SIGNING_KEY --signature~SIGNATURE_FILE --output SIGNED_BINARY_FILE BINARY_FILE
```
The above command verifies the signature, generates a signature block (refer to Signature Block Format) and appends it to the binary file.

**Signing using an External Hardware Security Module (HSM)**

For security reasons, you might also use an external Hardware Security Module (HSM) to store your private signing key, which cannot be accessed directly but has an interface to generate the signature of a binary file and its corresponding public key.

In such cases, disable the option `CONFIG_SECURE_BOOT_BUILD_SIGNED_BINARIES` and build the firmware. This secure-padded image then can be used to supply the external HSM for generating a signature. Refer to Signing using an External HSM to generate a signed image.

---

**Note:** For all the above three remote signing workflows, the signed binary is written to the filename provided to the `--output` argument.

### 4.29.14 Secure Boot Best Practices

- Generate the signing key on a system with a quality source of entropy.
- Keep the signing key private at all times. A leak of this key will compromise the Secure Boot system.
- Do not allow any third party to observe any aspects of the key generation or signing process using espsecure.py. Both processes are vulnerable to timing or other side-channel attacks.
- Enable all Secure Boot options in the Secure Boot Configuration. These include flash encryption, disabling of JTAG, disabling BASIC ROM interpreter, and disabling the UART bootloader encrypted flash access.
- Use Secure Boot in combination with flash encryption to prevent local readout of the flash contents.

### 4.29.15 Technical Details

The following sections contain low-level reference descriptions of various Secure Boot elements:

**Manual Commands**

Secure boot is integrated into the esp-idf build system, so `idf.py build` will sign an app image and `idf.py bootloader` will produce a signed bootloader if secure signed binaries on build is enabled.

However, it is possible to use the `espsecure.py` tool to make standalone signatures and digests.

To sign a binary image:

```
espsecure.py sign_data --version 2 --keyfile ./my_signing_key.pem --output ./image_→ signed.bin image-unsigned.bin
```

Keyfile is the PEM file containing an RSA-3072 private signing key.

### 4.29.16 Secure Boot & Flash Encryption

If Secure Boot is used without Flash Encryption, it is possible to launch “time-of-check to time-of-use” attack, where flash contents are swapped after the image is verified and running. Therefore, it is recommended to use both the features together.
4.29.17 Signed App Verification Without Hardware Secure Boot

The Secure Boot V2 signature of apps can be checked on OTA update, without enabling the hardware Secure Boot option. This option uses the same app signature scheme as Secure Boot V2, but unlike hardware Secure Boot it does not prevent an attacker who can write to flash from bypassing the signature protection.

This may be desirable in cases where the delay of Secure Boot verification on startup is unacceptable, and/or where the threat model does not include physical access or attackers writing to bootloader or app partitions in flash.

In this mode, the public key which is present in the signature block of the currently running app will be used to verify the signature of a newly updated app. (The signature on the running app isn’t verified during the update process, it’s assumed to be valid.) In this way the system creates a chain of trust from the running app to the newly updated app.

For this reason, it’s essential that the initial app flashed to the device is also signed. A check is run on app startup and the app will abort if no signatures are found. This is to try and prevent a situation where no update is possible.

The app should have only one valid signature block in the first position. Note again that, unlike hardware Secure Boot V2, the signature of the running app isn’t verified on boot. The system only verifies a signature block in the first position and ignores any other appended signatures.

Note: In general, it’s recommended to use full hardware Secure Boot unless certain that this option is sufficient for application security needs.

How To Enable Signed App Verification

1. Open Project Configuration Menu -> Security features
2. Ensure App Signing Scheme is RSA. For ESP32 ECO3 chip, select CONFIG_ESP32_REV_MIN to Rev 3 to get RSA option available
3. Enable CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
4. By default, “Sign binaries during build” will be enabled on selecting “Require signed app images” option, which will sign binary files as a part of build process. The file named in “Secure boot private signing key” will be used to sign the image.
5. If you disable “Sign binaries during build” option then all app binaries must be manually signed by following instructions in Remote Signing of Images.

Warning: It is very important that all apps flashed have been signed, either during the build or after the build.

4.29.18 Advanced Features

JTAG Debugging

By default, when Secure Boot is enabled then JTAG debugging is disabled via eFuse. The bootloader does this on first boot, at the same time it enables Secure Boot.

See JTAG with Flash Encryption or Secure Boot for more information about using JTAG Debugging with either Secure Boot or signed app verification enabled.

4.30 Thread Local Storage
4.30.1 Overview

Thread-local storage (TLS) is a mechanism by which variables are allocated such that there is one instance of the variable per extant thread. ESP-IDF provides three ways to make use of such variables:

- **FreeRTOS Native APIs**: ESP-IDF FreeRTOS native APIs.
- **Pthread APIs**: ESP-IDF pthread APIs.
- **C11 Standard**: C11 standard introduces special keywords to declare variables as thread local.

4.30.2 FreeRTOS Native APIs

The ESP-IDF FreeRTOS provides the following APIs to manage thread local variables:

- \texttt{vTaskSetThreadLocalStoragePointer()}
- \texttt{pvTaskGetThreadLocalStoragePointer()}
- \texttt{vTaskSetThreadLocalStoragePointerAndDelCallback()}

In this case, the maximum number of variables that can be allocated is limited by \texttt{CONFIG_FREERTOS_THREAD_LOCAL_STORAGE_POINTERS}. Variables are kept in the task control block (TCB) and accessed by their index. Note that index 0 is reserved for ESP-IDF internal uses.

Using the APIs above, you can allocate thread local variables of an arbitrary size, and assign them to any number of tasks. Different tasks can have different sets of TLS variables.

If size of the variable is more then 4 bytes, then you need to allocate/deallocate memory for it. Variable’s deallocation is initiated by FreeRTOS when task is deleted, but user must provide callback function to do proper cleanup.

4.30.3 Pthread APIs

The ESP-IDF provides the following \textit{POSIX Threads Support} to manage thread local variables:

- \texttt{pthread_key_create()}
- \texttt{pthread_key_delete()}
- \texttt{pthread_getspecific()}
- \texttt{pthread_setspecific()}

These APIs have all benefits of the ones above, but eliminates some their limits. The number of variables is limited only by size of available memory on the heap. Due to the dynamic nature, this APIs introduce additional performance overhead compared to the native one.

4.30.4 C11 Standard

The ESP-IDF FreeRTOS supports thread local variables according to C11 standard, ones specified with \texttt{__thread} keyword. For details on this feature, please refer to the \texttt{GCC documentation}.

Storage for that kind of variables is allocated on the task stack. Note that area for all such variables in the program is allocated on the stack of every task in the system even if that task does not use such variables at all. For example, ESP-IDF system tasks (e.g., \texttt{ipc}, \texttt{timer} tasks etc.) will also have that extra stack space allocated. Thus feature should be used with care.

Using C11 thread local variables comes at a trade-off. One one hand, they are quite handy to use in programming and can be accessed using minimal CPU instructions. However, this benefit comes at the cost of additional stack usage for all tasks in the system. Due to static nature of variables allocation, all tasks in the system have the same sets of C11 thread local variables.

4.31 Tools
4.31.1 IDF Frontend - idf.py

The idf.py command-line tool provides a front-end for easily managing your project builds, deployment and debugging, and more. It manages several tools, for example:

- **CMake**, which configures the project to be built.
- **Ninja**, which builds the project.
- **esptool.py**, which flashes the target.

The Step 5. First Steps on ESP-IDF contains a brief introduction on how to set up idf.py to configure, build, and flash projects.

**Important:** idf.py should be run in an ESP-IDF project directory, i.e., a directory containing a CMakeLists.txt file. Older style projects that contain a Makefile will not work with idf.py.

**Commands**

**Start a New Project:** create-project

```
idf.py create-project <project name>
```

This command creates a new ESP-IDF project. Additionally, the folder where the project will be created in can be specified by the --path option.

**Create a New Component:** create-component

```
idf.py create-component <component name>
```

This command creates a new component, which will have a minimum set of files necessary for building. The -C option can be used to specify the directory the component will be created in. For more information about components see the **Component CMakeLists Files**.

**Select the Target Chip:** set-target

ESP-IDF supports multiple targets (chips). A full list of supported targets in your version of ESP-IDF can be seen by running idf.py --list-targets.

```
idf.py set-target <target>
```

This command sets the current project target.

**Important:** idf.py set-target will clear the build directory and re-generate the sdkconfig file from scratch. The old sdkconfig file will be saved as sdkconfig.old.

**Note:** The behavior of the idf.py set-target command is equivalent to:

1. clearing the build directory (idf.py fullclean)
2. removing the sdkconfig file (mv sdkconfig sdkconfig.old)
3. configuring the project with the new target (idf.py -DIDF_TARGET=esp32 reconfigure)

It is also possible to pass the desired IDF_TARGET as an environment variable (e.g., export IDF_TARGET=esp32s2) or as a CMake variable (e.g., -DIDF_TARGET=esp32s2 argument to CMake or idf.py). Setting the environment variable is a convenient method if you mostly work with one type of the chip.

To specify the default value of IDF_TARGET for a given project, please add the CONFIG_IDF_TARGET option to the project’s sdkconfig.defaults file, e.g., CONFIG_IDF_TARGET="esp32s2". This value of the...
option will be used if IDF_TARGET is not specified by other methods, such as using an environment variable, a CMake variable, or the idf.py set-target command.

If the target has not been set by any of these methods, the build system will default to esp32 target.

### Start the Graphical Configuration Tool: menuconfig

```
idf.py menuconfig
```

### Build the Project: build

```
idf.py build
```

This command builds the project found in the current directory. This can involve multiple steps:

- Create the build directory if needed. The sub-directory build is used to hold build output, although this can be changed with the -B option.
- Run CMake as necessary to configure the project and generate build files for the main build tool.
- Run the main build tool (Ninja or GNU Make). By default, the build tool is automatically detected but it can be explicitly set by passing the -G option to idf.py.

Building is incremental, so if no source files or configuration has changed since the last build, nothing will be done. Additionally, the command can be run with app, bootloader and partition-table arguments to build only the app, bootloader or partition table as applicable.

### Remove the Build Output: clean

```
idf.py clean
```

This command removes the project build output files from the build directory, and the project will be fully rebuilt on next build. Using this command does not remove the CMake configuration output inside the build folder.

### Delete the Entire Build Contents: fullclean

```
idf.py fullclean
```

This command deletes the entire “build” directory contents, which includes all CMake configuration output. The next time the project is built, CMake will configure it from scratch. Note that this option recursively deletes all files in the build directory, so use with care. Project configuration is not deleted.

### Flash the Project: flash

```
idf.py flash
```

This command automatically builds the project if necessary, and then flash it to the target. You can use -p and -b options to set serial port name and flasher baud rate, respectively.

**Note:** The environment variables ESPPORT and ESPBAUD can be used to set default values for the -p and -b options, respectively. Providing these options on the command line overrides the default.

Similarly to the build command, the command can be run with app, bootloader and partition-table arguments to flash only the app, bootloader or partition table as applicable.

### Hints on How to Resolve Errors

idf.py will try to suggest hints on how to resolve errors. It works with a database of hints stored in tools/idf_py_actions/hints.yml and the hints will be printed if a match is found for the given error. The menuconfig target is not supported at the moment by automatic hints on resolving errors.
Chapter 4. API Guides

The `--no-hints` argument of `idf.py` can be used to turn the hints off in case they are not desired.

**Important Notes**

Multiple `idf.py` commands can be combined into one. For example, `idf.py -p COM4 clean flash monitor` will clean the source tree, then build the project and flash it to the target before running the serial monitor.

The order of multiple `idf.py` commands on the same invocation is not important, as they will automatically be executed in the correct order for everything to take effect (e.g., building before flashing, erasing before flashing).

For commands that are not known to `idf.py`, an attempt to execute them as a build system target will be made.

The command `idf.py` supports shell autocompletion for bash, zsh and fish shells.

In order to make shell autocompletion supported, please make sure you have at least Python 3.5 and click 7.1 or newer (Software).

To enable autocompletion for `idf.py`, use the `export` command (Step 4. Set up the environment variables). Autocompletion is initiated by pressing the TAB key. Type `idf.py -` and press the TAB key to autocomplete options.

The autocomplete support for PowerShell is planned in the future.

**Advanced Commands**

**Open the Documentation: docs**

```
idf.py docs
```

This command opens the documentation for the projects target and ESP-IDF version in the browser.

**Show Size: size**

```
idf.py size
```

This command prints app size information including the occupied RAM and flash and section (i.e., .bss) sizes.

```
idf.py size-components
```

Similarly, this command prints the same information for each component used in the project.

```
idf.py size-files
```

This command prints size information per source file in the project.

**Options**

- `--format` specifies the output format with available options: text, csv, json, default being text.
- `--output-file` optionally specifies the name of the file to print the command output to instead of the standard output.

**Reconfigure the Project: reconfigure**

```
idf.py reconfigure
```

This command forces CMake to be rerun regardless of whether it is necessary. It’s unnecessary during normal usage, but can be useful after adding/removing files from the source tree, or when modifying CMake cache variables. For example, `idf.py -DNAME='VALUE' reconfigure` can be used to set variable NAME in CMake cache to value VALUE.
Clean the Python Byte Code: python-clean

```
idf.py python-clean
```

This command deletes generated python byte code from the ESP-IDF directory. The byte code may cause issues when switching between ESP-IDF and Python versions. It is advised to run this target after switching versions of Python.

Generate a UF2 binary: uf2

```
idf.py uf2
```

This command will generate a UF2 (USB Flashing Format) binary uf2.bin in the build directory. This file includes all the necessary binaries (bootloader, app, and partition table) for flashing the target.

This UF2 file can be copied to a USB mass storage device exposed by another ESP running the ESP USB Bridge project. The bridge MCU will use it to flash the target MCU. This is as simple copying (or “drag-and-dropping”) the file to the exposed disk accessed by a file explorer in your machine.

To generate a UF2 binary for the application only (not including the bootloader and partition table), use the `uf2-app` command.

```
idf.py uf2-app
```

Global Options

To list all available root level options, run `idf.py --help`. To list options that are specific for a subcommand, run `idf.py <command> --help`, e.g., `idf.py monitor --help`. Here is a list of some useful options:

- `-C <dir>` allows overriding the project directory from the default current working directory.
- `-B <dir>` allows overriding the build directory from the default `build` subdirectory of the project directory.
- `--ccache` enables CCache when compiling source files if the `CCache` tool is installed. This can dramatically reduce the build time.

**Important:** Note that some older versions of CCache may exhibit bugs on some platforms, so if files are not rebuilt as expected, try disabling CCache and rebuiling the project. To enable CCache by default, set the `IDF_CCACHE_ENABLE` environment variable to a non-zero value.

- `-v` flag causes both `idf.py` and the build system to produce verbose build output. This can be useful for debugging build problems.
- `--cmake-warn-uninitialized` (or `-w`) causes CMake to print uninitialized variable warnings found in the project directory only. This only controls CMake variable warnings inside CMake itself, not other types of build warnings. This option can also be set permanently by setting the `IDF_CMAKE_WARN_UNINITIALIZED` environment variable to a non-zero value.
- `--no-hints` flag disables hints on resolving errors and disable capturing output.

4.31.2 IDF Docker Image

IDF Docker image (espressif/idf) is intended for building applications and libraries with specific versions of ESP-IDF, when doing automated builds.

The image contains:

- Common utilities such as git, wget, curl, zip.
- Python 3.7 or newer.
- A copy of a specific version of ESP-IDF (see below for information about versions). `IDF_PATH` environment variable is set, and points to ESP-IDF location in the container.
- All the build tools required for the specific version of ESP-IDF: CMake, ninja, cross-compiler toolchains, etc.
• All Python packages required by ESP-IDF are installed in a virtual environment.

The image entrypoint sets up PATH environment variable to point to the correct version of tools, and activates the Python virtual environment. As a result, the environment is ready to use the ESP-IDF build system.

The image can also be used as a base for custom images, if additional utilities are required.

Tags

Multiple tags of this image are maintained:

• latest: tracks master branch of ESP-IDF
• vX.Y: corresponds to ESP-IDF release vX.Y
• release-vX.Y: tracks release/vX.Y branch of ESP-IDF

Note: Versions of ESP-IDF released before this feature was introduced do not have corresponding Docker image versions. You can check the up-to-date list of available tags at https://hub.docker.com/r/espressif/idf/tags.

Usage

Setting up Docker Before using the espressif/idf Docker image locally, make sure you have Docker installed. Follow the instructions at https://docs.docker.com/install/, if it is not installed yet.

If using the image in CI environment, consult the documentation of your CI service on how to specify the image used for the build process.

Building a project with CMake In the project directory, run:

docker run --rm -v $PWD:/project -w /project espressif/idf idf.py build

The above command explained:

• docker run: runs a Docker image. It is a shorter form of the command docker container run.
• --rm: removes the container when the build is finished
• -v $PWD:/project: mounts the current directory on the host ($PWD) as /project directory in the container
• espressif/idf: uses Docker image espressif/idf with tag latest (implicitly added by Docker when no tag is specified)
• idf.py build: runs this command inside the container

To build with a specific Docker image tag, specify it as espressif/idf:TAG, for example:

docker run --rm -v $PWD:/project -w /project espressif/idf:release-v4.4 idf.py...

You can check the up-to-date list of available tags at https://hub.docker.com/r/espressif/idf/tags.

Using the image interactively It is also possible to do builds interactively, to debug build issues or test the automated build scripts. Start the container with -i -t flags:

docker run --rm -v $PWD:/project -w /project -it espressif/idf

Then inside the container, use idf.py as usual:

idf.py menuconfig
idf.py build
Note: Commands which communicate with the development board, such as `idf.py flash` and `idf.py monitor` will not work in the container unless the serial port is passed through into the container. This can be done with Docker for Linux with the device option. However currently this is not possible with Docker for Windows (https://github.com/docker/for-win/issues/1018) and Docker for Mac (https://github.com/docker/for-mac/issues/900). This limitation may be overcome by using remote serial ports. An example how to do this can be found in the following using remote serial port section.

Using remote serial port  The RFC2217 (Telnet) protocol can be used to remotely connect to a serial port. For more information please see the remote serial ports documentation in the esptool project. This method can also be used to access the serial port inside a Docker container if it cannot be accessed directly. Following is an example how to use the flash command from within a Docker container.

On host install and start `esp_rfc2217_server`:

- On Windows, package is available as a one-file bundled executable created by pyinstaller and it can be downloaded from the esptool releases page in a zip archive along with other esptool utilities:
  
  ```bash
  esp_rfc2217_server -v -p 4000 COM3
  ```

- On Linux/MacOS, package is available as part of `esptool` which can be found in ESP-IDF environment or by installing using pip:
  
  ```bash
  pip install esptool
  ```

And then starting the server by executing:

```bash
esp_rfc2217_server.py -v -p 4000 /dev/ttyUSB0
```

Now the device attached to the host can be flashed from inside a Docker container by using:

```bash
docker run --rm -v <host_path>:/<container_path> -w /<container_path> espressif/idf.py --port 'rfc2217://host.docker.internal:4000?ign_set_control' flash
```

Please make sure that `<host_path>` is properly set to your project path on the host and `<container_path>` is set as a working directory inside the container with the `-w` option. The `host.docker.internal` is a special Docker DNS name to access the host. This can be replaced with host IP if necessary.

Building custom images

The Dockerfile in ESP-IDF repository provides several build arguments which can be used to customize the Docker image:

- **IDF_CLONE_URL**: URL of the repository to clone ESP-IDF from. Can be set to a custom URL when working with a fork of ESP-IDF. Default is https://github.com/espressif/esp-idf.git.
- **IDF_CLONE_BRANCH_OR_TAG**: Name of a git branch or tag use when cloning ESP-IDF. This value is passed to `git clone` command using the `--branch` argument. Default is master.
- **IDF_CHECKOUT_REF**: If this argument is set to a non-empty value, `git checkout $IDF_CHECKOUT_REF` command will be performed after cloning. This argument can be set to the SHA of the specific commit to check out, for example if some specific commit on a release branch is desired.
- **IDF_CLONE_SHALLOW**: If this argument is set to a non-empty value, `--depth=1 --shallow-submodules` arguments will be used when performing `git clone`. This significantly reduces the amount of data downloaded and the size of the resulting Docker image. However, if switching to a different branch in such a “shallow” repository is necessary, an additional `git fetch origin <branch>` command must be executed first.
- **IDF_INSTALL_TARGETS**: Comma-separated list of IDF targets to install toolchains for, or all to install toolchains for all targets. Selecting specific targets reduces the amount of data downloaded and the size of the resulting Docker image. Default is all.
To use these arguments, pass them via the `--build-arg` command line option. For example, the following command will build a Docker image with a shallow clone of ESP-IDF v4.4.1 and tools for ESP32-C3, only:

```
docker build -t idf-custom:v4.4.1-esp32c3 \
    --build-arg IDF_CLONE_BRANCH_OR_TAG=v4.4.1 \
    --build-arg IDF_CLONE_SHALLOW=1 \
    --build-arg IDF_INSTALL_TARGETS=esp32c3 \
    tools/docker
```

### 4.31.3 IDF Windows Installer

**Command-line parameters**

Windows Installer `esp-idf-tools-setup` provides the following command-line parameters:

- `/CONFIG=[PATH]` - Path to ini configuration file to override default configuration of the installer. Default: config.ini.
- `/HELP` - Display command line options provided by Inno Setup installer.
- `/IDFDIR=[PATH]` - Path to directory where it will be installed. Default: {userdesktop}\esp-idf\.
- `/OFFLINE=[yes|no]` - Execute installation of Python packages by PIP in offline mode. The same result can be achieved by setting the environment variable PIP_NO_INDEX. Default: no.
- `/PYTHONNOUSERSITE=[yes|no]` - Set PYTHONNOUSERSITE variable before launching any Python command to avoid loading Python packages from AppDataRoaming. Default: yes.
- `/PYTHONWHEELSURL=[URL]` - Specify URLs to PyPi repositories for resolving binary Python Wheel dependencies. The same result can be achieved by setting the environment variable PYTHON_EXTRA_INDEX_URL. Default: https://dl.espressif.com/pypi.
- `/VERYSILENT /SUPPRESSMSGBOXES /SP- /NOCANCEL` - Perform silent installation.

**Unattended installation**

The unattended installation of IDF can be achieved by following command-line parameters:

```
esp-idf-tools-setup-x.x.exe /VERYSILENT /SUPPRESSMSGBOXES /SP- /NOCANCEL
```

The installer detaches its process from the command-line. Waiting for installation to finish could be achieved by following PowerShell script:

```
$installerProcess = Get-Process esp-idf-tools-setup
Wait-Process -Id $installerProcess.Id
```
### Custom Python and custom location of Python wheels

The IDF installer is using by default embedded Python with reference to Python Wheel mirror.

Following parameters allow to select custom Python and custom location of Python wheels:

```
esp-idf-tools-setup-x.x.exe /USEEMBEDDEDPYTHON=no /PYTHONWHEELSURL=https://pypi.org/simple/
```

### 4.31.4 IDF Component Manager

The IDF Component manager is a tool that downloads dependencies for any ESP-IDF CMake project. The download happens automatically during a run of CMake. It can source components either from the component registry or from a git repository.

A list of components can be found on [https://components.espressif.com/](https://components.espressif.com/)

#### Using with a project

Dependencies for each component in the project are defined in a separate manifest file named `idf_component.yml` placed in the root of the component. The manifest file template can be created for a component by running `idf.py create-manifest --component=my_component`. When a new manifest is added to one of the components in the project it’s necessary to reconfigure it manually by running `idf.py reconfigure`. Then build will track changes in `idf_component.yml` manifests and automatically triggers CMake when necessary.

There is an example application: `example/build_system/cmake/component_manager` that uses components installed by the component manager.

It’s not necessary to have a manifest for components that don’t need any managed dependencies.

When CMake configures the project (e.g. `idf.py reconfigure`) component manager does a few things:

- Processes `idf_component.yml` manifests for every component in the project and recursively solves dependencies
- Creates a dependencies.lock file in the root of the project with a full list of dependencies
- Downloads all dependencies to the `managed_components` directory

The lock-file `dependencies.lock` and content of `managed_components` directory is not supposed to be modified by a user. When the component manager runs it always make sure they are up to date. If these files were accidentally modified it’s possible to re-run the component manager by triggering CMake with `idf.py reconfigure`.

You may set build property `DEPENDENCIES_LOCK` to specify the lock-file path in the top-level CMakeLists.txt. For example, adding `idf_build_set_property(DEPENDENCIES_LOCK dependencies.lock.${IDF_TARGET})` before `project(PROJECT_NAME)` could help generate different lock files for different targets.

#### Defining dependencies in the manifest

```
dependencies:
  # Required IDF version
  idf: ">=4.1"
  # Defining a dependency from the registry:
  # https://components.espressif.com/component/example/cmp
  example/cmp: ">=1.0.0"
  # # Other ways to define dependencies
  # # For components maintained by Espressif only name can be used.

(continues on next page)
```
Disabling the Component Manager

The component manager can be explicitly disabled by setting IDF_COMPONENT_MANAGER environment variable to 0.

4.31.5 IDF Clang Tidy

The IDF Clang Tidy is a tool that uses clang-tidy to run static analysis on your current app.

**Warning:** This functionality and the toolchain it relies on are still under development. There may be breaking changes before a final release.

Prerequisites

If you have never run this tool before, take the following steps to get this tool prepared.

1. Run the export scripts (export.sh / export.bat / ...) to set up the environment variables.
2. Run `pip install --upgrade pyclang` to install this plugin. The extra commands would be activated in `idf.py` automatically.
3. Run `idf_tools.py install esp-clang` to install the clang-tidy required binaries

**Note:** This toolchain is still under development. After the final release, you don’t have to install them manually.

4. Get file from the llvm repository and add the folder of this script to the `$PATH`. Or you could pass an optional argument `--run-clang-tidy-py` later when you call `idf.py clang-check`. Please don’t forget to make the script executable.
5. Run the export scripts (export.sh / export.bat / ...) again to refresh the environment variables.

Extra Commands

**clang-check** Run `idf.py clang-check` to re-generate the compilation database and run `clang-tidy` under your current project folder. The output would be written to `<project_dir>/warnings.txt`.

Run `idf.py clang-check --help` to see the full documentation.

**clang-html-report**

1. Run `pip install codereport` to install the additional dependency.
2. Run `idf.py clang-html-report` to generate an HTML report in folder `<project_dir>/html_report` according to the `warnings.txt`. Please open the `<project_dir>/html_report/index.html` in your browser to check the report.

Bug Report

This tool is hosted in espressif/clang-tidy-runner. If you faced any bugs or have any feature request, please report them via github issues.

4.31.6 Downloadable Tools

ESP-IDF build process relies on a number of tools: cross-compiler toolchains, CMake build system, and others.

Installing the tools using an OS-specific package manager (like apt, yum, brew, etc.) is the preferred method when the required version of the tool is available. This recommendation is reflected in the Getting Started guide. For example, on Linux and macOS it is recommended to install CMake using an OS package manager.

However, some of the tools are IDF-specific and are not available in OS package repositories. Furthermore, different versions of ESP-IDF require different versions of the tools to operate correctly. To solve these two problems, ESP-IDF provides a set of scripts for downloading and installing the correct versions of tools, and exposing them in the environment.

The rest of the document refers to these downloadable tools simply as “tools”. Other kinds of tools used in ESP-IDF are:

- Python scripts bundled with ESP-IDF (such as `idf.py`)
- Python packages installed from PyPI.

The following sections explain the installation method, and provide the list of tools installed on each platform.

Note: This document is provided for advanced users who need to customize their installation, users who wish to understand the installation process, and ESP-IDF developers.

If you are looking for instructions on how to install the tools, see the Getting Started Guide.

Tools metadata file

The list of tools and tool versions required for each platform is located in `tools/tools.json`. The schema of this file is defined by `tools/tools_schema.json`.

This file is used by `tools/idf_tools.py` script when installing the tools or setting up the environment variables.
Tools installation directory

IDF_TOOLS_PATH environment variable specifies the location where the tools are to be downloaded and installed. If not set, IDF_TOOLS_PATH defaults to HOME/.espressif on Linux and macOS, and %USER_PROFILE%\.espressif on Windows.

Inside IDF_TOOLS_PATH, the scripts performing tools installation create the following directories and files:

- **dist** — where the archives of the tools are downloaded.
- **tools** — where the tools are extracted. The tools are extracted into subdirectories: tools/TOOL_NAME/VERSION/. This arrangement allows different versions of tools to be installed side by side.
- **idf-env.json** — user install options (targets, features) are stored in this file. Targets are selected chip targets for which tools are installed and kept up-to-date. Features determine the Python package set which should be installed. These options will be discussed later.
- **python_env** — not tools related; virtual Python environments are installed in the sub-directories. Note that the Python environment directory can be placed elsewhere by setting the IDF_PYTHON_ENV_PATH environment variable.
- **espidf.constraints.*.txt** — one constraint file for each ESP-IDF release containing Python package version requirements.

GitHub Assets Mirror

Most of the tools downloaded by the tools installer are GitHub Release Assets, which are files attached to a software release on GitHub.

If GitHub downloads are inaccessible or slow to access, it’s possible to configure a GitHub assets mirror.

To use Espressif’s download server, set the environment variable IDF_GITHUB_ASSETS to dl.espressif.com/github_assets. When the install process is downloading a tool from github.com, the URL will be rewritten to use this server instead.

Any mirror server can be used provided the URL matches the github.com download URL format: the install process will replace https://github.com with https://${IDF_GITHUB_ASSETS} for any GitHub asset URL that it downloads.

**Note:** The Espressif download server doesn’t currently mirror everything from GitHub, it only mirrors files attached as Assets to some releases as well as source archives for some releases.

idf_tools.py script

`tools/idf_tools.py` script bundled with ESP-IDF performs several functions:

- **install**: Download the tool into ${IDF_TOOLS_PATH}/dist directory, extract it into ${IDF_TOOLS_PATH}/tools/TOOL_NAME/VERSION. install command accepts the list of tools to install, in TOOL_NAME or TOOL_NAME@VERSION format. If all is given, all the tools (required and optional ones) are installed. If no argument or required is given, only the required tools are installed.
- **download**: Similar to install but doesn’t extract the tools. An optional --platform argument may be used to download the tools for the specific platform.
- **export**: Lists the environment variables which need to be set to use the installed tools. For most of the tools, setting PATH environment variable is sufficient, but some tools require extra environment variables. The environment variables can be listed in either of shell or key-value formats, set by --format parameter:
  - **export optional parameters**:
    - **--unset** Creates statement that unset some global variables, so the environment gets to the state it was before calling export.(sh/fish).
    - **--add_paths_extras** Adds extra ESP-IDF-related paths of $PATH to ${IDF_TOOLS_PATH}/esp-idf.json, which is used to remove global variables when
the active ESP-IDF environment is deactivated. Example: While processing `export.{sh/fish}` script, new paths are added to global variable `$PATH`. This option is used to save these new paths to the `${IDF_TOOLS_PATH}/esp-idf.json`.

- `shell` produces output suitable for evaluation in the shell. For example,

```bash
export PATH="/home/user/.espressif/tools/tool/v1.0.0/bin:$PATH"
```

on Linux and macOS, and

```bash
set "PATH=C:\Users\user\.espressif\tools\v1.0.0\bin;%PATH%"
```

on Windows.

**Note:** Exporting environment variables in Powershell format is not supported at the moment. Key-value format may be used instead.

The output of this command may be used to update the environment variables, if the shell supports this. For example:

```bash
eval $(IDF_PATH/tools/idf_tools.py export)
```

- `key-value` produces output in `VARIABLE=VALUE` format, suitable for parsing by other scripts:

```bash
PATH=/home/user/.espressif/tools/tool/v1.0.0:$PATH
```

Note that the script consuming this output has to perform expansion of `$VAR` or `%VAR%` patterns found in the output.

- `list`: Lists the known versions of the tools, and indicates which ones are installed. Following options are available to customize the output.
  - `--outdated`: List only outdated versions of tools installed in `IDF_TOOLS_PATH`.
- `check`: For each tool, checks whether the tool is available in the system path and in `IDF_TOOLS_PATH`.
- `install-python-env`: Create a Python virtual environment in the `${IDF_TOOLS_PATH}/python_env` directory (or directly in the directory set by the `IDF_PYTHON_ENV_PATH` environment variable) and install there the required Python packages. An optional `--features` argument allows one to specify a comma-separated list of features to be added or removed. Feature that begins with `--` will be removed and features with `+` or without any sign will be added. Example syntax for removing feature `XY` is `--features=--XY` and for adding `--features=+XY` or `--features=XY`. If both removing and adding options are provided with the same feature, no operation is performed. For each feature a requirements file must exist. For example, feature `XY` is a valid feature if `${IDF_PATH}/tools/requirements/requirements.XY.txt` is an existing file with a list of Python packages to be installed. There is one mandatory core feature ensuring core functionality of ESP-IDF (build, flash, monitor, debug in console). There can be an arbitrary number of optional features. The selected list of features is stored in `idf-env.json`. The requirements files contain a list of the desired Python packages to be installed and `espidf.constraints.*.txt` downloaded from `https://dl.espressif.com` and stored in `${IDF_TOOLS_PATH}`.

- `check-python-dependencies`: Checks if all required Python packages are installed. Packages from `${IDF_PATH}/tools/requirements/requirements.*.txt` files selected by the feature list of `idf-env.json` are checked with the package versions specified in the `espidf.constraints.*.txt` file. The constraint file is downloaded with `install-python-env` command. The use of constraints files can be disabled similarly to the `install-python-env` command.
- `uninstall`: Print and remove tools, that are currently not used by active ESP-IDF version.
  - `--dry-run` Print installed unused tools.
  - `--remove-archives` Additionally remove all older versions of previously downloaded installation packages.

**Install scripts**

Shell-specific user-facing scripts are provided in the root of ESP-IDF repository to facilitate tools installation. These are:
Chapter 4. API Guides

- install.bat for Windows Command Prompt
- install.ps1 for Powershell
- install.sh for Bash
- install.fish for Fish

Aside from downloading and installing the tools into IDF_TOOLS_PATH, these scripts prepare a Python virtual environment, and install the required packages into that environment.

These scripts accept optionally a comma separated list of chip targets and --enable-* arguments for enabling features. These arguments are passed to the idf_tools.py script which stores them in idf-env.json. Therefore, chip targets and features can be enabled incrementally.

Running the scripts without any optional arguments will install tools for all chip targets (by running idf_tools.py install --targets=all) and Python packages for core ESP-IDF functionality (by running idf_tools.py install-python-env --features=core).

Or for example, install.sh esp32 will install tools only for ESP32. See the Getting Started Guide for more examples.

install.sh --enable-XY will enable feature XY (by running idf_tools.py install-python-env --features=core,XY).

Export scripts

Since the installed tools are not permanently added into the user or system PATH environment variable, an extra step is required to use them in the command line. The following scripts modify the environment variables in the current shell to make the correct versions of the tools available:

- export.bat for Windows Command Prompt
- export.ps1 for Powershell
- export.sh for Bash
- export.fish for Fish

Note: To modify the shell environment in Bash, export.sh must be “sourced”: . ./export.sh (note the leading dot and space).

export.sh may be used with shells other than Bash (such as zsh). However in this case the IDF_PATH environment variable must be set before running the script. When used in Bash, the script will guess the IDF_PATH value from its own location.

In addition to calling idf_tools.py, these scripts list the directories which have been added to the PATH.

Other installation methods

Depending on the environment, more user-friendly wrappers for idf_tools.py are provided:

- IDF Tools installer for Windows can download and install the tools. Internally the installer uses idf_tools.py.
- Eclipse Plugin includes a menu item to set up the tools. Internally the plugin calls idf_tools.py.
- VSCode Extension for ESP-IDF includes an onboarding flow. This flow helps setting up the tools. Although the extension does not rely on idf_tools.py, the same installation method is used.

Custom installation

Although the methods above are recommended for ESP-IDF users, they are not a must for building ESP-IDF applications. ESP-IDF build system expects that all the necessary tools are installed somewhere, and made available in the PATH.
Uninstall ESP-IDF

Uninstalling ESP-IDF requires removing both the tools and the environment variables that have been configured during the installation.

- Windows users using the Windows ESP-IDF Tools Installer can simply run the uninstall wizard to remove ESP-IDF.
- To remove an installation performed by running the supported install scripts, simply delete the tools installation directory including the downloaded and installed tools. Any environment variables set by the export scripts are not permanent and will not be present after opening a new environment.
- When dealing with a custom installation, in addition to deleting the tools as mentioned above, you may also need to manually revert any changes to environment variables or system paths that were made to accommodate the ESP-IDF tools (e.g., IDF_PYTHON_ENV_PATH or IDF_TOOLS_PATH). If you manually copied any tools, you would need to track and delete those files manually.
- If you installed any plugins like the ESP-IDF Eclipse Plugin or VSCode ESP-IDF Extension, you should follow the specific uninstallation instructions described in the documentation of those components.

**Note:** Uninstalling the ESP-IDF tools does not remove any project files or your code. Be mindful of what you are deleting to avoid losing any work. If you are unsure about a step, refer back to the installation instructions.

These instructions assume that the tools were installed following the procedures in this provided document. If you’ve used a custom installation method, you might need to adapt these instructions accordingly.

List of IDF Tools

xtensa-esp-elf-gdb  GDB for Xtensa

License: GPL-3.0-or-later

More info: https://github.com/espressif/binutils-gdb
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<th>Download</th>
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SHA256: 2f958570f66a699ed32cbb076c6baf303349a26b301a7c4628be87ad39cf9f1 |

**riscv32-esp-elf-gdb**  
GDB for RISC-V  
License: GPL-3.0-or-later  
More info: [https://github.com/espressif/binutils-gdb](https://github.com/espressif/binutils-gdb)
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<td><a href="https://github.com/espressif/binutils-gdb/releases/download/esp-gdb-v12.1_20221002/riscv32-esp-elf-gdb-12.1_20221002-aarch64-apple-darwin21.1.tar.gz">https://github.com/espressif/binutils-gdb/releases/download/esp-gdb-v12.1_20221002/riscv32-esp-elf-gdb-12.1_20221002-aarch64-apple-darwin21.1.tar.gz</a> SHA256: f6513b57f282454979c39a201ff3f444d4180e16e39765c629e01036286c0e6</td>
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**xtensa-esp32-elf**  Toolchain for Xtensa (ESP32) based on GCC  
License: GPL-3.0-with-GCC-exception  
More info: https://github.com/espressif/crosstool-NG
<table>
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SHA256: 4d2e02ef47f1a934d4cfdbaecc486adfaab4c0e26deea2c18d6385527f39f864 |
| linux-arm64  | required     | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/xtensa-esp32-elf-12.2.0_20230208-aarch64-linux-gnu.tar.xz
SHA256: 9e211a182b6ea0396a41c78f52f51d964e7875fe274ea9c81111bf0d6c90e516 |
| linux-armel  | required     | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/xtensa-esp32-elf-12.2.0_20230208-arm-linux-gnueabi.tar.xz
SHA256: 2dd911b98b79b30042b7918ecef60cf10c7bd5b1da853e83b65f293b96dec800 |
| linux-armhf  | required     | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/xtensa-esp32-elf-12.2.0_20230208-arm-linux-gnueabihf.tar.xz
SHA256: a683a468555dcdbcb6e32a190842110d6f8534d6104d61cf0b9c9d50c6be16 |
SHA256: 292b19ea6186508a923f66d0103977e001d4eb8e77836e7e3d6ce6e5afa7d305 |
| macos        | required     | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/xtensa-esp32-elf-12.2.0_20230208-x86_64-apple-darwin.tar.xz
SHA256: b94d87f7d1d1dc32cd1d718935065e933b101a14df6b17be56748e5264955bdf |
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| win32       | required     | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/xtensa-esp32-elf-12.2.0_20230208-i686-w64-mingw32.zip
SHA256: 62bb6428d107ed3f44c212c77eef24804b7e97327b0f0ad2029c656c6dbd6ee |
| win64       | required     | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/xtensa-esp32-elf-12.2.0_20230208-x86_64-w64-mingw32.zip
SHA256: 8fe8f6e46476efc69012390106c8c660a14418f025137b0513670c72124339cf |

**xtensa-esp32s2-elf** Toolchain for Xtensa (ESP32-S2) based on GCC

License: GPL-3.0-with-GCC-exception

More info: https://github.com/espressif/crosstool-NG
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xtensa-esp32s3-elf Toolchain for Xtensa (ESP32-S3) based on GCC
License: GPL-3.0-with-GCC-exception
More info: https://github.com/espressif/crosstool-NG
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</tr>
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</table>

**esp-clang** Toolchain for all Espressif chips based on clang

License: Apache-2.0

More info: [https://github.com/espressif/llvm-project](https://github.com/espressif/llvm-project)

<table>
<thead>
<tr>
<th>Platform</th>
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</table>
riscv32-esp-elf  Toolchain for 32-bit RISC-V based on GCC
License: GPL-3.0-with-GCC-exception
More info: https://github.com/espressif/crosstool-NG

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| linux-arm64| required | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/riscv32-esp-elf-12.2.0_20230208-aarch64-linux-gnu.tar.xz  
SHA256: ae4bf1e6f2c91a10e8995399d2003502e167e8c95e7f4097309e84370906a |
| linux-armel | required | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/riscv32-esp-elf-12.2.0_20230208-arm-linux-gnueabi.tar.xz  
SHA256: 9740cbddb4cb5e05382991c83d8c96a5fb7d87046449e77791b3b0de29a3ddd8 |
| linux-armhf | required | https://github.com/espressif/crosstool-NG/releases/download/esp-12.2.0_20230208/riscv32-esp-elf-12.2.0_20230208-arm-linux-gnueabihf.tar.xz  
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SHA256: 9deae9e0013b2f7bbf017f9e8135755bfa89322f337c7dca35872bf12ec08176 |

esp32ulp-elf  Toolchain for ESP32 ULP coprocessor
License: GPL-3.0-or-later
More info: https://github.com/espressif/binutils-gdb
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**cmake** CMake build system

On Linux and macOS, it is recommended to install CMake using the OS-specific package manager (like apt, yum, brew, etc.). However, for convenience it is possible to install CMake using `idf_tools.py` along with the other tools.

License: BSD-3-Clause

More info: https://github.com/Kitware/CMake
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**openocd-esp32** OpenOCD for ESP32

License: GPL-2.0-only

More info: https://github.com/espressif/openocd-esp32

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**ninja**  
Ninja build system

On Linux and macOS, it is recommended to install ninja using the OS-specific package manager (like apt, yum, brew, etc.). However, for convenience it is possible to install ninja using idf_tools.py along with the other tools.

License: Apache-2.0

More info: [https://github.com/ninja-build/ninja](https://github.com/ninja-build/ninja)

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**idf-exe**  
IDF wrapper tool for Windows

License: Apache-2.0

More info: [https://github.com/espressif/idf_py_exe_tool](https://github.com/espressif/idf_py_exe_tool)

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**ccache**  
Ccache (compiler cache)

License: GPL-3.0-or-later

More info: [https://github.com/ccache/ccache](https://github.com/ccache/ccache)

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**dfu-util**  
dfu-util (Device Firmware Upgrade Utilities)

License: GPL-2.0-only


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4.32 Unit Testing in ESP32

ESP-IDF provides the following methods to test software.

- Target based tests using a central unit test application which runs on the esp32. These tests use the Unity unit test framework. They can be integrated into an ESP-IDF component by placing them in the component’s test subdirectory. This document mainly introduces this target based tests.
- Linux-host based unit tests in which part of the hardware can be abstracted via mocks. Currently, Linux-host based tests are still under development and only a small fraction of IDF components support them. More information on running IDF applications on the host can be found here: Running Applications on the Host Machine.

4.32.1 Normal Test Cases

Unit tests are located in the test subdirectory of a component. Tests are written in C, and a single C source file can contain multiple test cases. Test files start with the word “test”.

Each test file should include the unity.h header and the header for the C module to be tested.

Tests are added in a function in the C file as follows:

```c
TEST_CASE("test name", "[module name]"
{
    // Add test here
}
```

- The first argument is a descriptive name for the test.
- The second argument is an identifier in square brackets. Identifiers are used to group related test, or tests with specific properties.

**Note:** There is no need to add a main function with UNITY_BEGIN() and UNITY_END() in each test case. unity_platform.c will run UNITY_BEGIN() autonomously, and run the test cases, then call UNITY_END().

The test subdirectory should contain a component CMakeLists.txt, since they are themselves components (i.e., a test component). ESP-IDF uses the Unity test framework located in the unity component. Thus, each test component should specify the unity component as a component requirement using the REQUIRES argument. Normally, components should list their sources manually; for component tests however, this requirement is relaxed and the use of the SRC_DIRS argument in idf_component_register is advised.

Overall, the minimal test subdirectory CMakeLists.txt file should contain the following:
Chapter 4. API Guides

idf_component_register(SRC_DIRS "."  
INCLUDE_DIRS "."  
REQUIRES unity)

See [http://www.throwtheswitch.org/unity](http://www.throwtheswitch.org/unity) for more information about writing tests in Unity.

### 4.32.2 Multi-device Test Cases

The normal test cases will be executed on one DUT (Device Under Test). However, components that require some form of communication (e.g., GPIO, SPI) require another device to communicate with, thus cannot be tested through normal test cases. Multi-device test cases involve writing multiple test functions, and running them on multiple DUTs.

The following is an example of a multi-device test case:

```c
void gpio_master_test()
{
    gpio_config_t slave_config = {
        .pin_bit_mask = 1 << MASTER_GPIO_PIN,
        .mode = GPIO_MODE_INPUT,
    };
    gpio_config(&slave_config);
    unity_wait_for_signal("output high level");
    TEST_ASSERT(gpio_get_level(MASTER_GPIO_PIN) == 1);
}

void gpio_slave_test()
{
    gpio_config_t master_config = {
        .pin_bit_mask = 1 << SLAVE_GPIO_PIN,
        .mode = GPIO_MODE_OUTPUT,
    };
    gpio_config(&master_config);
    gpio_set_level(SLAVE_GPIO_PIN, 1);
    unity_send_signal("output high level");
}

TEST_CASE_MULTIPLE_DEVICES("gpio multiple devices test example", "[driver]", gpio_master_test, gpio_slave_test);
```

The macro `TEST_CASE_MULTIPLE_DEVICES` is used to declare a multi-device test case.

- The first argument is test case name.
- The second argument is test case description.
- From the third argument, up to 5 test functions can be defined, each function will be the entry point of tests running on each DUT.

Running test cases from different DUTs could require synchronizing between DUTs. We provide `unity_wait_for_signal` and `unity_send_signal` to support synchronizing with UART. As the scenario in the above example, the slave should get GPIO level after master set level. DUT UART console will prompt and user interaction is required:

**DUT1 (master) console:**

```
Waiting for signal: [output high level]!
Please press "Enter" key to once any board send this signal.
```

**DUT2 (slave) console:**

```
Send signal: [output high level]!
```

Once the signal is sent from DUT2, you need to press “Enter” on DUT1, then DUT1 unblocks from `unity_wait_for_signal` and starts to change GPIO level.
4.32.3 Multi-stage Test Cases

The normal test cases are expected to finish without reset (or only need to check if reset happens). Sometimes we expect to run some specific tests after certain kinds of reset. For example, we want to test if the reset reason is correct after a wake up from deep sleep. We need to create a deep-sleep reset first and then check the reset reason. To support this, we can define multi-stage test cases, to group a set of test functions:

```c
static void trigger_deepsleep(void)
{
    esp_sleep_enable_timer_wakeup(2000);
    esp_deep_sleep_start();
}

void check_deepsleep_reset_reason()
{
    soc_reset_reason_t reason = esp_rom_get_reset_reason(0);
    TEST_ASSERT(reason == RESET_REASON_CORE_DEEP_SLEEP);
}

TEST_CASE_MULTIPLE_STAGES("reset reason check for deepsleep", "[esp32]", trigger_deepsleep, check_deepsleep_reset_reason);
```

Multi-stage test cases present a group of test functions to users. It needs user interactions (select cases and select different stages) to run the case.

4.32.4 Tests For Different Targets

Some tests (especially those related to hardware) cannot run on all targets. Below is a guide how to make your unit tests run on only specified targets.

1. Wrap your test code by `!(TEMPORARY_)DISABLED_FOR_TARGETS()` macros and place them either in the original test file, or separate the code into files grouped by functions, but make sure all these files will be processed by the compiler. E.g.:

```c
#if !TEMPORARY_DISABLED_FOR_TARGETS(ESP32, ESP8266)
TEST_CASE("a test that is not ready for esp32 and esp8266 yet", "["]
{
}
#endif //!TEMPORARY_DISABLED_FOR_TARGETS(ESP32, ESP8266)
```

Once you need one of the tests to be compiled on a specified target, just modify the targets in the disabled list. It’s more encouraged to use some general conception that can be described in `soc_caps.h` to control the disabling of tests. If this is done but some of the tests are not ready yet, use both of them (and remove `!(TEMPORARY_)DISABLED_FOR_TARGETS()` later). E.g.:

```c
#if SOC_SDIO_SLAVE_SUPPORTED
#if !TEMPORARY_DISABLED_FOR_TARGETS(ESP64)
TEST_CASE("a sdio slave tests that is not ready for esp64 yet", "[sdio_slave]"
{
    //available for esp32 now, and will be available for esp64 in the future
}
#endif //!TEMPORARY_DISABLED_FOR_TARGETS(ESP64)
#endif //SOC_SDIO_SLAVE_SUPPORTED
```

2. For test code that you are 100% for sure that will not be supported (e.g. no peripheral at all), use `DISABLED_FOR_TARGETS`; for test code that should be disabled temporarily, or due to lack of runners, etc., use `TEMPORARY_DISABLED_FOR_TARGETS`.

Some old ways of disabling unit tests for targets, that have obvious disadvantages, are deprecated:

- DON’T put the test code under `test/target` folder and use `CMakeLists.txt` to choose one of the target folder. This is prevented because test code is more likely to be reused than the implementations. If you put
something into test/esp32 just to avoid building it on esp32s2, it’s hard to make the code tidy if you want to enable the test again on esp32s3.

- DON’T use CONFIG_IDF_TARGET_xxx macros to disable the test items any more. This makes it harder to track disabled tests and enable them again. Also, a black-list style #if !disabled is preferred to white-list style #if CONFIG_IDF_TARGET_xxx, since you will not silently disable cases when new targets are added in the future. But for test implementations, it’s allowed to use #if CONFIG_IDF_TARGET_xxx to pick one of the implementation code.

- Test item: some items that will be performed on some targets, but skipped on other targets. E.g.
  There are three test items SD 1-bit, SD 4-bit and SDSPI. For ESP32-S2, which doesn’t have SD host, among the tests only SDSPI is enabled on ESP32-S2.

- Test implementation: some code will always happen, but in different ways. E.g.
  There is no SDIO PKT_LEN register on ESP8266. If you want to get the length from the slave as a step in the test process, you can have different implementation code protected by #if CONFIG_IDF_TARGET_reading reading in different ways.
  But please avoid using #else macro. When new target is added, the test case will fail at building stage, so that the maintainer will be aware of this, and choose one of the implementations explicitly.

### 4.32.5 Building Unit Test App

Follow the setup instructions in the top-level esp-idf README. Make sure that IDF_PATH environment variable is set to point to the path of esp-idf top-level directory.

Change into tools/unit-test-app directory to configure and build it:

- idf.py menuconfig - configure unit test app.
- idf.py -T all build - build unit test app with tests for each component having tests in the test subdirectory.
- idf.py -T "xxx yyy" build - build unit test app with tests for some space-separated specific components (For instance: idf.py -T heap build - build unit tests only for heap component directory).
- idf.py -T all -E "xxx yyy" build - build unit test app with all unit tests, except for unit tests of some components (For instance: idf.py -T all -E "ulp mbedtls" build - build all unit tests excludes ulp and mbedtls components).

**Note:** Due to inherent limitations of Windows command prompt, following syntax has to be used in order to build unit-test-app with multiple components: idf.py -T xxx -T yyy build or with escaped quotes: idf.py -T \"xxx yyy\" build in PowerShell or idf.py -T \"ssd1306 hts221\" build in Windows command prompt.

When the build finishes, it will print instructions for flashing the chip. You can simply run idf.py flash to flash all build output.

You can also run idf.py -T all flash or idf.py -T xxx flash to build and flash. Everything needed will be rebuilt automatically before flashing.

Use menuconfig to set the serial port for flashing. For more information, see tools/unit-test-app/README.md.

### 4.32.6 Running Unit Tests

After flashing reset the ESP32 and it will boot the unit test app.

When unit test app is idle, press “Enter” will make it print test menu with all available tests:

<table>
<thead>
<tr>
<th>Number</th>
<th>Test Description</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;esp_ota_begin() verifies arguments&quot; [ota]</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>&quot;esp_ota_get_next_update_partition logic&quot; [ota]</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>&quot;Verify bootloader image in flash&quot; [bootloader_support]</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>&quot;Verify unit test app image&quot; [bootloader_support]</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>&quot;can use new and delete&quot; [cxx]</td>
<td></td>
</tr>
</tbody>
</table>

(continues on next page)
can call virtual functions" [cxx]
(7)  "can use static initializers for non-POD types" [cxx]
(8)  "can use std::vector" [cxx]
(9)  "static initialization guards work as expected" [cxx]
(10) "global initializers run in the correct order" [cxx]
(11) "before scheduler has started, static initializers work correctly" [cxx]
(12) "adc2 work with wifi" [adc]
(13) "gpio master/slave test example" [ignore][misc][test_env=UT_T2_1][multi_device]
          (1)  "gpio_master_test"
          (2)  "gpio_slave_test"
(14) "SPI Master clockdiv calculation routines" [spi]
(15) "SPI Master test" [spi][ignore]
(16) "SPI Master test, interaction of multiple devs" [spi][ignore]
(17) "SPI Master no response when switch from host1 (SPI2) to host2 (SPI3)" [spi]
(18) "SPI Master DMA test, TX and RX in different regions" [spi]
(19) "SPI Master DMA test: length, start, not aligned" [spi]
(20) "reset reason check for deepsleep" [esp32][test_env=UT_T2_1][multi_stage]
          (1)  "trigger_deepsleep"
          (2)  "check_deepsleep_reset_reason"

The normal case will print the case name and description. Master-slave cases will also print the sub-menu (the registered test function names).

Test cases can be run by inputting one of the following:

- Test case name in quotation marks to run a single test case
- Test case index to run a single test case
- Module name in square brackets to run all test cases for a specific module
- An asterisk to run all test cases

[multi_device] and [multi_stage] tags tell the test runner whether a test case is a multi devices or multiple stages of test case. These tags are automatically added by `TEST_CASE_MULTIPLE_DEVICES` and `TEST_CASE_MULTIPLE_STAGES` macros.

After you select a multi-device test case, it will print sub-menu:

Running gpio master/slave test example...
  gpio master/slave test example
      (1)  "gpio_master_test"
      (2)  "gpio_slave_test"

You need to input a number to select the test running on the DUT.

Similar to multi-device test cases, multi-stage test cases will also print sub-menu:

Running reset reason check for deepsleep...
  reset reason check for deepsleep
      (1)  "trigger_deepsleep"
      (2)  "check_deepsleep_reset_reason"

First time you execute this case, input 1 to run first stage (trigger deepsleep). After DUT is rebooted and able to run test cases, select this case again and input 2 to run the second stage. The case only passes if the last stage passes and all previous stages trigger reset.

### 4.32.7 Timing Code with Cache Compensated Timer

Instructions and data stored in external memory (e.g. SPI Flash and SPI RAM) are accessed through the CPU’s unified instruction and data cache. When code or data is in cache, access is very fast (i.e., a cache hit).
Chapter 4. API Guides

However, if the instruction or data is not in cache, it needs to be fetched from external memory (i.e., a cache miss). Access to external memory is significantly slower, as the CPU must execute stall cycles whilst waiting for the instruction or data to be retrieved from external memory. This can cause the overall code execution speed to vary depending on the number of cache hits or misses.

Code and data placements can vary between builds, and some arrangements may be more favorable with regards to cache access (i.e., minimizing cache misses). This can technically affect execution speed, however these factors are usually irrelevant as their effect ‘average out’ over the device’s operation.

The effect of the cache on execution speed, however, can be relevant in benchmarking scenarios (especially micro benchmarks). There might be some variability in measured time between runs and between different builds. A technique for eliminating for some of the variability is to place code and data in instruction or data RAM (IRAM/DRAM), respectively. The CPU can access IRAM and DRAM directly, eliminating the cache out of the equation. However, this might not always be viable as the size of IRAM and DRAM is limited.

The cache compensated timer is an alternative to placing the code/data to be benchmarked in IRAM/DRAM. This timer uses the processor’s internal event counters in order to determine the amount of time spent on waiting for code/data in case of a cache miss, then subtract that from the recorded wall time.

```c
// Start the timer
ccomp_timer_start();

// Function to time
func_code_to_time();

// Stop the timer, and return the elapsed time in microseconds relative to
// ccomp_timer_start
int64_t t = ccomp_timer_stop();
```

One limitation of the cache compensated timer is that the task that benchmarked functions should be pinned to a core. This is due to each core having its own event counters that are independent of each other. For example, if `ccomp_timer_start` gets called on one core, put to sleep by the scheduler, wakes up, and gets rescheduled on the other core, then the corresponding `ccomp_timer_stop` will be invalid.

4.32.8 Mocks

Note: Currently, mocking is only possible with some selected components when running on the Linux host. In the future, we plan to make essential components in IDF mock-able. This will also include mocking when running on the ESP32.

One of the biggest problems regarding unit testing on embedded systems are the strong hardware dependencies. Running unit tests directly on the ESP32 can be especially difficult for higher layer components for the following reasons:

• Decreased test reliability due to lower layer components and/or hardware setup.
• Increased difficulty in testing edge cases due to limitations of lower layer components and/or hardware setup
• Increased difficulty in identifying the root cause due to the large number of dependencies influencing the behavior

When testing a particular component, (i.e., the component under test), mocking allows the dependencies of the component under test to be substituted (i.e., mocked) entirely in software. Through mocking, hardware details are emulated and specified at run time, but only if necessary. To allow mocking, ESP-IDF integrates the CMock mocking framework as a component. With the addition of some CMake functions in the ESP-IDF build system, it is possible to conveniently mock the entirety (or a part) of an IDF component.

Ideally, all components that the component under test is dependent on should be mocked, thus allowing the test environment complete control over all interactions with the component under test. However, if mocking all dependent components becomes too complex or too tedious (e.g. because you need to mock too many function calls) you have the following options:
• Include more “real” IDF code in the tests. This may work but increases the dependency on the “real” code’s behavior. Furthermore, once a test fails, you may not know if the failure is in your actual code under test or the “real” IDF code.
• Re-evaluate the design of the code under test and attempt to reduce its dependencies by dividing the code under test into more manageable components. This may seem burdensome but it is quite common that unit tests expose software design weaknesses. Fixing design weaknesses will not only help with unit testing in the short term, but will help future code maintenance as well.

Refer to cmock/CMock/docs/CMock_Summary.md for more details on how CMock works and how to create and use mocks.

Requirements
Mocking with CMock requires Ruby on the host machine. Furthermore, since mocking currently only works on the Linux target, the requirements of the latter also need to be fulfilled:
• Installed ESP-IDF including all ESP-IDF requirements
• System package requirements (libbsd, libbsd-dev)
• A recent enough Linux or macOS version and GCC compiler
• All components the application depends on must be either supported on the Linux target (Linux/POSIX simulator) or mock-able

An application that runs on the Linux target has to set the COMPONENTS variable to main in the CMakeLists.txt of the application’s root directory:

```
set(COMPONENTS main)
```

This prevents the automatic inclusion of all components from ESP-IDF to the build process which is otherwise done for convenience.

Mock a Component

If a mocked component, called a component mock, is already available in ESP-IDF, then it can be used right away as long as it satisfies the required functionality. Refer to Component Linux/Mock Support Overview to see which components are mocked already. Then refer to Adjustments in Unit Test in order to use the component mock.

It is necessary to create component mocks if they are not yet provided in ESP-IDF. To create a component mock, the component needs to be overwritten in a particular way. Overriding a component entails creating a component with the exact same name as the original component, then letting the build system discover it later than the original component (see Multiple components with the same name for more details).

In the component mock, the following parts are specified:

• The headers providing the functions to generate mocks for
• Include paths of the aforementioned headers
• Dependencies of the mock component (this is necessary e.g. if the headers include files from other components)

All these parts have to be specified using the IDF build system function idf_component_mock. You can use the IDF build system function idf_component_get_property with the tag COMPONENT_OVERRIDEN_DIR to access the component directory of the original component and then register the mock component parts using idf_component_mock:

```
idf_component_get_property(original_component_dir <original-component-name>_COMPONENT_OVERRIDEN_DIR)
...
idf_component_mock(INCLUDE_DIRS "${original_component_dir}/include"
```

(continues on next page)
The component mock also requires a separate mock directory containing a `mock_config.yaml` file that configures CMock. A simple `mock_config.yaml` could look like this:

```yaml
:cmock:
  :plugins:
    - expect
    - expect_any_args
```

For more details about the CMock configuration YAML file, have a look at [CMock_Summary.md](https://cmock/CMock/docs/CMock_Summary.md).

Note that the component mock does not have to mock the original component in its entirety. As long as the test project’s dependencies and dependencies of other code to the original components are satisfied by the component mock, partial mocking is adequate. In fact, most of the component mocks in IDF in `tools/mocks` are only partially mocking the original component.

Examples of component mocks can be found under `tools/mocks` in the IDF directory. General information on how to override an IDF component can be found in *Multiple components with the same name*. There are several examples for testing code while mocking dependencies with CMock (non-exhaustive list):

- unit test for the NVS Page class.
- unit test for `esp_event`.
- unit test for `mqtt`.

**Adjustments in Unit Test**

The unit test needs to inform the cmake build system to mock dependent components (i.e., it needs to override the original component with the mock component). This is done by either placing the component mock into the project’s components directory or adding the mock component’s directory using the following line in the project’s root `CMakeLists.txt`:

```cmake
list(APPEND EXTRA_COMPONENT_DIRS "<mock_component_dir>")
```

Both methods will override existing components in ESP-IDF with the component mock. The latter is particularly convenient if you use component mocks that are already supplied by IDF.

Users can refer to the `esp_event` host-based unit test and its `esp_event/host_test/esp_event_unit_test/CMakeLists.txt` as an example of a component mock.

### 4.33 Running Applications on Host

**Note:** Running IDF applications on host is currently still an experimental feature, thus there is no guarantee for API stability. However, user feedback via the ESP-IDF GitHub repository or the ESP32 forum is highly welcome, and may help influence the future design of the IDF host-based applications.

This document provides an overview of the methods to run IDF applications on Linux, and what type of IDF applications can typically be run on Linux.

#### 4.33.1 Introduction

Typically, an IDF application is built (cross-compiled) on a host machine, uploaded (i.e., flashed) to an ESP chip for execution, and monitored by the host machine via a UART/USB port. However, execution of an IDF application on...
an ESP chip (hence forth referred to as “running on target”) can be limiting in various development/usage/testing scenarios.

Therefore, it is possible for an IDF application to be built and executed entirely within the same Linux host machine (hence forth referred to as “running on host”). Running ESP-IDF applications on host has several advantages:

- No need to upload to a target.
- Faster execution on a host machine, compared to running on an ESP chip.
- No requirements for any specific hardware, except the host machine itself.
- Easier automation and setup for software testing.
- Large number of tools for code and runtime analysis (e.g. Valgrind).

A large number of IDF components depend on chip-specific hardware. These hardware dependencies must be mocked or simulated when running on host. ESP-IDF currently supports the following mocking and simulation approaches:

1. Using the FreeRTOS POSIX/Linux simulator that simulates FreeRTOS scheduling. On top of this simulation, other APIs are also simulated or implemented when running on host.
2. Using CMock to mock all dependencies and run the code in complete isolation.

In principle, it is possible to mix both approaches (POSIX/Linux simulator and mocking using CMock), but this has not been done yet in ESP-IDF. Note that despite the name, the FreeRTOS POSIX/Linux simulator currently also works on MacOS. Running IDF applications on host machines is often used for testing. However, simulating the environment and mocking dependencies does not fully represent the target device. Thus, testing on the target device is still necessary, though with a different focus that usually puts more weight on integration and system testing.

**Note:** Another possibility to run applications on the host is to use the QEMU simulator. However, QEMU development for IDF applications is currently work in progress and has not been documented yet.

### CMock-Based Approach

This approach uses the CMock framework to solve the problem of missing hardware and software dependencies. CMock-based applications running on the host machine have the added advantage that they usually only compile the necessary code, i.e., the (mostly mocked) dependencies instead of the entire system. For a general introduction to Mocks and how to configure and use them in ESP-IDF, please refer to [Mocks](#).

### POSIX/Linux Simulator Approach

The FreeRTOS POSIX/Linux simulator is available on ESP-IDF as a preview target already. It is the base for the Linux target which is already available as a preview. Using this simulator, IDF components can be implemented on the host to make them available to IDF applications when running on host. Currently, only a limited number of components are ready to be built on Linux. Furthermore the functionality of each component ported to Linux may also be limited or different compared to the functionality when building that component for a chip target. For more information if the desired components are supported on Linux, please refer to [Component Linux/Mock Support Overview](#).

### 4.33.2 Requirements

- Installed ESP-IDF including all ESP-IDF requirements
- System package requirements (libbsd, libbsd-dev)
- A recent enough Linux or macOS version and GCC compiler
- All components the application depends on must be either supported on the Linux target (Linux/POSIX simulator) or mock-able

An application that runs on the Linux target has to set the COMPONENTS variable to main in the CMakeLists.txt of the application’s root directory:
This prevents the automatic inclusion of all components from ESP-IDF to the build process which is otherwise done for convenience.

If any mocks are used, then Ruby is required, too.

### 4.33.3 Build and Run

To build the application on Linux, the target has to be set to `linux` and then it can be built and run:

```
idf.py --preview set-target linux
idf.py build
idf.py monitor
```

### 4.33.4 Component Linux/Mock Support Overview

Note that any “Yes” here does not necessarily mean a full implementation or mocking. It can also mean a partial implementation or mocking of functionality. Usually, the implementation or mocking is done to a point where enough functionality is provided to build and run a test application.

<table>
<thead>
<tr>
<th>Component</th>
<th>Mock</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>driver</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>esp_common</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>esp_event</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>esp_hw_support</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>esp_partition</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>esp_rom</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>esp_system</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>esp_timer</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>esp_tls</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>freertos</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>hal</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>heap</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>http_parser</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>log</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>lwip</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>lwip</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>soc</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>spi_flash</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>tcp_transport</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

### 4.34 Wi-Fi Driver

#### 4.34.1 ESP32 Wi-Fi Feature List

The following features are supported:

- 4 virtual Wi-Fi interfaces, which are STA, AP, Sniffer and reserved.
- Station-only mode, AP-only mode, station/AP-coexistence mode
- IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, and APIs to configure the protocol mode
- WPA/WPA2/WPA3/WPA2-Enterprise/WPA3-Enterprise/WAPI/WPS and DPP
• AMSDU, AMPDU, HT40, QoS, and other key features
• Modem-sleep
• The Espressif-specific ESP-NOW protocol and Long Range mode, which supports up to 1 km of data traffic
• Up to 20 Mbit/s TCP throughput and 30 Mbit/s UDP throughput over the air
• Sniffer
• Both fast scan and all-channel scan
• Multiple antennas
• Channel state information
• Wi-Fi Aware (NAN)

4.34.2 How To Write a Wi-Fi Application

Preparation

Generally, the most effective way to begin your own Wi-Fi application is to select an example which is similar to your own application, and port the useful part into your project. It is not a MUST, but it is strongly recommended that you take some time to read this article first, especially if you want to program a robust Wi-Fi application.

This article is supplementary to the Wi-Fi APIs/Examples. It describes the principles of using the Wi-Fi APIs, the limitations of the current Wi-Fi API implementation, and the most common pitfalls in using Wi-Fi. This article also reveals some design details of the Wi-Fi driver. We recommend you to select an example.

Setting Wi-Fi Compile-time Options

Refer to Wi-Fi Menuconfig.

Init Wi-Fi

Refer to ESP32 Wi-Fi station General Scenario and ESP32 Wi-Fi AP General Scenario.

Start/Connect Wi-Fi

Refer to ESP32 Wi-Fi station General Scenario and ESP32 Wi-Fi AP General Scenario.

Event-Handling

Generally, it is easy to write code in “sunny-day” scenarios, such as WIFI_EVENT_STA_START and WIFI_EVENT_STA_CONNECTED. The hard part is to write routines in “rainy-day” scenarios, such as WIFI_EVENT_STA_DISCONNECTED. Good handling of “rainy-day” scenarios is fundamental to robust Wi-Fi applications. Refer to ESP32 Wi-Fi Event Description, ESP32 Wi-Fi station General Scenario, and ESP32 Wi-Fi AP General Scenario. See also the overview of the Event Loop Library in ESP-IDF.

Write Error-Recovery Routines Correctly at All Times

Just like the handling of “rainy-day” scenarios, a good error-recovery routine is also fundamental to robust Wi-Fi applications. Refer to ESP32 Wi-Fi API Error Code.

4.34.3 ESP32 Wi-Fi API Error Code

All of the ESP32 Wi-Fi APIs have well-defined return values, namely, the error code. The error code can be categorized into:

• No errors, e.g., ESP_OK means that the API returns successfully.
• Recoverable errors, such as ESP_ERR_NO_MEM.
• Non-recoverable, non-critical errors.
• Non-recoverable, critical errors.

Whether the error is critical or not depends on the API and the application scenario, and it is defined by the API user.

**The primary principle to write a robust application with Wi-Fi API is to always check the error code and write the error-handling code.** Generally, the error-handling code can be used:

- For recoverable errors, in which case you can write a recoverable-error code. For example, when `esp_wifi_start()` returns ESP_ERR_NO_MEM, the recoverable-error code `vTaskDelay` can be called in order to get a microseconds delay for another try.
- For non-recoverable, yet non-critical errors, in which case printing the error code is a good method for error handling.
- For non-recoverable and also critical errors, in which case “assert” may be a good method for error handling. For example, if `esp_wifi_set_mode()` returns ESP_ERR_WIFI_NOT_INIT, it means that the Wi-Fi driver is not initialized by `esp_wifi_init()` successfully. You can detect this kind of error very quickly in the application development phase.

In `esp_common/include/esp_err.h`, `ESP_ERROR_CHECK` checks the return values. It is a rather commonplace error-handling code and can be used as the default error-handling code in the application development phase. However, it is strongly recommended that API users write their own error-handling code.

### 4.3.4 ESP32 Wi-Fi API Parameter Initialization

When initializing struct parameters for the API, one of two approaches should be followed:

- Explicitly set all fields of the parameter.
- Use `get API` to get current configuration first, then set application specific fields.

Initializing or getting the entire structure is very important, because most of the time the value 0 indicates that the default value is used. More fields may be added to the struct in the future and initializing these to zero ensures the application will still work correctly after ESP-IDF is updated to a new release.

### 4.3.5 ESP32 Wi-Fi Programming Model

The ESP32 Wi-Fi programming model is depicted as follows:

![Wi-Fi Programming Model](image)

Fig. 57: Wi-Fi Programming Model

The Wi-Fi driver can be considered a black box that knows nothing about high-layer code, such as the TCP/IP stack, application task, and event task. The application task (code) generally calls *Wi-Fi driver APIs* to initialize Wi-Fi...
and handles Wi-Fi events when necessary. Wi-Fi driver receives API calls, handles them, and posts events to the application.

Wi-Fi event handling is based on the `esp_event` library. Events are sent by the Wi-Fi driver to the default event loop. Application may handle these events in callbacks registered using `esp_event_handler_register()`. Wi-Fi events are also handled by `esp_netif` component to provide a set of default behaviors. For example, when Wi-Fi station connects to an AP, esp_netif will automatically start the DHCP client by default.

### 4.34.6 ESP32 Wi-Fi Event Description

#### WIFI_EVENT_WIFI_READY

The Wi-Fi driver will never generate this event, which, as a result, can be ignored by the application event callback. This event may be removed in future releases.

#### WIFI_EVENT_SCAN_DONE

The scan-done event is triggered by `esp_wifi_scan_start()` and will arise in the following scenarios:

- The scan is completed, e.g., the target AP is found successfully, or all channels have been scanned.
- The scan is stopped by `esp_wifi_scan_stop()`.
- The `esp_wifi_scan_start()` is called before the scan is completed. A new scan will override the current scan and a scan-done event will be generated.

The scan-done event will not arise in the following scenarios:

- It is a blocked scan.
- The scan is caused by `esp_wifi_connect()`.

Upon receiving this event, the event task does nothing. The application event callback needs to call `esp_wifi_scan_get_ap_num()` and `esp_wifi_scan_get_ap_records()` to fetch the scanned AP list and trigger the Wi-Fi driver to free the internal memory which is allocated during the scan (do not forget to do this!). Refer to [ESP32 Wi-Fi Scan](#) for a more detailed description.

#### WIFI_EVENT_STA_START

If `esp_wifi_start()` returns ESP_OK and the current Wi-Fi mode is station or station/AP, then this event will arise. Upon receiving this event, the event task will initialize the LwIP network interface (netif). Generally, the application event callback needs to call `esp_wifi_connect()` to connect to the configured AP.

#### WIFI_EVENT_STA_STOP

If `esp_wifi_stop()` returns ESP_OK and the current Wi-Fi mode is station or station/AP, then this event will arise. Upon receiving this event, the event task will release the station’s IP address, stop the DHCP client, remove TCP/UDP-related connections, and clear the LwIP station netif, etc. The application event callback generally does not need to do anything.

#### WIFI_EVENT_STA_CONNECTED

If `esp_wifi_connect()` returns ESP_OK and the station successfully connects to the target AP, the connection event will arise. Upon receiving this event, the event task starts the DHCP client and begins the DHCP process of getting the IP address. Then, the Wi-Fi driver is ready for sending and receiving data. This moment is good for beginning the application work, provided that the application does not depend on LwIP, namely the IP address. However, if the application is LwIP-based, then you need to wait until the got ip event comes in.
**WIFI_EVENT_STA_DISCONNECTED**

This event can be generated in the following scenarios:

- When `esp_wifi_disconnect()` or `esp_wifi_stop()` is called and the station is already connected to the AP.
- When `esp_wifi_connect()` is called, but the Wi-Fi driver fails to set up a connection with the AP due to certain reasons, e.g., the scan fails to find the target AP or the authentication times out. If there are more than one AP with the same SSID, the disconnected event will be raised after the station fails to connect all of the found APs.
- When the Wi-Fi connection is disrupted because of specific reasons, e.g., the station continuously loses N beacons, the AP kicks off the station, or the AP’s authentication mode is changed.

Upon receiving this event, the default behaviors of the event task are:

- Shutting down the station’s LwIP netif.
- Notifying the LwIP task to clear the UDP/TCP connections which cause the wrong status to all sockets. For socket-based applications, the application callback can choose to close all sockets and re-create them, if necessary, upon receiving this event.

The most common event handle code for this event in application is to call `esp_wifi_connect()` to reconnect the Wi-Fi. However, if the event is raised because `esp_wifi_disconnect()` is called, the application should not call `esp_wifi_connect()` to reconnect. It is the application’s responsibility to distinguish whether the event is caused by `esp_wifi_disconnect()` or other reasons. Sometimes a better reconnection strategy is required. Refer to [Wi-Fi Reconnect](#) and [Scan When Wi-Fi Is Connecting](#).

Another thing that deserves attention is that the default behavior of LwIP is to abort all TCP socket connections on receiving the disconnect. In most cases, it is not a problem. However, for some special applications, this may not be what they want. Consider the following scenarios:

- The application creates a TCP connection to maintain the application-level keep-alive data that is sent out every 60 seconds.
- Due to certain reasons, the Wi-Fi connection is cut off, and the `WIFI_EVENT_STA_DISCONNECTED` is raised. According to the current implementation, all TCP connections will be removed and the keep-alive socket will be in a wrong status. However, since the application designer believes that the network layer should ignore this error at the Wi-Fi layer, the application does not close the socket.
- Five seconds later, the Wi-Fi connection is restored because `esp_wifi_connect()` is called in the application event callback function. Moreover, the station connects to the same AP and gets the same IPV4 address as before.
- Sixty seconds later, when the application sends out data with the keep-alive socket, the socket returns an error and the application closes the socket and re-creates it when necessary.

In above scenarios, ideally, the application sockets and the network layer should not be affected, since the Wi-Fi connection only fails temporarily and recovers very quickly. The application can enable “Keep TCP connections when IP changed” via LwIP menuconfig.

**IP_EVENT_STA_GOT_IP**

This event arises when the DHCP client successfully gets the IPV4 address from the DHCP server, or when the IPV4 address is changed. The event means that everything is ready and the application can begin its tasks (e.g., creating sockets).

The IPV4 may be changed because of the following reasons:

- The DHCP client fails to renew/rebind the IPV4 address, and the station’s IPV4 is reset to 0.
- The DHCP client rebinds to a different address.
- The static-configured IPV4 address is changed.

Whether the IPV4 address is changed or not is indicated by the field `ip_change` of `ip_event_got_ip_t`. The socket is based on the IPV4 address, which means that, if the IPV4 changes, all sockets relating to this IPV4 will become abnormal. Upon receiving this event, the application needs to close all sockets and recreate the application when the IPV4 changes to a valid one.
**IP_EVENT_GOT_IP6**

This event arises when the IPV6 SLAAC support auto-configures an address for the ESP32, or when this address changes. The event means that everything is ready and the application can begin its tasks, e.g., creating sockets.

**IP_EVENT_STA_LOST_IP**

This event arises when the IPV4 address becomes invalid.

IP_EVENT_STA_LOST_IP does not arise immediately after the Wi-Fi disconnects. Instead, it starts an IPV4 address lost timer. If the IPV4 address is got before ip lost timer expires, IP_EVENT_STA_LOST_IP does not happen. Otherwise, the event arises when the IPV4 address lost timer expires.

Generally, the application can ignore this event, because it is just a debug event to inform that the IPV4 address is lost.

**WIFI_EVENT_AP_START**

Similar to WIFI_EVENT_STA_START.

**WIFI_EVENT_AP_STOP**

Similar to WIFI_EVENT_STA_STOP.

**WIFI_EVENT_AP_STACONNECTED**

Every time a station is connected to ESP32 AP, the WIFI_EVENT_AP_STACONNECTED will arise. Upon receiving this event, the event task will do nothing, and the application callback can also ignore it. However, you may want to do something, for example, to get the info of the connected STA.

**WIFI_EVENT_AP_STADISCONNECTED**

This event can happen in the following scenarios:

- The application calls `esp_wifi_disconnect()`, or `esp_wifi_deauth_sta()`, to manually disconnect the station.
- The Wi-Fi driver kicks off the station, e.g., because the AP has not received any packets in the past five minutes. The time can be modified by `esp_wifi_set_inactive_time()`.
- The station kicks off the AP.

When this event happens, the event task will do nothing, but the application event callback needs to do something, e.g., close the socket which is related to this station.

**WIFI_EVENT_AP_PROBEREQRECVED**

This event is disabled by default. The application can enable it via API `esp_wifi_set_event_mask()`. When this event is enabled, it will be raised each time the AP receives a probe request.

**WIFI_EVENT_STA_BEACON_TIMEOUT**

If the station does not receive the beacon of the connected AP within the inactive time, the beacon timeout happens, the WIFI_EVENT_STA_BEACON_TIMEOUT will arise. The application can set inactive time via API `esp_wifi_set_inactive_time()`.
Chapter 4. API Guides

WIFI_EVENT_CONNECTIONLESS_MODULE_WAKE_INTERVAL_START

The WIFI_EVENT_CONNECTIONLESS_MODULE_WAKE_INTERVAL_START will arise at the start of connectionless module Interval. See connectionless module power save.

4.34.7 ESP32 Wi-Fi Station General Scenario

Below is a “big scenario” which describes some small scenarios in station mode:

1. Wi-Fi/LwIP Init Phase

- s1.1: The main task calls esp_netif_init() to create an LwIP core task and initialize LwIP-related work.
- s1.2: The main task calls esp_event_loop_create() to create a system Event task and initialize an application event’s callback function. In the scenario above, the application event’s callback function does nothing but relaying the event to the application task.
- s1.3: The main task calls esp_netif_create_default_wifi_ap() or esp_netif_create_default_wifi_sta() to create default network interface instance binding station or AP with TCP/IP stack.
- s1.4: The main task calls esp_wifi_init() to create the Wi-Fi driver task and initialize the Wi-Fi driver.
- s1.5: The main task calls OS API to create the application task.

Step 1.1 ~ 1.5 is a recommended sequence that initializes a Wi-Fi-/LwIP-based application. However, it is NOT a must-follow sequence, which means that you can create the application task in step 1.1 and put all other initialization in the application task. Moreover, you may not want to create the application task in the initialization phase if the application task depends on the sockets. Rather, you can defer the task creation until the IP is obtained.

2. Wi-Fi Configuration Phase

Once the Wi-Fi driver is initialized, you can start configuring the Wi-Fi driver. In this scenario, the mode is station, so you may need to call esp_wifi_set_mode() (WIFI_MODE_STA) to configure the Wi-Fi mode as station. You can call other esp_wifi_set_xxx APIs to configure more settings, such as the protocol mode, the country code, and the bandwidth. Refer to ESP32 Wi-Fi Configuration.

Generally, the Wi-Fi driver should be configured before the Wi-Fi connection is set up. But this is NOT mandatory, which means that you can configure the Wi-Fi connection anytime, provided that the Wi-Fi driver is initialized successfully. However, if the configuration does not need to change after the Wi-Fi connection is set up, you should configure the Wi-Fi driver at this stage, because the configuration APIs (such as esp_wifi_set_protocol()) will cause the Wi-Fi to reconnect, which may not be desirable.

If the Wi-Fi NVS flash is enabled by menuconfig, all Wi-Fi configuration in this phase, or later phases, will be stored into flash. When the board powers on/reboots, you do not need to configure the Wi-Fi driver from scratch. You only need to call esp_wifi_get_xxx APIs to fetch the configuration stored in flash previously. You can also configure the Wi-Fi driver if the previous configuration is not what you want.

3. Wi-Fi Start Phase

- s3.1: Call esp_wifi_start() to start the Wi-Fi driver.
- s3.2: The Wi-Fi driver posts WIFI_EVENT_STA_START to the event task; then, the event task will do some common things and will call the application event callback function.
- s3.3: The application event callback function relays the WIFI_EVENT_STA_START to the application task. We recommend that you call esp_wifi_connect(). However, you can also call esp_wifi_connect() in other phrases after the WIFI_EVENT_STA_START arises.
Chapter 4. API Guides

Fig. 58: Sample Wi-Fi Event Scenarios in Station Mode

1. Init Phase
   1.1. Create / init LwIP
   1.2. Create / init event
   1.3. Create / init Wi-Fi
   1.4. Create app tasks

2. Configure Phase
   2. Configure Wi-Fi

3. Start Phase
   3.1. Start Wi-Fi
   3.2. WIFI_EVENT_STA_START
   3.3. WIFI_EVENT_STA_START

4. Connect Phase
   4.1. Connect Wi-Fi
   4.2. WIFI_EVENT_STA_CONNECTED
   4.3. WIFI_EVENT_STA_CONNECTED

5. Get IP Phase
   5.1. Start DHCP client
   5.2. WIFI_EVENT_STA_GOT_IP
   5.3. WIFI_EVENT_STA_GOT_IP
   5.4. Socket activated

6. Disconnect Phase
   6.1. WIFI_EVENT_STA_DISCONNECTED
   6.2. WIFI_EVENT_STA_DISCONNECTED
   6.3. Disconnect handling

7. IP Change Phase
   7.1. WIFI_EVENT_STA_GOT_IP
   7.2. WIFI_EVENT_STA_GOT_IP
   7.3. Socket error handling

8. Deinit Phase
   8.1. Disconnect Wi-Fi
   8.2. Stop Wi-Fi
   8.3. Deinit Wi-Fi

Espressif Systems

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4. Wi-Fi Connect Phase

- s4.1: Once `esp_wifi_connect()` is called, the Wi-Fi driver will start the internal scan/connection process.
- s4.2: If the internal scan/connection process is successful, the `WIFI_EVENT_STA_CONNECTED` will be generated. In the event task, it starts the DHCP client, which will finally trigger the DHCP process.
- s4.3: In the above-mentioned scenario, the application event callback will relay the event to the application task. Generally, the application needs to do nothing, and you can do whatever you want, e.g., print a log.

In step 4.2, the Wi-Fi connection may fail because, for example, the password is wrong, or the AP is not found. In a case like this, `WIFI_EVENT_STA_DISCONNECTED` will arise and the reason for such a failure will be provided. For handling events that disrupt Wi-Fi connection, please refer to phase 6.

5. Wi-Fi ‘Got IP’ Phase

- s5.1: Once the DHCP client is initialized in step 4.2, the got IP phase will begin.
- s5.2: If the IP address is successfully received from the DHCP server, then `IP_EVENT_STA_GOT_IP` will arise and the event task will perform common handling.
- s5.3: In the application event callback, `IP_EVENT_STA_GOT_IP` is relayed to the application task. For LwIP-based applications, this event is very special and means that everything is ready for the application to begin its tasks, e.g., creating the TCP/UDP socket. A very common mistake is to initialize the socket before `IP_EVENT_STA_GOT_IP` is received. **DO NOT start the socket-related work before the IP is received.**

6. Wi-Fi Disconnect Phase

- s6.1: When the Wi-Fi connection is disrupted, e.g., the AP is powered off or the RSSI is poor, `WIFI_EVENT_STA_DISCONNECTED` will arise. This event may also arise in phase 3. Here, the event task will notify the LwIP task to clear/remove all UDP/TCP connections. Then, all application sockets will be in a wrong status. In other words, no socket can work properly when this event happens.
- s6.2: In the scenario described above, the application event callback function relays `WIFI_EVENT_STA_DISCONNECTED` to the application task. The recommended actions are: 1) call `esp_wifi_connect()` to reconnect the Wi-Fi, 2) close all sockets, and 3) re-create them if necessary. For details, please refer to `WIFI_EVENT_STA_DISCONNECTED`.

7. Wi-Fi IP Change Phase

- s7.1: If the IP address is changed, the `IP_EVENT_STA_GOT_IP` will arise with “ip_change” set to true.
- s7.2: This event is important to the application. When it occurs, the timing is good for closing all created sockets and recreating them.

8. Wi-Fi Deinit Phase

- s8.1: Call `esp_wifi_disconnect()` to disconnect the Wi-Fi connectivity.
- s8.2: Call `esp_wifi_stop()` to stop the Wi-Fi driver.
- s8.3: Call `esp_wifi_deinit()` to unload the Wi-Fi driver.

4.3.4.8 ESP32 Wi-Fi AP General Scenario

Below is a “big scenario” which describes some small scenarios in AP mode:
Fig. 59: Sample Wi-Fi Event Scenarios in AP Mode
4.34.9 ESP32 Wi-Fi Scan

Currently, the `esp_wifi_scan_start()` API is supported only in station or station/AP mode.

### Scan Type

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Scan</td>
<td>Scan by sending a probe request. The default scan is an active scan.</td>
</tr>
<tr>
<td>Passive Scan</td>
<td>No probe request is sent out. Just switch to the specific channel and wait for a beacon. Application can enable it via the <code>scan_type</code> field of <code>wifi_scan_config_t</code>.</td>
</tr>
<tr>
<td>Foreground Scan</td>
<td>This scan is applicable when there is no Wi-Fi connection in station mode. Foreground or background scanning is controlled by the Wi-Fi driver and cannot be configured by the application.</td>
</tr>
<tr>
<td>Background Scan</td>
<td>This scan is applicable when there is a Wi-Fi connection in station mode or in station/AP mode. Whether it is a foreground scan or background scan depends on the Wi-Fi driver and cannot be configured by the application.</td>
</tr>
<tr>
<td>All-Channel Scan</td>
<td>It scans all of the channels. If the channel field of <code>wifi_scan_config_t</code> is set to 0, it is an all-channel scan.</td>
</tr>
<tr>
<td>Specific Channel</td>
<td>It scans specific channels only. If the channel field of <code>wifi_scan_config_t</code> set to 1-14, it is a specific-channel scan.</td>
</tr>
</tbody>
</table>

The scan modes in above table can be combined arbitrarily, so there are in total 8 different scans:

- All-Channel Background Active Scan
- All-Channel Background Passive Scan
- All-Channel Foreground Active Scan
- All-Channel Foreground Passive Scan
- Specific-Channel Background Active Scan
- Specific-Channel Background Passive Scan
- Specific-Channel Foreground Active Scan
- Specific-Channel Foreground Passive Scan

### Scan Configuration

The scan type and other per-scan attributes are configured by `esp_wifi_scan_start()`. The table below provides a detailed description of `wifi_scan_config_t`. 
### Field Description

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssid</td>
<td>If the SSID is not NULL, it is only the AP with the same SSID that can be scanned.</td>
</tr>
<tr>
<td>bssid</td>
<td>If the BSSID is not NULL, it is only the AP with the same BSSID that can be scanned.</td>
</tr>
<tr>
<td>channel</td>
<td>If “channel” is 0, there will be an all-channel scan; otherwise, there will be a specific-channel scan.</td>
</tr>
<tr>
<td>show_hidden</td>
<td>If “show_hidden” is 0, the scan ignores the AP with a hidden SSID; otherwise, the scan considers the hidden AP a normal one.</td>
</tr>
<tr>
<td>scan_type</td>
<td>If “scan_type” is WIFI_SCAN_TYPE_ACTIVE, the scan is “active”; otherwise, it is a “passive” one.</td>
</tr>
</tbody>
</table>
| scan_time | This field is used to control how long the scan dwells on each channel. For passive scans, scan_time.passive designates the dwell time for each channel. For active scans, dwell times for each channel are listed in the table below. Here, min is short for scan_time.active.min and max is short for scan_time.active.max.  
• min=0, max=0: scan dwells on each channel for 120 ms.  
• min>0, max=0: scan dwells on each channel for 120 ms.  
• min=0, max>0: scan dwells on each channel for max ms.  
• min>0, max>0: the minimum time the scan dwells on each channel is min ms. If no AP is found during this time frame, the scan switches to the next channel. Otherwise, the scan dwells on the channel for max ms. If you want to improve the performance of the scan, you can try to modify these two parameters. |

There are also some global scan attributes which are configured by API esp_wifi_set_config(), refer to Station Basic Configuration.

### Scan All APs on All Channels (Foreground)

**Scenario:**

The scenario above describes an all-channel, foreground scan. The foreground scan can only occur in station mode where the station does not connect to any AP. Whether it is a foreground or background scan is totally determined by the Wi-Fi driver, and cannot be configured by the application.

Detailed scenario description:

#### Scan Configuration Phase

- s1.1: Call esp_wifi_set_country() to set the country info if the default country info is not what you want. Refer to Wi-Fi Country Code.
- s1.2: Call esp_wifi_scan_start() to configure the scan. To do so, you can refer to Scan Configuration. Since this is an all-channel scan, just set the SSID/BSSID/channel to 0.

#### Wi-Fi Driver’s Internal Scan Phase

- s2.1: The Wi-Fi driver switches to channel 1. In this case, the scan type is WIFI_SCAN_TYPE_ACTIVE, and a probe request is broadcasted. Otherwise, the Wi-Fi will wait for a beacon from the APs. The Wi-Fi driver will stay in channel 1 for some time. The dwell time is configured in min/max time, with the default value being 120 ms.
- s2.2: The Wi-Fi driver switches to channel 2 and performs the same operation as in step 2.1.
- s2.3: The Wi-Fi driver scans the last channel N, where N is determined by the country code which is configured in step 1.1.

#### Scan-Done Event Handling Phase

- s3.1: When all channels are scanned, WIFI_EVENT_SCAN_DONE will arise.
Fig. 60: Foreground Scan of all Wi-Fi Channels
• s3.2: The application’s event callback function notifies the application task that \textit{WIFI\_EVENT\_SCAN\_DONE} is received. \texttt{esp\_wifi\_scan\_get\_ap\_num()} is called to get the number of APs that have been found in this scan. Then, it allocates enough entries and calls \texttt{esp\_wifi\_scan\_get\_ap\_records()} to get the AP records. Please note that the AP records in the Wi-Fi driver will be freed once \texttt{esp\_wifi\_scan\_get\_ap\_records()} is called. Do not call \texttt{esp\_wifi\_scan\_get\_ap\_records()} twice for a single scan-done event. If \texttt{esp\_wifi\_scan\_get\_ap\_records()} is not called when the scan-done event occurs, the AP records allocated by the Wi-Fi driver will not be freed. So, make sure you call \texttt{esp\_wifi\_scan\_get\_ap\_records()}, yet only once.

\textbf{Scan All APs on All Channels (Background)}

\textbf{Scenario:}
The scenario above is an all-channel background scan. Compared to \textit{Scan All APs on All Channels (Foreground)}, the difference in the all-channel background scan is that the Wi-Fi driver will scan the back-to-home channel for 30 ms before it switches to the next channel to give the Wi-Fi connection a chance to transmit/receive data.

\textbf{Scan for Specific AP on All Channels}

\textbf{Scenario:}
This scan is similar to \textit{Scan All APs on All Channels (Foreground)}. The differences are:

• s1.1: In step 1.2, the target AP will be configured to SSID/BSSID.
• s2.1 \sim s2.N: Each time the Wi-Fi driver scans an AP, it will check whether it is a target AP or not. If the scan is \textit{WIFI\_FAST\_SCAN} scan and the target AP is found, then the scan-done event will arise and scanning will end; otherwise, the scan will continue. Please note that the first scanned channel may not be channel 1, because the Wi-Fi driver optimizes the scanning sequence.

It is a possible situation that there are multiple APs that match the target AP info, e.g., two APs with the SSID of “ap” are scanned. In this case, if the scan is \textit{WIFI\_FAST\_SCAN}, then only the first scanned “ap” will be found. If the scan is \textit{WIFI\_ALL\_CHANNEL\_SCAN}, both “ap” will be found and the station will connect the “ap” according to the configured strategy. Refer to \textit{Station Basic Configuration}.

You can scan a specific AP, or all of them, in any given channel. These two scenarios are very similar.

\textbf{Scan in Wi-Fi Connect}

When \texttt{esp\_wifi\_connect()} is called, the Wi-Fi driver will try to scan the configured AP first. The scan in “Wi-Fi Connect” is the same as \textit{Scan for Specific AP On All Channels}, except that no scan-done event will be generated when the scan is completed. If the target AP is found, the Wi-Fi driver will start the Wi-Fi connection; otherwise, \textit{WIFI\_EVENT\_STA\_DISCONNECTED} will be generated. Refer to \textit{Scan for Specific AP On All Channels}.

\textbf{Scan in Blocked Mode}

If the block parameter of \texttt{esp\_wifi\_scan\_start()} is true, then the scan is a blocked one, and the application task will be blocked until the scan is done. The blocked scan is similar to an unblocked one, except that no scan-done event will arise when the blocked scan is completed.

\textbf{Parallel Scan}

Two application tasks may call \texttt{esp\_wifi\_scan\_start()} at the same time, or the same application task calls \texttt{esp\_wifi\_scan\_start()} before it gets a scan-done event. Both scenarios can happen. However, the Wi-Fi driver does not support multiple concurrent scans adequately. As a result, concurrent scans should be avoided. Support for concurrent scan will be enhanced in future releases, as the ESP32’s Wi-Fi functionality improves continuously.

Espressif Systems 2607 Release v5.1.2
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Fig. 61: Background Scan of all Wi-Fi Channels

1.1 > Configure country code
1.2 > Scan configuration

2.1 > Scan channel 1
2.2 > Back to home channel H
2.3 > Scan channel 2
2.4 > Back to home channel H
...  
2.x-1 > Scan channel N
2.x > Back to home channel H

3.1 > WIFI_EVENT_SCAN_DONE
3.2 > WIFI_EVENT_SCAN_DONE
Fig. 62: Scan of specific Wi-Fi Channels
Scan When Wi-Fi Is Connecting

The \texttt{esp_wifi_scan_start()} fails immediately if the Wi-Fi is connecting, because the connecting has higher priority than the scan. If scan fails because of connecting, the recommended strategy is to delay for some time and retry scan again. The scan will succeed once the connecting is completed.

However, the retry/delay strategy may not work all the time. Considering the following scenarios:

- The station is connecting a non-existing AP or it connects the existing AP with a wrong password, it always raises the event \texttt{WIFI_EVENT_STA_DISCONNECTED}.
- The application calls \texttt{esp_wifi_connect()} to reconnect on receiving the disconnect event.
- Another application task, e.g., the console task, calls \texttt{esp_wifi_scan_start()} to do scan, the scan always fails immediately because the station keeps connecting.
- When scan fails, the application simply delays for some time and retries the scan.

In the above scenarios, the scan will never succeed because the connecting is in process. So if the application supports similar scenario, it needs to implement a better reconnection strategy. For example:

- The application can choose to define a maximum continuous reconnection counter and stop reconnecting once the counter reaches the maximum.
- The application can choose to reconnect immediately in the first N continuous reconnection, then give a delay sometime and reconnect again.

The application can define its own reconnection strategy to avoid the scan starve to death. Refer to <Wi-Fi Reconnect>.

### 4.34.10 ESP32 Wi-Fi Station Connecting Scenario

This scenario depicts the case if only one target AP is found in the scan phase. For scenarios where more than one AP with the same SSID is found, refer to ESP32 Wi-Fi Station Connecting When Multiple APs Are Found.

Generally, the application can ignore the connecting process. Below is a brief introduction to the process for those who are really interested.

Scenario:

**Scan Phase**

- s1.1: The Wi-Fi driver begins scanning in “Wi-Fi Connect”. Refer to Scan in Wi-Fi Connect for more details.
- s1.2: If the scan fails to find the target AP, \texttt{WIFI_EVENT_STA_DISCONNECTED} will arise and the reason code will be \texttt{WIFI_REASON_NO_AP_FOUND}. Refer to Wi-Fi Reason Code.

**Auth Phase**

- s2.1: The authentication request packet is sent and the auth timer is enabled.
- s2.2: If the authentication response packet is not received before the authentication timer times out, \texttt{WIFI_EVENT_STA_DISCONNECTED} will arise and the reason code will be \texttt{WIFI_REASON_AUTH_EXPIRE}. Refer to Wi-Fi Reason Code.
- s2.3: The auth-response packet is received and the auth-timer is stopped.
- s2.4: The AP rejects authentication in the response and \texttt{WIFI_EVENT_STA_DISCONNECTED} arises, while the reason code is \texttt{WIFI_REASON_AUTH_FAIL} or the reasons specified by the AP. Refer to Wi-Fi Reason Code.

**Association Phase**

- s3.1: The association request is sent and the association timer is enabled.
- s3.2: If the association response is not received before the association timer times out, \texttt{WIFI_EVENT_STA_DISCONNECTED} will arise and the reason code will be \texttt{WIFI_REASON_ASSOC_EXPIRE}. Refer to Wi-Fi Reason Code.
Fig. 63: Wi-Fi Station Connecting Process

1. Scan Phase
   1.1 > Scan
   1.2 > WIFI_EVENT_STA_DISCONNECTED

2. Auth Phase
   2.1 > Auth request
   2.2 > WIFI_EVENT_STA_DISCONNECTED
   2.3 > Auth response
   2.4 > WIFI_EVENT_STA_DISCONNECTED

3. Assoc Phase
   3.1 > Assoc request
   3.2 > WIFI_EVENT_STA_DISCONNECTED
   3.3 > Assoc response
   3.4 > WIFI_EVENT_STA_DISCONNECTED

4. 4-way Handshake Phase
   4.1 > WIFI_EVENT_STA_DISCONNECTED
   4.2 > 1/4 EAPOL
   4.3 > 2/4 EAPOL
   4.4 > WIFI_EVENT_STA_DISCONNECTED
   4.5 > 3/4 EAPOL
   4.6 > 4/4 EAPOL
   4.7 > WIFI_EVENT_STA_CONNECTED
Chapter 4. API Guides

- s3.3: The association response is received and the association timer is stopped.
- s3.4: The AP rejects the association in the response and `WIFI_EVENT_STA_DISCONNECTED` arises, while the reason code is the one specified in the association response. Refer to `Wi-Fi Reason Code`.

Four-way Handshake Phase

- s4.1: The handshake timer is enabled, and the 1/4 EAPOL is not received before the handshake timer expires. `WIFI_EVENT_STA_DISCONNECTED` will arise and the reason code will be `WIFI_REASON_HANDSHAKE_TIMEOUT`. Refer to `Wi-Fi Reason Code`.
- s4.2: The 1/4 EAPOL is received.
- s4.3: The station replies 2/4 EAPOL.
- s4.4: If the 3/4 EAPOL is not received before the handshake timer expires, `WIFI_EVENT_STA_DISCONNECTED` will arise and the reason code will be `WIFI_REASON_HANDSHAKE_TIMEOUT`. Refer to `Wi-Fi Reason Code`.
- s4.5: The 3/4 EAPOL is received.
- s4.6: The station replies 4/4 EAPOL.
- s4.7: The station raises `WIFI_EVENT_STA_CONNECTED`.

Wi-Fi Reason Code

The table below shows the reason-code defined in ESP32. The first column is the macro name defined in `esp_wifi/include/esp_wifi_types.h`. The common prefix `WIFI_REASON` is removed, which means `UNSPECIFIED` actually stands for `WIFI_REASON_UNSPECIFIED` and so on. The second column is the value of the reason. The third column is the standard value to which this reason is mapped in section 9.4.1.7 of IEEE 802.11-2020. (For more information, refer to the standard mentioned above.) The last column describes the reason.

<table>
<thead>
<tr>
<th>Reason Code</th>
<th>Value</th>
<th>Mapped To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNSPECIFIED</td>
<td>1</td>
<td>1</td>
<td>Generally, it means an internal failure, e.g., the memory runs out, the internal TX fails, or the reason is received from the remote side.</td>
</tr>
<tr>
<td>AUTH_EXPIRE</td>
<td>2</td>
<td></td>
<td>The previous authentication is no longer valid. For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• auth is timed out.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the reason is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the reason is received from the AP. For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP has not received any packets from the station in the past five minutes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP is stopped by calling <code>esp_wifi_stop()</code>.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the station is de-authed by calling <code>esp_wifi_deauth_sta()</code></td>
</tr>
<tr>
<td>AUTH_LEAVE</td>
<td>3</td>
<td></td>
<td>De-authenticated, because the sending station is leaving (or has left). For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
</tbody>
</table>

continues on next page
<table>
<thead>
<tr>
<th>Reason code</th>
<th>Value</th>
<th>Mapped To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS-SOC_EXPIRE</td>
<td>4</td>
<td>4</td>
<td>Disassociated due to inactivity. For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP has not received any packets from the station in the past five minutes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP is stopped by calling <code>esp_wifi_stop()</code>.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the station is de-authed by calling <code>esp_wifi_deauth_sta()</code>.</td>
</tr>
<tr>
<td>AS-SOC_TOOMANY</td>
<td>5</td>
<td>5</td>
<td>Disassociated, because the AP is unable to handle all currently associated STAs at the same time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the stations associated with the AP reach the maximum number that the AP can support.</td>
</tr>
<tr>
<td>NOT_AUTHED</td>
<td>6</td>
<td>6</td>
<td>Class-2 frame received from a non-authenticated STA.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP receives a packet with data from a non-authenticated station.</td>
</tr>
<tr>
<td>NOT_ASSOCED</td>
<td>7</td>
<td>7</td>
<td>Class-3 frame received from a non-associated STA.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP receives a packet with data from a non-associated station.</td>
</tr>
<tr>
<td>AS-SOC_LEAVE</td>
<td>8</td>
<td>8</td>
<td>Disassociated, because the sending station is leaving (or has left) BSS.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the station is disconnected by <code>esp_wifi_disconnect()</code> and other APIs.</td>
</tr>
<tr>
<td>AS-SOC_NOT_AUTHED</td>
<td>9</td>
<td>9</td>
<td>Station requesting (re)association is not authenticated by the responding STA.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• the AP receives packets with data from an associated, yet not authenticated, station.</td>
</tr>
<tr>
<td>DIS-AS-SOC_PWRCAP_BAD</td>
<td>10</td>
<td>10</td>
<td>Disassociated, because the information in the Power Capability element is unacceptable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
</tbody>
</table>

continues on next page
Table 32 – continued from previous page

<table>
<thead>
<tr>
<th>Reason code</th>
<th>Value</th>
<th>Mapped To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIS-ASSOC_SUPCHAN_BAD</td>
<td>11</td>
<td>11</td>
<td>Disassociated, because the information in the Supported Channels element is unacceptable. For the ESP station, this reason is reported when: • it is received from the AP.</td>
</tr>
<tr>
<td>IE_INVALID</td>
<td>13</td>
<td>13</td>
<td>Invalid element, i.e., an element whose content does not meet the specifications of the Standard in frame formats clause. For the ESP station, this reason is reported when: • it is received from the AP. For the ESP AP, this reason is reported when: • the AP parses a wrong WPA or RSN IE.</td>
</tr>
<tr>
<td>MIC_FAILURE</td>
<td>14</td>
<td>14</td>
<td>Message integrity code (MIC) failure. For the ESP station, this reason is reported when: • it is received from the AP.</td>
</tr>
<tr>
<td>4WAY_HANDSHAKE_TIMEOUT</td>
<td>15</td>
<td>15</td>
<td>Four-way handshake times out. For legacy reasons, in ESP this reason code is replaced with WIFI_REASON_HANDSHAKE_TIMEOUT. For the ESP station, this reason is reported when: • the handshake times out. • it is received from the AP.</td>
</tr>
<tr>
<td>GROUPKEY_UPDATE_TIMEOUT</td>
<td>16</td>
<td>16</td>
<td>Group-Key Handshake times out. For the ESP station, this reason is reported when: • it is received from the AP.</td>
</tr>
<tr>
<td>IE_IN_4WAY_DIFFERS</td>
<td>17</td>
<td>17</td>
<td>The element in the four-way handshake is different from the (Re-)Association Request/Probe and Response/Beacon frame. For the ESP station, this reason is reported when: • it is received from the AP. • the station finds that the four-way handshake IE differs from the IE in the (Re-)Association Request/Probe and Response/Beacon frame.</td>
</tr>
<tr>
<td>GROUP_CIPHER_INVALID</td>
<td>18</td>
<td>18</td>
<td>Invalid group cipher. For the ESP station, this reason is reported when: • it is received from the AP.</td>
</tr>
<tr>
<td>PAIRWISE_CIPHER_INVALID</td>
<td>19</td>
<td>19</td>
<td>Invalid pairwise cipher. For the ESP station, this reason is reported when: • it is received from the AP.</td>
</tr>
<tr>
<td>AKMP_INVALID</td>
<td>20</td>
<td>20</td>
<td>Invalid AKMP. For the ESP station, this reason is reported when: - it is received from the AP.</td>
</tr>
<tr>
<td>UNSUPPORTED_RSN_IE_VERSION</td>
<td>21</td>
<td>21</td>
<td>Unsupported RSN IE version. For the ESP station, this reason is reported when: • it is received from the AP.</td>
</tr>
</tbody>
</table>

continues on next page
<table>
<thead>
<tr>
<th>Reason code</th>
<th>Value</th>
<th>Mapped To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN-VALID_RSN_IE_CAP</td>
<td>22</td>
<td>22</td>
<td>Invalid RSNE capabilities. For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td>802_1X_AUTH_FAILED</td>
<td>23</td>
<td>23</td>
<td>IEEE 802.1X authentication failed. For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For the ESP AP, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• IEEE 802.1X authentication fails.</td>
</tr>
<tr>
<td>CIPHER_SUITE_REJECTED</td>
<td>24</td>
<td>24</td>
<td>Cipher suite rejected due to security policies. For the ESP station, this reason is reported when:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• it is received from the AP.</td>
</tr>
<tr>
<td>TDLS_PEER_UNREACHABLE</td>
<td>25</td>
<td>25</td>
<td>TDLS direct-link teardown due to TDLS peer STA unreachable via the TDLS direct link.</td>
</tr>
<tr>
<td>TDLS_UNSPECIFIED</td>
<td>26</td>
<td>26</td>
<td>TDLS direct-link teardown for unspecified reason.</td>
</tr>
<tr>
<td>SSP_REQUESTED_DISASSOC</td>
<td>31</td>
<td>31</td>
<td>Disassociated because session terminated by SSP request.</td>
</tr>
<tr>
<td>NO_SSP_ROAMING_AGREEMENT</td>
<td>32</td>
<td>32</td>
<td>Disassociated because of lack of SSP roaming agreement.</td>
</tr>
<tr>
<td>BAD_CIPHER_OR_AKM</td>
<td>33</td>
<td>33</td>
<td>Requested service rejected because of SSP cipher suite or AKM requirement.</td>
</tr>
<tr>
<td>NOTAUTHORIZED_THIS_LOCATION</td>
<td>34</td>
<td>34</td>
<td>Requested service not authorized in this location.</td>
</tr>
<tr>
<td>SERVICE_CHANGE_PRECLUDES_TS</td>
<td>35</td>
<td>35</td>
<td>TS deleted because QoS AP lacks sufficient bandwidth for this QoS STA due to a change in BSS service characteristics or operational mode (e.g., an HT BSS change from 40 MHz channel to 20 MHz channel).</td>
</tr>
<tr>
<td>UNSPECIFIED_QOS</td>
<td>36</td>
<td>36</td>
<td>Disassociated for unspecified, QoS-related reason.</td>
</tr>
<tr>
<td>NOT_ENOUGH_BW</td>
<td>37</td>
<td>37</td>
<td>Disassociated because QoS AP lacks sufficient bandwidth for this QoS STA.</td>
</tr>
<tr>
<td>MISSING_ACKS</td>
<td>38</td>
<td>38</td>
<td>Disassociated because excessive number of frames need to be acknowledged, but are not acknowledged due to AP transmissions and/or poor channel conditions.</td>
</tr>
<tr>
<td>EXCEEDED_TXOP</td>
<td>39</td>
<td>39</td>
<td>Disassociated because STA is transmitting outside the limits of its TXOPs.</td>
</tr>
<tr>
<td>STA_LEAVING</td>
<td>40</td>
<td>40</td>
<td>Requesting STA is leaving the BSS (or resetting).</td>
</tr>
<tr>
<td>END_BA</td>
<td>41</td>
<td>41</td>
<td>Requesting STA is no longer using the stream or session.</td>
</tr>
<tr>
<td>UNKNOWN_BA</td>
<td>42</td>
<td>42</td>
<td>Requesting STA received frames using a mechanism for which a setup has not been completed.</td>
</tr>
<tr>
<td>TIME_OUT</td>
<td>43</td>
<td>43</td>
<td>Requested from peer STA due to timeout</td>
</tr>
<tr>
<td>RESERVED</td>
<td>44</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>PEER_INITIATED</td>
<td>45</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>AP_INITIATED</td>
<td>46</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>INVALID_FT_ACTION_FRAME_COUNT</td>
<td>47</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>48</td>
<td></td>
</tr>
</tbody>
</table>

continues on next page
<table>
<thead>
<tr>
<th>Reason code</th>
<th>Value</th>
<th>Mapped To</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INVALID_PMKID</td>
<td>49</td>
<td>49</td>
<td>Invalid pairwise master key identifier (PMKID).</td>
</tr>
<tr>
<td>INVALID_MDE</td>
<td>50</td>
<td>50</td>
<td>Invalid MDE.</td>
</tr>
<tr>
<td>INVALID_FTE</td>
<td>51</td>
<td>51</td>
<td>Invalid FTE</td>
</tr>
<tr>
<td>TRANSMISSION_LINK_ESTABLISHMENT_FAILED</td>
<td>67</td>
<td>67</td>
<td>Transmission link establishment in alternative channel failed.</td>
</tr>
<tr>
<td>ALTERNATIVE_CHANNEL_OCCUPIED</td>
<td>68</td>
<td>68</td>
<td>The alternative channel is occupied.</td>
</tr>
<tr>
<td>BEACON_TIMEOUT</td>
<td>200</td>
<td>reserved</td>
<td>Espressif-specific Wi-Fi reason code: when the station loses N beacons continuously, it will disrupt the connection and report this reason.</td>
</tr>
<tr>
<td>NO_AP_FOUND</td>
<td>201</td>
<td>reserved</td>
<td>Espressif-specific Wi-Fi reason code: when the station fails to scan the target AP, this reason code will be reported.</td>
</tr>
<tr>
<td>AUTH_FAIL</td>
<td>202</td>
<td>reserved</td>
<td>Espressif-specific Wi-Fi reason code: the authentication fails, but not because of ASSOC_EXPIRE or ASSOC_TOOMANY.</td>
</tr>
<tr>
<td>ASSOC_FAIL</td>
<td>203</td>
<td>reserved</td>
<td>Espressif-specific Wi-Fi reason code: the association fails, but not because of ASSOC_EXPIRE or ASSOC_TOOMANY.</td>
</tr>
<tr>
<td>HANDSHAKE_TIMEOUT</td>
<td>204</td>
<td>reserved</td>
<td>Espressif-specific Wi-Fi reason code: the handshake fails for the same reason as that in WIFI_REASON_4WAY_HANDSHAKE_TIMEOUT.</td>
</tr>
<tr>
<td>CONNECTION_FAIL</td>
<td>205</td>
<td>reserved</td>
<td>Espressif-specific Wi-Fi reason code: the connection to the AP has failed.</td>
</tr>
</tbody>
</table>

Wi-Fi Reason code related to wrong password

The table below shows the Wi-Fi reason-code may related to wrong password.

<table>
<thead>
<tr>
<th>Reason code</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4WAY_HANDSHAKE_TIMEOUT</td>
<td>15</td>
<td>Four-way handshake times out. Setting wrong password when STA connecting to an encrypted AP.</td>
</tr>
</tbody>
</table>
| NO_AP_FOUND | 201 | This may related to wrong password in the two scenarios:  
  • Setting password when STA connecting to an unencrypted AP.  
  • Doesn’t setting password when STA connecting to an encrypted AP. |
| HANDSHAKE_TIMEOUT | 204 | Four-way handshake fails. |

Wi-Fi Reason code related to low RSSI

The table below shows the Wi-Fi reason-code may related to low RSSI.
4.34.11 ESP32 Wi-Fi Station Connecting When Multiple APs Are Found

This scenario is similar as ESP32 Wi-Fi Station Connecting Scenario. The difference is that the station will not raise the event WIFI_EVENT_STA_DISCONNECTED unless it fails to connect all of the found APs.

4.34.12 Wi-Fi Reconnect

The station may disconnect due to many reasons, e.g., the connected AP is restarted. It is the application’s responsibility to reconnect. The recommended reconnection strategy is to call \texttt{esp\_wifi\_connect()} on receiving event WIFI_EVENT_STA_DISCONNECTED.

Sometimes the application needs more complex reconnection strategy:

- If the disconnect event is raised because the \texttt{esp\_wifi\_disconnect()} is called, the application may not want to do the reconnection.
- If the \texttt{esp\_wifi\_scan\_start()} may be called at anytime, a better reconnection strategy is necessary. Refer to Scan When Wi-Fi Is Connecting.

Another thing that need to be considered is that the reconnection may not connect the same AP if there are more than one APs with the same SSID. The reconnection always select current best APs to connect.

4.34.13 Wi-Fi Beacon Timeout

The beacon timeout mechanism is used by ESP32 station to detect whether the AP is alive or not. If the station does not receive the beacon of the connected AP within the inactive time, the beacon timeout happens. The application can set inactive time via API \texttt{esp\_wifi\_set\_inactive\_time()}.

After the beacon times out, the station sends 5 probe requests to the AP. If still no probe response or beacon is received from AP, the station disconnects from the AP and raises the event WIFI_EVENT_STA_DISCONNECTED.

It should be considered that the timer used for beacon timeout will be reset during the scanning process. It means that the scan process will affect the triggering of the event WIFI_EVENT_STA_BEACON_TIMEOUT.

4.34.14 ESP32 Wi-Fi Configuration

All configurations will be stored into flash when the Wi-Fi NVS is enabled; otherwise, refer to Wi-Fi NVS Flash.

Wi-Fi Mode

Call \texttt{esp\_wifi\_set\_mode()} to set the Wi-Fi mode.
### Mode Description

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIFI_MODE_NULL</td>
<td>NULL mode: in this mode, the internal data struct is not allocated to the station and the AP, while both the station and AP interfaces are not initialized for RX/TX Wi-Fi data. Generally, this mode is used for Sniffer, or when you only want to stop both the station and the AP without calling <code>esp_wifi_deinit()</code> to unload the whole Wi-Fi driver.</td>
</tr>
<tr>
<td>WIFI_MODE_STA</td>
<td>Station mode: in this mode, <code>esp_wifi_start()</code> will init the internal station data, while the station’s interface is ready for the RX and TX Wi-Fi data. After <code>esp_wifi_connect()</code>, the station will connect to the target AP.</td>
</tr>
<tr>
<td>WIFI_MODE_AP</td>
<td>AP mode: in this mode, <code>esp_wifi_start()</code> will init the internal AP data, while the AP’s interface is ready for RX/TX Wi-Fi data. Then, the Wi-Fi driver starts broad-casting beacons, and the AP is ready to get connected to other stations.</td>
</tr>
<tr>
<td>WIFI_MODE_APSTA</td>
<td>Station/AP coexistence mode: in this mode, <code>esp_wifi_start()</code> will simultaneously initialize both the station and the AP. This is done in station mode and AP mode. Please note that the channel of the external AP, which the ESP station is connected to, has higher priority over the ESP AP channel.</td>
</tr>
</tbody>
</table>

### Station Basic Configuration

API `esp_wifi_set_config()` can be used to configure the station. And the configuration will be stored in NVS. The table below describes the fields in detail.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssid</td>
<td>This is the SSID of the target AP, to which the station wants to connect.</td>
</tr>
<tr>
<td>password</td>
<td>Password of the target AP.</td>
</tr>
<tr>
<td>scan_method</td>
<td>For WIFI_FAST_SCAN scan, the scan ends when the first matched AP is found. For WIFI_ALL_CHANNEL_SCAN, the scan finds all matched APs on all channels. The default scan is WIFI_FAST_SCAN.</td>
</tr>
<tr>
<td>bssid_set</td>
<td>If <code>bssid_set</code> is 0, the station connects to the AP whose SSID is the same as the field “ssid”, while the field “bssid” is ignored. In all other cases, the station connects to the AP whose SSID is the same as the “ssid” field, while its BSSID is the same the “bssid” field.</td>
</tr>
<tr>
<td>bssid</td>
<td>This is valid only when <code>bssid_set</code> is 1; see field “bssid_set”.</td>
</tr>
<tr>
<td>channel</td>
<td>If the channel is 0, the station scans the channel 1 ~ N to search for the target AP; otherwise, the station starts by scanning the channel whose value is the same as that of the “channel” field, and then scans the channel 1 ~ N but skip the specific channel to find the target AP. For example, if the channel is 3, the scan order will be 3, 1, 2, 4, ..., N. If you do not know which channel the target AP is running on, set it to 0.</td>
</tr>
<tr>
<td>sort_method</td>
<td>This field is only for WIFI_ALL_CHANNEL_SCAN. If the <code>sort_method</code> is WIFI_CONNECT_AP_BY_SIGNAL, all matched APs are sorted by signal, and the AP with the best signal will be connected firstly. For example, the station wants to connect an AP whose SSID is “apxx”. If the scan finds two APs whose SSID equals to “apxx”, and the first AP’s signal is -90 dBm while the second AP’s signal is -30 dBm, the station connects the second AP firstly, and it would not connect the first one unless it fails to connect the second one. If the <code>sort_method</code> is WIFI_CONNECT_AP_BY_SECURITY, all matched APs are sorted by security. For example, the station wants to connect an AP whose SSID is “apxx”. If the scan finds two APs whose SSID is “apxx”, and the security of the first found AP is open while the second one is WPA2, the station connects to the second AP firstly, and it would not connect the first one unless it fails to connect the second one.</td>
</tr>
<tr>
<td>threshold</td>
<td>The threshold is used to filter the found AP. If the RSSI or security mode is less than the configured threshold, the AP will be discarded. If the RSSI is set to 0, it means the default threshold and the default RSSI threshold are -127 dBm. If the authmode threshold is set to 0, it means the default threshold and the default authmode threshold are open.</td>
</tr>
</tbody>
</table>
**Attention:** WEP/WPA security modes are deprecated in IEEE 802.11-2016 specifications and are recommended not to be used. These modes can be rejected using authmode threshold by setting threshold as WPA2 by threshold.authmode as WIFI_AUTH_WPA2_PSK.

**AP Basic Configuration**

API `esp_wifi_set_config()` can be used to configure the AP. And the configuration will be stored in NVS. The table below describes the fields in detail.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssid</td>
<td>SSID of AP; if the ssid[0] is 0xFF and ssid[1] is 0xFF, the AP defaults the SSID to ESP_aabbcc, where “aabbcc” is the last three bytes of the AP MAC.</td>
</tr>
<tr>
<td>password</td>
<td>Password of AP; if the auth mode is WIFI_AUTH_OPEN, this field will be ignored.</td>
</tr>
<tr>
<td>ssid_len</td>
<td>Length of SSID; if ssid_len is 0, check the SSID until there is a termination character. If ssid_len &gt; 32, change it to 32; otherwise, set the SSID length according to ssid_len.</td>
</tr>
<tr>
<td>channel</td>
<td>Channel of AP; if the channel is out of range, the Wi-Fi driver defaults to channel 1. So, please make sure the channel is within the required range. For more details, refer to Wi-Fi Country Code.</td>
</tr>
<tr>
<td>authmode</td>
<td>Auth mode of ESP AP; currently, ESP AP does not support AUTH_WEP. If the authmode is an invalid value, AP defaults the value to WIFI_AUTH_OPEN.</td>
</tr>
<tr>
<td>ssid_hidden</td>
<td>If ssid_hidden is 1, AP does not broadcast the SSID; otherwise, it does broadcast the SSID.</td>
</tr>
<tr>
<td>max_connection</td>
<td>The max number of stations allowed to connect in, the default value is 10. ESP Wi-Fi supports up to 15 (ESP_WIFI_MAX_CONN_NUM) Wi-Fi connections. Please note that ESP AP and ESP-NOW share the same encryption hardware keys, so the max_connection parameter will be affected by the CONFIG_ESP_WIFI_ESPNOW_MAX_ENCRYPT_NUM. The total number of encryption hardware keys is 17, if CONFIG_ESP_WIFI_ESPNOW_MAX_ENCRYPT_NUM &lt;= 2, the max_connection can be set up to 15, otherwise the max_connection can be set up to (17 - CONFIG_ESP_WIFI_ESPNOW_MAX_ENCRYPT_NUM).</td>
</tr>
<tr>
<td>beacon_interval</td>
<td>Beacon interval; the value is 100 ~ 60000 ms, with default value being 100 ms. If the value is out of range, AP defaults it to 100 ms.</td>
</tr>
</tbody>
</table>

**Wi-Fi Protocol Mode**

Currently, the ESP-IDF supports the following protocol modes:
### Long Range (LR)

Long Range (LR) mode is an Espressif-patented Wi-Fi mode which can achieve a one-kilometer line of sight range. Compared to the traditional 802.11b mode, it has better reception sensitivity, stronger anti-interference ability, and longer transmission distance.

**LR Compatibility** Since LR is Espressif-unique Wi-Fi mode, only ESP32 chip series devices (except ESP32-C2) can transmit and receive the LR data. In other words, the ESP32 chip series devices (except ESP32-C2) should NOT transmit the data in LR data rate if the connected device does not support LR. The application can achieve this by configuring a suitable Wi-Fi mode. If the negotiated mode supports LR, the ESP32 chip series devices (except ESP32-C2) may transmit data in LR rate. Otherwise, ESP32 chip series devices (except ESP32-C2) will transmit all data in the traditional Wi-Fi data rate.

The following table depicts the Wi-Fi mode negotiation:

<table>
<thead>
<tr>
<th>AP/STA</th>
<th>BGN</th>
<th>BG</th>
<th>B</th>
<th>BGNLR</th>
<th>BGLR</th>
<th>BLR</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGN</td>
<td>BGN</td>
<td>BG</td>
<td>B</td>
<td>BGN</td>
<td>BG</td>
<td>B</td>
<td>*</td>
</tr>
<tr>
<td>BG</td>
<td>BG</td>
<td>BG</td>
<td>B</td>
<td>BG</td>
<td>BG</td>
<td>B</td>
<td>*</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>*</td>
</tr>
<tr>
<td>BGNLR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BGNLR</td>
<td>BGLR</td>
<td>BLR</td>
<td>LR</td>
</tr>
<tr>
<td>BGLR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BGLR</td>
<td>BGLR</td>
<td>BLR</td>
<td>LR</td>
</tr>
<tr>
<td>BLR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>BLR</td>
<td>BLR</td>
<td>BLR</td>
<td>LR</td>
</tr>
<tr>
<td>LR</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
</tr>
</tbody>
</table>
In the above table, the row is the Wi-Fi mode of AP and the column is the Wi-Fi mode of station. The “-” indicates Wi-Fi mode of the AP and station are not compatible.

According to the table, the following conclusions can be drawn:

- For LR-enabled AP of ESP32, it is incompatible with traditional 802.11 mode, because the beacon is sent in LR mode.
- For LR-enabled station of ESP32 whose mode is NOT LR-only mode, it is compatible with traditional 802.11 mode.
- If both station and AP are ESP32 series chips devices (except ESP32-C2) and both of them have enabled LR mode, the negotiated mode supports LR.

If the negotiated Wi-Fi mode supports both traditional 802.11 mode and LR mode, it is the Wi-Fi driver’s responsibility to automatically select the best data rate in different Wi-Fi modes and the application can ignore it.

**LR Impacts to Traditional Wi-Fi Device**  The data transmission in LR rate has no impacts on the traditional Wi-Fi device because:

- The CCA and backoff process in LR mode are consistent with 802.11 specification.
- The traditional Wi-Fi device can detect the LR signal via CCA and do backoff.

In other words, the transmission impact in LR mode is similar to that in 802.11b mode.

**LR Transmission Distance**  The reception sensitivity gain of LR is about 4 dB larger than that of the traditional 802.11b mode. Theoretically, the transmission distance is about 2 to 2.5 times the distance of 11B.

**LR Throughput**  The LR rate has very limited throughput, because the raw PHY data rate LR is 1/2 Mbps and 1/4 Mbps.

**When to Use LR**  The general conditions for using LR are:

- Both the AP and station are Espressif devices.
- Long distance Wi-Fi connection and data transmission is required.
- Data throughput requirements are very small, such as remote device control.

**Wi-Fi Country Code**

Call `esp_wifi_set_country()` to set the country info. The table below describes the fields in detail. Please consult local 2.4 GHz RF operating regulations before configuring these fields.
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cc[3]</td>
<td>Country code string. This attribute identifies the country or noncountry entity in which the station/AP is operating. If it is a country, the first two octets of this string is the two-character country info as described in the document ISO/IEC3166-1. The third octet is one of the following:</td>
</tr>
<tr>
<td></td>
<td>• an ASCII space character, which means the regulations under which the station/AP is operating encompass all environments for the current frequency band in the country.</td>
</tr>
<tr>
<td></td>
<td>• an ASCII ‘O’ character, which means the regulations under which the station/AP is operating are for an outdoor environment only.</td>
</tr>
<tr>
<td></td>
<td>• an ASCII ‘I’ character, which means the regulations under which the station/AP is operating are for an indoor environment only.</td>
</tr>
<tr>
<td></td>
<td>• an ASCII ‘X’ character, which means the station/AP is operating under a noncountry entity. The first two octets of the noncountry entity is two ASCII ‘XX’ characters.</td>
</tr>
<tr>
<td></td>
<td>• the binary representation of the Operating Class table number currently in use. Refer to Annex E of IEEE Std 802.11-2020.</td>
</tr>
<tr>
<td>schan</td>
<td>Start channel. It is the minimum channel number of the regulations under which the station/AP can operate.</td>
</tr>
<tr>
<td>nchan</td>
<td>Total number of channels as per the regulations. For example, if the schan=1, nchan=13, then the station/AP can send data from channel 1 to 13.</td>
</tr>
<tr>
<td>policy</td>
<td>Country policy. This field controls which country info will be used if the configured country info is in conflict with the connected AP’s. For more details on related policies, see the following section.</td>
</tr>
</tbody>
</table>

The default country info is:

```c
wifi_country_t config = {
    .cc = "01",
    .schan = 1,
    .nchan = 11,
    .policy = WIFI_COUNTRY_POLICY_AUTO,
};
```

If the Wi-Fi Mode is station/AP coexist mode, they share the same configured country info. Sometimes, the country info of AP, to which the station is connected, is different from the country info of configured. For example, the configured station has country info:

```c
wifi_country_t config = {
    .cc = "JP",
    .schan = 1,
    .nchan = 14,
    .policy = WIFI_COUNTRY_POLICY_AUTO,
};
```

but the connected AP has country info:

```c
wifi_country_t config = {
    .cc = "CN",
    .schan = 1,
    .nchan = 13,
};
```

then country info of connected AP’s is used.

The following table depicts which country info is used in different Wi-Fi modes and different country policies, and it also describes the impact on active scan.
<table>
<thead>
<tr>
<th>Wi-Fi Mode</th>
<th>Policy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>WIFI_COUNTRY_POLICY_AUTO</td>
<td>If the connected AP has country IE in its beacon, the country info equals to the country info in beacon. Otherwise, use the default country info. For scan: Use active scan from 1 to 11 and use passive scan from 12 to 14. Always keep in mind that if an AP with hidden SSID and station is set to a passive scan channel, the passive scan will not find it. In other words, if the application hopes to find the AP with hidden SSID in every channel, the policy of country info should be configured to WIFI_COUNTRY_POLICY_MANUAL.</td>
</tr>
<tr>
<td>Station</td>
<td>WIFI_COUNTRY_POLICY_MANUAL</td>
<td>Always use the configured country info. For scan: Use active scan from schan to schan+nchan-1.</td>
</tr>
<tr>
<td>AP</td>
<td>WIFI_COUNTRY_POLICY_AUTO</td>
<td>Always use the configured country info.</td>
</tr>
<tr>
<td>AP</td>
<td>WIFI_COUNTRY_POLICY_MANUAL</td>
<td>Always use the configured country info.</td>
</tr>
<tr>
<td>Station/AP-coexistence</td>
<td>WIFI_COUNTRY_POLICY_AUTO</td>
<td>Same as station mode with policy WIFI_COUNTRY_POLICY_AUTO. AP: If the station does not connect to any external AP, the AP uses the configured country info. If the station connects to an external AP, the AP has the same country info as the station.</td>
</tr>
<tr>
<td>Station/AP-coexistence</td>
<td>WIFI_COUNTRY_POLICY_MANUAL</td>
<td>Same as station mode with policy WIFI_COUNTRY_POLICY_MANUAL. AP: Same as AP mode with policy WIFI_COUNTRY_POLICY_MANUAL.</td>
</tr>
</tbody>
</table>

**Home Channel**  In AP mode, the home channel is defined as the AP channel. In station mode, home channel is defined as the channel of AP which the station is connected to. In station/AP-coexistence mode, the home channel of AP and station must be the same, and if they are different, the station’s home channel is always in priority. For example, assume that the AP is on channel 6, and the station connects to an AP whose channel is 9. Since the station’s home channel has higher priority, the AP needs to switch its channel from 6 to 9 to make sure that it has the same home channel as the station. While switching channel, the ESP32 in AP mode will notify the connected stations about the channel migration using a Channel Switch Announcement (CSA). Station that supports channel switching will transit without disconnecting and reconnecting to the AP.

**Wi-Fi Vendor IE Configuration**

By default, all Wi-Fi management frames are processed by the Wi-Fi driver, and the application can ignore them. However, some applications may have to handle the beacon, probe request, probe response, and other management frames. For example, if you insert some vendor-specific IE into the management frames, it is only the management frames which contain this vendor-specific IE that will be processed. In ESP32, `esp_wifi_set_vendor_ie()` and `esp_wifi_set_vendor_ie_cb()` are responsible for this kind of tasks.

**4.34.15 Wi-Fi Easy Connect™ (DPP)**

Wi-Fi Easy Connect™ (or Device Provisioning Protocol) is a secure and standardized provisioning protocol for configuring Wi-Fi devices. More information can be found in `esp_dpp`. 
WPA2-Enterprise

WPA2-Enterprise is the secure authentication mechanism for enterprise wireless networks. It uses RADIUS server for authentication of network users before connecting to the Access Point. The authentication process is based on 802.1X policy and comes with different Extended Authentication Protocol (EAP) methods such as TLS, TTLS, and PEAP. RADIUS server authenticates the users based on their credentials (username and password), digital certificates, or both. When ESP32 in station mode tries to connect an AP in enterprise mode, it sends authentication request to AP which is sent to RADIUS server by AP for authenticating the station. Based on different EAP methods, the parameters can be set in configuration which can be opened using `idf.py menuconfig`. WPA2_Enterprise is supported by ESP32 only in station mode.

For establishing a secure connection, AP and station negotiate and agree on the best possible cipher suite to be used. ESP32 supports 802.1X/EAP (WPA) method of AKM and Advanced encryption standard with Counter Mode Cipher Block Chaining Message Authentication protocol (AES-CCM) cipher suite. It also supports the cipher suites supported by mbedtls if `USE_MBEDTLS_CRYPTO` flag is set.

ESP32 currently supports the following EAP methods:

- **EAP-TLS**: This is a certificate-based method and only requires SSID and EAP-IDF.
- **PEAP**: This is a Protected EAP method. Username and Password are mandatory.
- **EAP-TTLS**: This is a credential-based method. Only server authentication is mandatory while user authentication is optional. Username and Password are mandatory. It supports different Phase2 methods, such as:
  - MSCHAP and MSCHAP-V2.
- **EAP-FAST**: This is an authentication method based on Protected Access Credentials (PAC) which also uses identity and password. Currently, `USE_MBEDTLS_CRYPTO` flag should be disabled to use this feature.

Detailed information on creating certificates and how to run wpa2_enterprise example on ESP32 can be found in `wifi/wifi_enterprise`.

4.34.16 Wi-Fi Aware™ (NAN)

Wi-Fi Aware™ or NAN (Neighbor Awareness Networking) is a protocol that allows Wi-Fi devices to discover services in their proximity. NAN uses direct device-to-device communication and does not require any Internet or AP connection.

Multiple NAN devices in the vicinity will form a NAN cluster which allows them to communicate with each other. NAN devices in a cluster synchronise their clocks and listen to each other periodically on Channel 6. Devices can advertise (Publish) or seek for (Subscribe) services within their NAN Cluster using Service Discovery protocols. Matching of services is done by service name and optionally matching filters. Once a Subscriber gets a match with a Publisher, it can either send a message (Follow-up) or establish a datapath (NDP) with the Publisher. After NDP is setup both devices will obtain an IPv6 address and can use it for communication.

Please note that NAN Datapath security is not supported i.e. the data packets will go out unencrypted. NAN uses a separate interface for Discovery and Datapath, which is other than that used for STA and AP. NAN operates in standalone mode, which means co-existence with STA or AP interface is not supported.

Refer to ESP-IDF examples `examples/wifi/wifi_aware/nan_publisher/README.md` and `examples/wifi/wifi_aware/nan_subscriber/README.md` to setup a NAN Publisher and Subscriber.

4.34.17 Wireless Network Management

Wireless Network Management allows client devices to exchange information about the network topology, including information related to RF environment. This makes each client network-aware, facilitating overall improvement in the performance of the wireless network. It is part of 802.11v specification. It also enables the client to support Network assisted Roaming. - Network assisted Roaming: Enables WLAN to send messages to associated clients, resulting clients to associate with APs with better link metrics. This is useful for both load balancing and in directing poorly connected clients.
Current implementation of 802.11v includes support for BSS transition management frames.

### 4.34.18 Radio Resource Measurement

Radio Resource Measurement (802.11k) is intended to improve the way traffic is distributed within a network. In a WLAN, each device normally connects to the access point (AP) that provides the strongest signal. Depending on the number and geographic locations of the subscribers, this arrangement can sometimes lead to excessive demand on one AP and underutilization of others, resulting in degradation of overall network performance. In a network conforming to 802.11k, if the AP having the strongest signal is loaded to its full capacity, a wireless device can be moved to one of the underutilized APs. Even though the signal may be weaker, the overall throughput is greater because more efficient use is made of the network resources.

Current implementation of 802.11k includes support for beacon measurement report, link measurement report, and neighbor request.

Refer ESP-IDF example `examples/wifi/roaming/README.md` to set up and use these APIs. Example code only demonstrates how these APIs can be used, and the application should define its own algorithm and cases as required.

### 4.34.19 Fast BSS Transition

Fast BSS transition (802.11R FT), is a standard to permit continuous connectivity aboard wireless devices in motion, with fast and secure client transitions from one Basic Service Set (abbreviated BSS, and also known as a base station or more colloquially, an access point) to another performed in a nearly seamless manner avoiding 802.11 4 way handshake. 802.11R specifies transitions between access points by redefining the security key negotiation protocol, allowing both the negotiation and requests for wireless resources to occur in parallel. The key derived from the server to be cached in the wireless network, so that a reasonable number of future connections can be based on the cached key, avoiding the 802.1X process

ESP32 station supports FT for WPA2-PSK networks. Do note that ESP32 station only support FT over the air protocol only.

A config option `CONFIG_ESP_WIFI_11R_SUPPORT` and configuration parameter `ft_enabled` in `wifi_ststa_config_t` is provided to enable 802.11R support for station. Refer ESP-IDF example `examples/wifi/roaming/README.md` for further details.

### 4.34.20 ESP32 Wi-Fi Power-saving Mode

#### Station Sleep

Currently, ESP32 Wi-Fi supports the Modem-sleep mode which refers to the legacy power-saving mode in the IEEE 802.11 protocol. Modem-sleep mode works in station-only mode and the station must connect to the AP first. If the Modem-sleep mode is enabled, station will switch between active and sleep state periodically. In sleep state, RF, PHY and BB are turned off in order to reduce power consumption. Station can keep connection with AP in modem-sleep mode.

Modem-sleep mode includes minimum and maximum power-saving modes. In minimum power-saving mode, station wakes up every DTIM to receive beacon. Broadcast data will not be lost because it is transmitted after DTIM. However, it cannot save much more power if DTIM is short for DTIM is determined by AP.

In maximum power-saving mode, station wakes up in every listen interval to receive beacon. This listen interval can be set to be longer than the AP DTIM period. Broadcast data may be lost because station may be in sleep state at DTIM time. If listen interval is longer, more power is saved, but broadcast data is more easy to lose. Listen interval can be configured by calling API `esp_wifi_set_config()` before connecting to AP.

Call `esp_wifi_set_ps(WIFI_PS_MIN_MODEM)` to enable Modem-sleep minimum power-saving mode or `esp_wifi_set_ps(WIFI_PS_MAX_MODEM)` to enable Modem-sleep maximum power-saving mode after calling `esp_wifi_init()`. When station connects to AP, Modem-sleep will start. When station disconnects from AP, Modem-sleep will stop.
Call `esp_wifi_set_ps(WIFI_PS_NONE)` to disable Modem-sleep mode entirely. Disabling it increases power consumption, but minimizes the delay in receiving Wi-Fi data in real time. When Modem-sleep mode is enabled, the delay in receiving Wi-Fi data may be the same as the DTIM cycle (minimum power-saving mode) or the listening interval (maximum power-saving mode).

Note that in coexist mode, Wi-Fi will remain active only during Wi-Fi time slice, and sleep during non Wi-Fi time slice even if `esp_wifi_set_ps(WIFI_PS_NONE)` is called. Please refer to coexist policy.

The default Modem-sleep mode is `WIFI_PS_MIN_MODEM`.

### AP Sleep

Currently, ESP32 AP does not support all of the power-saving feature defined in Wi-Fi specification. To be specific, the AP only caches unicast data for the stations connect to this AP, but does not cache the multicast data for the stations. If stations connected to the ESP32 AP are power-saving enabled, they may experience multicast packet loss.

In the future, all power-saving features will be supported on ESP32 AP.

### Disconnected State Sleep

Disconnected state is the duration without Wi-Fi connection between `esp_wifi_start()` to `esp_wifi_stop()`.

Currently, ESP32 Wi-Fi supports sleep mode in disconnected state if running at station mode. This feature could be configured by Menuconfig choice `CONFIG_ESP_WIFI_STA_DISCONNECTED_PM_ENABLE`.

If `CONFIG_ESP_WIFI_STA_DISCONNECTED_PM_ENABLE` is enabled, RF, PHY and BB would be turned off in disconnected state when IDLE. The current would be same with current at modem-sleep.

The choice `CONFIG_ESP_WIFI_STA_DISCONNECTED_PM_ENABLE` would be selected by default, while it would be selected forcefully in Menuconfig at coexistence mode.

### Connectionless Modules Power-saving

Connectionless modules are those Wi-Fi modules not relying on Wi-Fi connection, e.g ESP-NOW, DPP, FTM. These modules start from `esp_wifi_start()`, working until `esp_wifi_stop()`.

Currently, if ESP-NOW works at station mode, its supported to sleep at both connected state and disconnected state.

#### Connectionless Modules TX

For each connectionless module, its supported to TX at any sleeping time without any extra configuration.

Meanwhile, `esp_wifi_80211_tx()` is supported at sleep as well.

#### Connectionless Modules RX

For each connectionless module, two parameters shall be configured to RX at sleep, which are Window and Interval.

At the start of Interval time, RF, PHY, BB would be turned on and kept for Window time. Connectionless Module could RX in the duration.

**Interval**

- There is only one Interval. Its configured by `esp_wifi_set_connectionless_interval()`. The unit is milliseconds.
- The default value of Interval is `ESP_WIFI_CONNECTIONLESS_INTERVAL_DEFAULT_MODE`.
- Event `WIFI_EVENT_CONNECTIONLESS_MODULE_WAKE_INTERVAL_START` would be posted at the start of Interval. Since Window also starts at that moment, its recommended to TX in that event.
- At connected state, the start of Interval would be aligned with TBTT.
Window

- Each connectionless module has its own Window after start. Connectionless Modules Power-saving would work with the max one among them.
- Window is configured by module_name_set_wake_window(). The unit is milliseconds.
- The default value of Window is the maximum.

<table>
<thead>
<tr>
<th>Interval</th>
<th>ESP_WIFI_CONNECTIONLESS_INTERVAL_DEFAULT_MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window 0</td>
<td>not used</td>
</tr>
<tr>
<td>Window 1 - maximum</td>
<td>default mode</td>
</tr>
<tr>
<td></td>
<td>used periodically (Window &lt; Interval) / used all time (Window ≥ Interval)</td>
</tr>
</tbody>
</table>

Table 33: RF, PHY and BB usage under different circumstances

Default mode  If Interval is ESP_WIFI_CONNECTIONLESS_INTERVAL_DEFAULT_MODE with non-zero Window, Connectionless Modules Power-saving would work in default mode.

In default mode, RF, PHY, BB would be kept on if no coexistence with non-Wi-Fi protocol.

With coexistence, RF, PHY, BB resources are allocated by coexistence module to Wi-Fi connectionless module and non-Wi-Fi module, using time-division method. In default mode, Wi-Fi connectionless module is allowed to use RF, BB, PHY periodically under a stable performance.

It's recommended to configure Connectionless Modules Power-saving to default mode if there is Wi-Fi connectionless module coexists with non-Wi-Fi module.

4.3.4.21 ESP32 Wi-Fi Throughput

The table below shows the best throughput results gained in Espressif’s lab and in a shielded box.

<table>
<thead>
<tr>
<th>Type/Throughput</th>
<th>Air In Lab</th>
<th>Shield-box</th>
<th>Test Tool</th>
<th>IDF Version (commit ID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw 802.11</td>
<td>N/A</td>
<td>130 MBit/s</td>
<td>Internal tool</td>
<td>NA</td>
</tr>
<tr>
<td>Packet RX</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw 802.11</td>
<td>N/A</td>
<td>130 MBit/s</td>
<td>Internal tool</td>
<td>NA</td>
</tr>
<tr>
<td>Packet TX</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDP RX</td>
<td>30 MBit/s</td>
<td>85 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>UDP TX</td>
<td>30 MBit/s</td>
<td>75 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>TCP RX</td>
<td>20 MBit/s</td>
<td>65 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>TCP TX</td>
<td>20 MBit/s</td>
<td>75 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
</tbody>
</table>

When the throughput is tested by iperf example, the sdkconfig is examples/wifi/iperf/sdkconfig.defaults.esp32.

4.3.4.22 Wi-Fi 80211 Packet Send

The esp_wifi_80211_tx() API can be used to:
- Send the beacon, probe request, probe response, and action frame.
- Send the non-QoS data frame.

It cannot be used for sending encrypted or QoS frames.

Preconditions of Using esp_wifi_80211_tx()

- The Wi-Fi mode is station, or AP, or station/AP.
- Either `esp_wifi_set_promiscuous(true)`, or `esp_wifi_start()`, or both of these APIs return `ESP_OK`. This is because Wi-Fi hardware must be initialized before `esp_wifi_80211_tx()` is called. In ESP32, both `esp_wifi_set_promiscuous(true)` and `esp_wifi_start()` can trigger the initialization of Wi-Fi hardware.
- The parameters of `esp_wifi_80211_tx()` are hereby correctly provided.

**Data Rate**

- The default data rate is 1 Mbps.
- Can set any rate through `esp_wifi_config_80211_tx_rate()` API.
- Can set any bandwidth through `esp_wifi_set_bandwidth()` API.

**Side-Effects to Avoid in Different Scenarios**

Theoretically, if the side-effects the API imposes on the Wi-Fi driver or other stations/APs are not considered, a raw 802.11 packet can be sent over the air with any destination MAC, any source MAC, any BSSID, or any other types of packet. However, robust or useful applications should avoid such side-effects. The table below provides some tips and recommendations on how to avoid the side-effects of `esp_wifi_80211_tx()` in different scenarios.
### Scenario Description

| No Wi-Fi connection | In this scenario, no Wi-Fi connection is set up, so there are no side-effects on the Wi-Fi driver. If `en_sys_seq=true`, the Wi-Fi driver is responsible for the sequence control. If `en_sys_seq=false`, the application needs to ensure that the buffer has the correct sequence. Theoretically, the MAC address can be any address. However, this may impact other stations/APs with the same MAC/BSSID. Side-effect example#1 The application calls `esp_wifi_80211_tx()` to send a beacon with `BSSID == mac_x` in AP mode, but the `mac_x` is not the MAC of the AP interface. Moreover, there is another AP, e.g., “other-AP”, whose BSSID is `mac_x`. If this happens, an “unexpected behavior” may occur, because the stations which connect to the “other-AP” cannot figure out whether the beacon is from the “other-AP” or the `esp_wifi_80211_tx()`. To avoid the above-mentioned side-effects, it is recommended that:
| | • If `esp_wifi_80211_tx()` is called in station mode, the first MAC should be a multicast MAC or the exact target-device’s MAC, while the second MAC should be that of the station interface.
| | • If `esp_wifi_80211_tx()` is called in AP mode, the first MAC should be a multicast MAC or the exact target-device’s MAC, while the second MAC should be that of the AP interface.
| | The recommendations above are only for avoiding side-effects and can be ignored when there are good reasons.
| Have Wi-Fi connection | When the Wi-Fi connection is already set up, and the sequence is controlled by the application, the latter may impact the sequence control of the Wi-Fi connection as a whole. So, the `en_sys_seq` need to be true, otherwise `ESP_ERR_INVALID_ARG` is returned. The MAC-address recommendations in the “No Wi-Fi connection” scenario also apply to this scenario. If the Wi-Fi mode is station mode, the MAC address1 is the MAC of AP to which the station is connected, and the MAC address2 is the MAC of station interface, it is said that the packet is sent from the station to AP. Otherwise, if the Wi-Fi is in AP mode, the MAC address1 is the MAC of the station that connects to this AP, and the MAC address2 is the MAC of AP interface, it is said that the packet is sent from the AP to station. To avoid conflicting with Wi-Fi connections, the following checks are applied:
| | • If the packet type is data and is sent from the station to AP, the ToDS bit in IEEE 80211 frame control should be 1 and the FromDS bit should be 0. Otherwise, the packet will be discarded by Wi-Fi driver.
| | • If the packet type is data and is sent from the AP to station, the ToDS bit in IEEE 80211 frame control should be 0 and the FromDS bit should be 1. Otherwise, the packet will be discarded by Wi-Fi driver.
| | • If the packet is sent from station to AP or from AP to station, the Power Management, More Data, and Re-Transmission bits should be 0. Otherwise, the packet will be discarded by Wi-Fi driver.
| | `ESP_ERR_INVALID_ARG` is returned if any check fails. |

### 4.34.23 Wi-Fi Sniffer Mode

The Wi-Fi sniffer mode can be enabled by `esp_wifi_set_promiscuous()`. If the sniffer mode is enabled, the following packets can be dumped to the application:

- 802.11 Management frame.
- 802.11 Data frame, including MPDU, AMPDU, and AMSDU.
- 802.11 MIMO frame, for MIMO frame, the sniffer only dumps the length of the frame.
- 802.11 Control frame.
- 802.11 CRC error frame.

The following packets will NOT be dumped to the application:

- Other 802.11 error frames.
For frames that the sniffer can dump, the application can additionally decide which specific type of packets can be filtered to the application by using `esp_wifi_set_promiscuous_filter()` and `esp_wifi_set_promiscuous_ctrl_filter()`. By default, it will filter all 802.11 data and management frames to the application.

The Wi-Fi sniffer mode can be enabled in the Wi-Fi mode of `WIFI_MODE_NULL`, `WIFI_MODE_STA`, `WIFI_MODE_AP`, or `WIFI_MODE_APSTA`. In other words, the sniffer mode is active when the station is connected to the AP, or when the AP has a Wi-Fi connection. Please note that the sniffer has a great impact on the throughput of the station or AP Wi-Fi connection. Generally, the sniffer should be enabled only if the station/AP Wi-Fi connection does not experience heavy traffic.

Another noteworthy issue about the sniffer is the callback `wifi_promiscuous_cb_t`. The callback will be called directly in the Wi-Fi driver task, so if the application has a lot of work to do for each filtered packet, the recommendation is to post an event to the application task in the callback and defer the real work to the application task.

### 4.34.24 Wi-Fi Multiple Antennas

The Wi-Fi multiple antennas selecting can be depicted as following picture:

```
<table>
<thead>
<tr>
<th>Enabled</th>
<th>________</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna 0</td>
<td>\</td>
</tr>
</tbody>
</table>

RX/TX | --- antenna 0 | \   \ | \ GPIO[0] <----> antenna_select[0] ---| |
| Antenna | --- antenna 1 | \ / | GPI0[1] <----> antenna_select[1] ---| |
| ...     | ________ /// | / | GPI0[2] <----> antenna_select[2] ---| Switch...
```

ESP32 supports up to sixteen antennas through external antenna switch. The antenna switch can be controlled by up to four address pins - antenna_select[0:3]. Different input value of antenna_select[0:3] means selecting different antenna. For example, the value `0b1011` means the antenna 11 is selected. The default value of antenna_select[3:0] is `0b0000`, which means the antenna 0 is selected by default.

Up to four GPIOs are connected to the four active high antenna_select pins. ESP32 can select the antenna by control the GPIO[0:3]. The API `esp_wifi_set_ant_gpio()` is used to configure which GPIOs are connected to antenna_selects. If GPIO[x] is connected to antenna_select[x], then gpio_config->gpio_cfg[x].gpio_select should be set to 1 and gpio_config->gpio_cfg[x].gpio_num should be provided.

For the specific implementation of the antenna switch, there may be illegal values in antenna_select[0:3]. It means that ESP32 may support less than sixteen antennas through the switch. For example, ESP32-WROOM-DA which uses RTC6603SP as the antenna switch, supports two antennas. Two GPIOs are connected to two active high antenna selection inputs. The value `0b01` means the antenna 0 is selected, the value `0b10` means the antenna 1 is selected. Values `0b00` and `0b11` are illegal.

Although up to sixteen antennas are supported, only one or two antennas can be simultaneously enabled for RX/TX. The API `esp_wifi_set_ant()` is used to configure which antennas are enabled.

The enabled antennas selecting algorithm is also configured by `esp_wifi_set_ant()`. The RX/TX antenna mode can be `WIFI_ANT_MODE_ANT0`, `WIFI_ANT_MODE_ANT1`, or `WIFI_ANT_MODE_AUTO`. If the antenna mode is `WIFI_ANT_MODE_ANT0`, the enabled antenna 0 is selected for RX/TX data. If the antenna mode is `WIFI_ANT_MODE_ANT1`, the enabled antenna 1 is selected for RX/TX data. Otherwise, Wi-Fi automatically selects the enabled antenna that has better signal.

If the RX antenna mode is `WIFI_ANT_MODE_AUTO`, the default antenna mode also needs to be set, because the RX antenna switching only happens when some conditions are met. For example, the RX antenna starts to switch if
the RSSI is lower than -65 dBm or another antenna has better signal. RX uses the default antenna if the conditions are not met. If the default antenna mode is `WIFI_ANT_MODE_ANT1`, the enabled antenna 1 is used as the default RX antenna, otherwise the enabled antenna 0 is used.

Some limitations need to be considered:

- The TX antenna can be set to `WIFI_ANT_MODE_AUTO` only if the RX antenna mode is `WIFI_ANT_MODE_AUTO`, because TX antenna selecting algorithm is based on RX antenna in `WIFI_ANT_MODE_AUTO` type.
- When the TX antenna mode or RX antenna mode is configured to `WIFI_ANT_MODE_AUTO` the switching mode will easily trigger the switching phase, as long as there is deterioration of the RF signal. So in situations where the RF signal is not stable, the antenna switching will occur frequently, resulting in an RF performance that may not meet expectations.
- Currently, Bluetooth® does not support the multiple antennas feature, so please do not use multiple antennas related APIs.

Following is the recommended scenarios to use the multiple antennas:

- The applications can always choose to select a specified antenna or implement their own antenna selecting algorithm, e.g., selecting the antenna mode based on the information collected by the application. Refer to ESP-IDF example examples/wifi/antenna/README.md for the antenna selecting algorithm design.
- Both RX/TX antenna modes are configured to `WIFI_ANT_MODE_ANT0` or `WIFI_ANT_MODE_ANT1`.

**Wi-Fi Multiple Antennas Configuration**

Generally, following steps can be taken to configure the multiple antennas:

- Configure which GPIOs are connected to the antenna_selects. For example, if four antennas are supported and GPIO20/GPIO21 are connected to antenna_select[0]/antenna_select[1], the configurations look like:

```c
wifi_ant_gpio_config_t ant_gpio_config = {
    .gpio_cfg[0] = { .gpio_select = 1, .gpio_num = 20 },
    .gpio_cfg[1] = { .gpio_select = 1, .gpio_num = 21 }
};
```

- Configure which antennas are enabled and how RX/TX use the enabled antennas. For example, if antenna1 and antenna3 are enabled, the RX needs to select the better antenna automatically and uses antenna1 as its default antenna, the TX always selects the antenna3. The configuration looks like:

```c
wifi_ant_config_t config = {
    .rx_ant_mode = WIFI_ANT_MODE_AUTO,
    .rx_ant_default = WIFI_ANT_ANT0,
    .tx_ant_mode = WIFI_ANT_MODE_ANT1,
    .enabled_ant0 = 1,
    .enabled_ant1 = 3
};
```

### 4.34.25 Wi-Fi Channel State Information

Channel state information (CSI) refers to the channel information of a Wi-Fi connection. In ESP32, this information consists of channel frequency responses of sub-carriers and is estimated when packets are received from the transmitter. Each channel frequency response of sub-carrier is recorded by two bytes of signed characters. The first one is imaginary part and the second one is real part. There are up to three fields of channel frequency responses according to the type of received packet. They are legacy long training field (LLTF), high throughput LTF (HT-LTF), and space time block code HT-LTF (STBC-HT-LTF). For different types of packets which are received on channels with different state, the sub-carrier index and total bytes of signed characters of CSI are shown in the following table.
### Chapter 4. API Guides

#### channel secondary channel

<table>
<thead>
<tr>
<th>packet information</th>
<th>secondary channel</th>
<th>none</th>
<th>HT</th>
<th>below</th>
<th>above</th>
</tr>
</thead>
<tbody>
<tr>
<td>signal mode</td>
<td>non HT</td>
<td>HT</td>
<td>HT</td>
<td>HT</td>
<td>HT</td>
</tr>
<tr>
<td>channel bandwidth</td>
<td>20 MHz</td>
<td>20 MHz</td>
<td>20 MHz</td>
<td>40 MHz</td>
<td>20 MHz</td>
</tr>
<tr>
<td>STBC</td>
<td>non STBC</td>
<td>STBC</td>
<td>STBC</td>
<td>STBC</td>
<td>STBC</td>
</tr>
<tr>
<td>sub-carrier index</td>
<td>LLTF</td>
<td>0<del>31, -32</del>1</td>
<td>0<del>31, -32</del>1</td>
<td>0~63</td>
<td>0~63</td>
</tr>
<tr>
<td></td>
<td>HT-LTF</td>
<td>0<del>31, -32</del>1</td>
<td>0<del>31, -32</del>1</td>
<td>0~63</td>
<td>0<del>63, 64</del>1</td>
</tr>
<tr>
<td></td>
<td>STBC-HT-LTF</td>
<td>0<del>31, -32</del>1</td>
<td>0<del>31, -32</del>1</td>
<td>0~62</td>
<td>0<del>60, 60</del>1</td>
</tr>
<tr>
<td>total bytes</td>
<td>128</td>
<td>256</td>
<td>384</td>
<td>128</td>
<td>256</td>
</tr>
</tbody>
</table>

All of the information in the table can be found in the structure wifi_csi_info_t.

- Secondary channel refers to secondary_channel field of rx_ctrl field.
- Signal mode of packet refers to sig_mode field of rx_ctrl field.
- Channel bandwidth refers to cwb field of rx_ctrl field.
- STBC refers to stbc field of rx_ctrl field.
- Total bytes refers to len field.
- The CSI data corresponding to each Long Training Field (LTF) type is stored in a buffer starting from the buf field. Each item is stored as two bytes: imaginary part followed by real part. The order of each item is the same as the sub-carrier in the table. The order of LTF is: LLTF, HT-LTF, STBC-HT-LTF. However, all 3 LTFs may not be present, depending on the channel and packet information (see above).
- If first_word_invalid field of wifi_csi_info_t is true, it means that the first four bytes of CSI data is invalid due to a hardware limitation in ESP32.
- More information like RSSI, noise floor of RF, receiving time and antenna is in the rx_ctrl field.

When imaginary part and real part data of sub-carrier are used, please refer to the table below.

<table>
<thead>
<tr>
<th>PHY standard</th>
<th>Sub-carrier range</th>
<th>Pilot sub-carrier</th>
<th>Sub-carrier(total/data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11a/g</td>
<td>-26 to +26</td>
<td>-21, -7, +7, +21</td>
<td>52 total, 48 usable</td>
</tr>
<tr>
<td>802.11n, 20MHz</td>
<td>-28 to +28</td>
<td>-21, -7, +7, +21</td>
<td>56 total, 52 usable</td>
</tr>
<tr>
<td>802.11n, 40MHz</td>
<td>-57 to +57</td>
<td>-53, -25, -11, +11, +25, +53</td>
<td>114 total, 108 usable</td>
</tr>
</tbody>
</table>

**Note:**

- For STBC packet, CSI is provided for every space-time stream without CSD (cyclic shift delay). As each cyclic shift on the additional chains shall be -200 ns, only the CSD angle of first space-time stream is recorded in sub-carrier 0 of HT-LTF and STBC-HT-LTF for there is no channel frequency response in sub-carrier 0. CSD[10:0] is 11 bits, ranging from -pi to pi.
- If LLTF, HT-LTF, or STBC-HT-LTF is not enabled by calling API esp_wifi_set_csi_config(), the total bytes of CSI data will be fewer than that in the table. For example, if LLTF and HT-LTF is not enabled...
Chapter 4. API Guides

and STBC-HT-LTF is enabled, when a packet is received with the condition above/HT/40MHz/STBC, the total bytes of CSI data is 244 \((61 + 60) \times 2 + 2 = 244\). The result is aligned to four bytes, and the last two bytes are invalid.

4.34.26 Wi-Fi Channel State Information Configure

To use Wi-Fi CSI, the following steps need to be done.

- Select Wi-Fi CSI in menuconfig. Go to Menuconfig > Components config > Wi-Fi > Wi-Fi CSI (Channel State Information).
- Set CSI receiving callback function by calling API `esp_wifi_set_csi_rx_cb()`.
- Configure CSI by calling API `esp_wifi_set_csi_config()`.
- Enable CSI by calling API `esp_wifi_set_csi()`.

The CSI receiving callback function runs from Wi-Fi task. So, do not do lengthy operations in the callback function. Instead, post necessary data to a queue and handle it from a lower priority task. Because station does not receive any packet when it is disconnected and only receives packets from AP when it is connected, it is suggested to enable sniffer mode to receive more CSI data by calling `esp_wifi_set_promiscuous()`.

4.34.27 Wi-Fi HT20/40

ESP32 supports Wi-Fi bandwidth HT20 or HT40 and does not support HT20/40 coexist. `esp_wifi_set_bandwidth()` can be used to change the default bandwidth of station or AP. The default bandwidth for ESP32 station and AP is HT40.

In station mode, the actual bandwidth is firstly negotiated during the Wi-Fi connection. It is HT40 only if both the station and the connected AP support HT40, otherwise it is HT20. If the bandwidth of connected AP is changes, the actual bandwidth is negotitated again without Wi-Fi disconnecting.

Similarly, in AP mode, the actual bandwidth is negotiated between AP and the stations that connect to the AP. It is HT40 if the AP and one of the stations support HT40, otherwise it is HT20.

In station/AP coexist mode, the station/AP can configure HT20/40 seperately. If both station and AP are negotiated to HT40, the HT40 channel should be the channel of station because the station always has higher priority than AP in ESP32. For example, the configured bandwidth of AP is HT40, the configured primary channel is 6, and the configured secondary channel is 10. The station is connected to an router whose primary channel is 6 and secondary channel is 2, then the actual channel of AP is changed to primary 6 and secondary 2 automatically.

Theoretically, the HT40 can gain better throughput because the maximum raw physical (PHY) data rate for HT40 is 150 Mbps while it is 72 Mbps for HT20. However, if the device is used in some special environment, e.g., there are too many other Wi-Fi devices around the ESP32 device, the performance of HT40 may be degraded. So if the applications need to support same or similar scenarios, it is recommended that the bandwidth is always configured to HT20.

4.34.28 Wi-Fi QoS

ESP32 supports all the mandatory features required in WFA Wi-Fi QoS Certification.

Four ACs (Access Category) are defined in Wi-Fi specification, and each AC has its own priority to access the Wi-Fi channel. Moreover, a map rule is defined to map the QoS priority of other protocol, e.g., 802.11D or TCP/IP precedence is mapped to Wi-Fi AC.

The table below describes how the IP Precedences are mapped to Wi-Fi ACs in ESP32. It also indicates whether the AMPDU is supported for this AC. The table is sorted from high to low priority. That is to say, the AC_VO has the highest priority.
### IP Precedence

<table>
<thead>
<tr>
<th>IP Precedence</th>
<th>Wi-Fi AC</th>
<th>Support AMPDU?</th>
</tr>
</thead>
<tbody>
<tr>
<td>6, 7</td>
<td>AC_VO (Voice)</td>
<td>No</td>
</tr>
<tr>
<td>4, 5</td>
<td>AC_VI (Video)</td>
<td>Yes</td>
</tr>
<tr>
<td>3, 0</td>
<td>AC_BE (Best Effort)</td>
<td>Yes</td>
</tr>
<tr>
<td>1, 2</td>
<td>AC_BK (Background)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The application can make use of the QoS feature by configuring the IP precedence via socket option IP_TOS. Here is an example to make the socket to use VI queue:

```c
const int ip_precedence_vi = 4;
const int ip_precedence_offset = 5;
int priority = (ip_precedence_vi << ip_precedence_offset);
setsockopt(socket_id, IPPROTO_IP, IP_TOS, &priority, sizeof(priority));
```

Theoretically, the higher priority AC has better performance than the lower priority AC. However, it is not always true. Here are some suggestions about how to use the Wi-Fi QoS:

- Some really important application traffic can be put into the AC_VO queue. But avoid using the AC_VO queue for heavy traffic, as it may impact the management frames which also use this queue. Eventually, it is worth noting that the AC_VO queue does not support AMPDU, and its performance with heavy traffic is no better than other queues.
- Avoid using more than two precedences supported by different AMPDUs, e.g., when socket A uses precedence 0, socket B uses precedence 1, and socket C uses precedence 2. This can be a bad design because it may need much more memory. To be specific, the Wi-Fi driver may generate a Block Ack session for each precedence and it needs more memory if the Block Ack session is set up.

### 4.34.29 Wi-Fi AMSDU

ESP32 supports receiving and transmitting AMSDU. AMSDU TX is disabled by default, since enable AMSDU TX need more memory. Select `CONFIG_ESP_WIFI_AMSDU_TX_ENABLED` to enable AMSDU Tx feature, it depends on `CONFIG_SPIRAM`.

### 4.34.30 Wi-Fi Fragment

supports Wi-Fi receiving fragment, but does not support Wi-Fi transmitting fragment.

### 4.34.31 WPS Enrollee

ESP32 supports WPS enrollee feature in Wi-Fi mode `WIFI_MODE_STA` or `WIFI_MODE_APSTA`. Currently, ESP32 supports WPS enrollee type PBC and PIN.

### 4.34.32 Wi-Fi Buffer Usage

This section is only about the dynamic buffer configuration.

**Why Buffer Configuration Is Important**

In order to get a high-performance system, consider the memory usage/configuration carefully for the following reasons:

- the available memory in ESP32 is limited.
- currently, the default type of buffer in LwIP and Wi-Fi drivers is “dynamic”, which means that both the LwIP and Wi-Fi share memory with the application. Programmers should always keep this in mind; otherwise, they will face a memory issue, such as “running out of heap memory”.

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Espressif Systems 2634 Release v5.1.2
it is very dangerous to run out of heap memory, as this will cause ESP32 an “undefined behavior”. Thus, enough heap memory should be reserved for the application, so that it never runs out of it.

- the Wi-Fi throughput heavily depends on memory-related configurations, such as the TCP window size and Wi-Fi RX/TX dynamic buffer number.
- the peak heap memory that the ESP32 LwIP/Wi-Fi may consume depends on a number of factors, such as the maximum TCP/UDP connections that the application may have.
- the total memory that the application requires is also an important factor when considering memory configuration.

Due to these reasons, there is not a good-for-all application configuration. Rather, it is recommended to consider memory configurations separately for every different application.

Dynamic vs. Static Buffer

The default type of buffer in Wi-Fi drivers is “dynamic”. Most of the time the dynamic buffer can significantly save memory. However, it makes the application programming a little more difficult, because in this case the application needs to consider memory usage in Wi-Fi.

LwIP also allocates buffers at the TCP/IP layer, and this buffer allocation is also dynamic. See lwIP documentation section about memory use and performance.

Peak Wi-Fi Dynamic Buffer

The Wi-Fi driver supports several types of buffer (refer to Wi-Fi Buffer Configure). However, this section is about the usage of the dynamic Wi-Fi buffer only. The peak heap memory that Wi-Fi consumes is the theoretically-maximum memory that the Wi-Fi driver consumes. Generally, the peak memory depends on:

- \( b_{rx} \) the number of dynamic RX buffers that are configured
- \( b_{tx} \) the number of dynamic TX buffers that are configured
- \( m_{rx} \) the maximum packet size that the Wi-Fi driver can receive
- \( m_{tx} \) the maximum packet size that the Wi-Fi driver can send

So, the peak memory that the Wi-Fi driver consumes (\( p \)) can be calculated with the following formula:

\[
p = (b_{rx} \times m_{rx}) + (b_{tx} \times m_{tx})
\]

Generally, the dynamic TX long buffers and dynamic TX long long buffers can be ignored, because they are management frames which only have a small impact on the system.

4.34.33 How to Improve Wi-Fi Performance

The performance of ESP32 Wi-Fi is affected by many parameters, and there are mutual constraints between each parameter. A proper configuration cannot only improve performance, but also increase available memory for applications and improve stability.

This section briefly explains the operating mode of the Wi-Fi/LwIP protocol stack and the role of each parameter. It also gives several recommended configuration ranks to help choose the appropriate rank according to the usage scenario.

Protocol Stack Operation Mode

The ESP32 protocol stack is divided into four layers: Application, LwIP, Wi-Fi, and Hardware.

- During receiving, hardware puts the received packet into DMA buffer, and then transfers it into the RX buffer of Wi-Fi and LwIP in turn for related protocol processing, and finally to the application layer. The Wi-Fi RX buffer and the LwIP RX buffer shares the same buffer by default. In other words, the Wi-Fi forwards the packet to LwIP by reference by default.
During sending, the application copies the messages to be sent into the TX buffer of the LwIP layer for TCP/IP encapsulation. The messages will then be passed to the TX buffer of the Wi-Fi layer for MAC encapsulation and wait to be sent.

**Parameters**

Increasing the size or number of the buffers mentioned above properly can improve Wi-Fi performance. Meanwhile, it will reduce available memory to the application. The following is an introduction to the parameters that users need to configure:

**RX direction:**

- **CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM** This parameter indicates the number of DMA buffer at the hardware layer. Increasing this parameter will increase the sender’s one-time receiving throughput, thereby improving the Wi-Fi protocol stack ability to handle burst traffic.

- **CONFIG_ESP_WIFI_DYNAMIC_RX_BUFFER_NUM** This parameter indicates the number of RX buffer in the Wi-Fi layer. Increasing this parameter will improve the performance of packet reception. This parameter needs to match the RX buffer size of the LwIP layer.

- **CONFIG_ESP_WIFI_RX_BA_WIN** This parameter indicates the size of the AMPDU BA Window at the receiving end. This parameter should be configured to the smaller value between twice of **CONFIG_ESP_WIFI_STATIC_RX_BUFFER_NUM** and **CONFIG_ESP_WIFI_DYNAMIC_RX_BUFFER_NUM**.

- **CONFIG_LWIP_TCP_WND_DEFAULT** This parameter represents the RX buffer size of the LwIP layer for each TCP stream. Its value should be configured to the value of **WIFI_DYNAMIC_RX_BUFFER_NUM** (KB) to reach a high and stable performance. Meanwhile, in case of multiple streams, this value needs to be reduced proportionally.

**TX direction:**

- **CONFIG_ESP_WIFI_TX_BUFFER** This parameter indicates the type of TX buffer, it is recommended to configure it as a dynamic buffer, which can make full use of memory.

- **CONFIG_ESP_WIFI_DYNAMIC_TX_BUFFER_NUM** This parameter indicates the number of TX buffer on the Wi-Fi layer. Increasing this parameter will improve the performance of packet sending. The parameter value needs to match the TX buffer size of the LwIP layer.

- **CONFIG_LWIP_TCP_SND_BUF_DEFAULT** This parameter represents the TX buffer size of the LwIP layer for each TCP stream. Its value should be configured to the value of **WIFI_DYNAMIC_TX_BUFFER_NUM** (KB) to reach a high and stable performance. In case of multiple streams, this value needs to be reduced proportionally.

**Throughput optimization by placing code in IRAM:**
Chapter 4. API Guides

- **CONFIG_ESP_WIFI_IRAM_OPT** If this option is enabled, some Wi-Fi functions are moved to IRAM, improving throughput. This increases IRAM usage by 15 kB.
- **CONFIG_ESP_WIFI_RX_IRAM_OPT** If this option is enabled, some Wi-Fi RX functions are moved to IRAM, improving throughput. This increases IRAM usage by 16 kB.
- **CONFIG_LWIP_IRAM_OPTIMIZATION** If this option is enabled, some LwIP functions are moved to IRAM, improving throughput. This increases IRAM usage by 13 kB.

**Note:** The buffer size mentioned above is fixed as 1.6 KB.

**How to Configure Parameters**

The memory of ESP32 is shared by protocol stack and applications. Here, several configuration ranks are given. In most cases, the user should select a suitable rank for parameter configuration according to the size of the memory occupied by the application.

The parameters not mentioned in the following table should be set to the default.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Iperf</th>
<th>TX prior</th>
<th>High-performance</th>
<th>RX prior</th>
<th>Default</th>
<th>Memory saving</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available memory (KB)</td>
<td>37.1</td>
<td>113.8</td>
<td>123.3</td>
<td>145.5</td>
<td>144.5</td>
<td>170.2</td>
<td>185.2</td>
</tr>
<tr>
<td>WIFI_STATIC_RX_BUFFER_NUM</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>WIFI_DYNAMIC_RX_BUFFER_NUM</td>
<td>124</td>
<td>34</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_DYNAMIC_TX_BUFFER_NUM</td>
<td>124</td>
<td>18</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_RX_BA_WIN</td>
<td>8</td>
<td>12</td>
<td>6</td>
<td>10</td>
<td>6</td>
<td>Disable</td>
<td></td>
</tr>
<tr>
<td>TCP_SND_BUF_DEFAULT (KB)</td>
<td>28</td>
<td>24</td>
<td>18</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>TCP_WND_DEFAULT (KB)</td>
<td>16</td>
<td>24</td>
<td>34</td>
<td>20</td>
<td>12</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>WIFI_I RAM_OPT</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>WIFI_RX_I RAM</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>LWIP_IRAM_OPTIMIZATION</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>TCP TX throughput (Mbit/s)</td>
<td>74.6</td>
<td>50.8</td>
<td>46.5</td>
<td>39.9</td>
<td>44.2</td>
<td>33.8</td>
<td>25.6</td>
</tr>
<tr>
<td>TCP RX throughput (Mbit/s)</td>
<td>63.6</td>
<td>35.5</td>
<td>42.3</td>
<td>48.5</td>
<td>40.5</td>
<td>30.1</td>
<td>27.8</td>
</tr>
<tr>
<td>UDP TX throughput (Mbit/s)</td>
<td>76.2</td>
<td>75.1</td>
<td>74.1</td>
<td>72.4</td>
<td>69.6</td>
<td>64.1</td>
<td>36.5</td>
</tr>
<tr>
<td>UDP RX throughput (Mbit/s)</td>
<td>83.1</td>
<td>66.3</td>
<td>75.1</td>
<td>75.6</td>
<td>73.1</td>
<td>65.3</td>
<td>54.7</td>
</tr>
</tbody>
</table>

**Note:** The test was performed with a single stream in a shielded box using an ASUS RT-N66U router. ESP32’s CPU is dual core with 240 MHz. ESP32’s flash is in QIO mode with 80 MHz.

**Ranks:**
- **Iperf rank** ESP32 extreme performance rank used to test extreme performance.
- **High-performance rank** The ESP32’s high-performance configuration rank, suitable for scenarios where the application occupies less memory and has high-performance requirements. In this rank, users can choose to use the RX prior rank or the TX prior rank according to the usage scenario.
Chapter 4. API Guides

- **Default rank**  ESP32’s default configuration rank, the available memory, and performance are in balance.
- **Memory saving rank**  This rank is suitable for scenarios where the application requires a large amount of memory, and the transceiver performance will be reduced in this rank.
- **Minimum rank**  This is the minimum configuration rank of ESP32. The protocol stack only uses the necessary memory for running. It is suitable for scenarios where there is no requirement for performance and the application requires lots of space.

**Using PSRAM**

PSRAM is generally used when the application takes up a lot of memory. In this mode, the `CONFIG_ESP_WIFI_TX_BUFFER` is forced to be static. `CONFIG_ESP_WIFI_STATIC_TX_BUFFER_NUM` indicates the number of DMA buffers at the hardware layer, and increasing this parameter can improve performance. The following are the recommended ranks for using PSRAM:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Iperf</th>
<th>Default</th>
<th>Memory saving</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available memory (KB)</td>
<td>113.8</td>
<td>152.4</td>
<td>181.2</td>
<td>202.6</td>
</tr>
<tr>
<td>WiFi STATIC RX BUFFER NUM</td>
<td>8</td>
<td>4</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>WiFi DYNAMIC RX BUFFER NUM</td>
<td>128</td>
<td>128</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>WiFi STATIC TX BUFFER NUM</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>WiFi_RX_BA_WIN</td>
<td>16</td>
<td>16</td>
<td>8</td>
<td>Disable</td>
</tr>
<tr>
<td>TCP SND BUF_DEFAULT (KB)</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>TCP WND_DEFAULT (KB)</td>
<td>65</td>
<td>65</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>WIFI_IRAM_OPT</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>WIFI_RX_IRAM OPT</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LWIP IRAM OPTIMIZATION</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>TCP TX throughput (Mbit/s)</td>
<td>37.5</td>
<td>31.7</td>
<td>21.7</td>
<td>14.6</td>
</tr>
<tr>
<td>TCP RX throughput (Mbit/s)</td>
<td>31.5</td>
<td>29.8</td>
<td>26.5</td>
<td>21.1</td>
</tr>
<tr>
<td>UDP TX throughput (Mbit/s)</td>
<td>69.1</td>
<td>31.5</td>
<td>27.1</td>
<td>24.1</td>
</tr>
<tr>
<td>UDP RX throughput (Mbit/s)</td>
<td>40.1</td>
<td>38.5</td>
<td>37.5</td>
<td>36.9</td>
</tr>
</tbody>
</table>

**4.34.34  Wi-Fi Menuconfig**

**Wi-Fi Buffer Configure**

If you are going to modify the default number or type of buffer, it would be helpful to also have an overview of how the buffer is allocated/freed in the data path. The following diagram shows this process in the TX direction:

![Fig. 65: TX Buffer Allocation](image-url)
Description:

- The application allocates the data which needs to be sent out.
- The application calls TCPIP-/Socket-related APIs to send the user data. These APIs will allocate a PBUF used in LwIP, and make a copy of the user data.
- When LwIP calls a Wi-Fi API to send the PBUF, the Wi-Fi API will allocate a “Dynamic Tx Buffer” or “Static Tx Buffer”, make a copy of the LwIP PBUF, and finally send the data.

The following diagram shows how buffer is allocated/freed in the RX direction:

![Fig. 66: RX Buffer Allocation](image)

Description:

- The Wi-Fi hardware receives a packet over the air and puts the packet content to the “Static Rx Buffer”, which is also called “RX DMA Buffer”.
- The Wi-Fi driver allocates a “Dynamic Rx Buffer”, makes a copy of the “Static Rx Buffer”, and returns the “Static Rx Buffer” to hardware.
- The Wi-Fi driver delivers the packet to the upper-layer (LwIP), and allocates a PBUF for holding the “Dynamic Rx Buffer”.
- The application receives data from LwIP.

The diagram shows the configuration of the Wi-Fi internal buffer.
<table>
<thead>
<tr>
<th>Buffer Type</th>
<th>Alloc Type</th>
<th>Default</th>
<th>Configurable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static RX Buffer (Hardware RX Buffer)</td>
<td>Static</td>
<td>10 * 1600 Bytes</td>
<td>Yes</td>
<td>This is a kind of DMA memory. It is initialized in <code>esp_wifi_init()</code> and freed in <code>esp_wifi_deinit()</code>. The ‘Static Rx Buffer’ forms the hardware receiving list. Upon receiving a frame over the air, hardware writes the frame into the buffer and raises an interrupt to the CPU. Then, the Wi-Fi driver reads the content from the buffer and returns the buffer back to the list. If needs be, the application can reduce the memory statically allocated by Wi-Fi. It can reduce this value from 10 to 6 to save 6400 Bytes of memory. It is not recommended to reduce the configuration to a value less than 6 unless the AMPDU feature is disabled.</td>
</tr>
<tr>
<td>Dynamic RX Buffer</td>
<td>Dynamic</td>
<td>32</td>
<td>Yes</td>
<td>The buffer length is variable and it depends on the received frames’ length. When the Wi-Fi driver receives a frame from the ‘Hardware Rx Buffer’, the ‘Dynamic Rx Buffer’ needs to be allocated from the heap. The number of the Dynamic Rx Buffer, configured in the menu-config, is used to limit the total un-freed Dynamic Rx Buffer number.</td>
</tr>
<tr>
<td>Dynamic TX Buffer</td>
<td>Dynamic</td>
<td>32</td>
<td>Yes</td>
<td>This is a kind of DMA memory. It is allocated to the heap. When the upper-layer (LwIP) sends packets to the Wi-Fi driver, it firstly allocates a ‘Dynamic TX Buffer’ and makes a copy of the upper-layer buffer. The Dynamic and Static TX Buffers are mutually exclusive.</td>
</tr>
<tr>
<td>Static TX Buffer</td>
<td>Static</td>
<td>16 * 1600 Bytes</td>
<td>Yes</td>
<td>This is a kind of DMA memory. It is initialized in <code>esp_wifi_init()</code> and freed in <code>esp_wifi_deinit()</code>. When the upper-layer (LwIP) sends packets to the Wi-Fi driver, it firstly allocates a ‘Static TX Buffer’ and makes a copy of the upper-layer buffer. The Dynamic and Static TX Buffers are mutually exclusive. The TX buffer must be a DMA buffer. For this reason, if PSRAM is enabled, the TX buffer must be static.</td>
</tr>
<tr>
<td>Management Short Buffer</td>
<td>Dynamic</td>
<td>8</td>
<td>NO</td>
<td>Wi-Fi driver’s internal buffer.</td>
</tr>
<tr>
<td>Management Long Buffer</td>
<td>Dynamic</td>
<td>32</td>
<td>NO</td>
<td>Wi-Fi driver’s internal buffer.</td>
</tr>
<tr>
<td>Management Long Long Buffer</td>
<td>Dynamic</td>
<td>32</td>
<td>NO</td>
<td>Wi-Fi driver’s internal buffer.</td>
</tr>
</tbody>
</table>
Wi-Fi NVS Flash

If the Wi-Fi NVS flash is enabled, all Wi-Fi configurations set via the Wi-Fi APIs will be stored into flash, and the Wi-Fi driver will start up with these configurations the next time it powers on/reboots. However, the application can choose to disable the Wi-Fi NVS flash if it does not need to store the configurations into persistent memory, or has its own persistent storage, or simply due to debugging reasons, etc.

Wi-Fi Aggregate MAC Protocol Data Unit (AMPDU)

ESP32 supports both receiving and transmitting AMPDU, and the AMPDU can greatly improve the Wi-Fi throughput.

Generally, the AMPDU should be enabled. Disabling AMPDU is usually for debugging purposes.

4.34.35 Troubleshooting

Please refer to a separate document with *Espressif Wireshark User Guide*.

Espressif Wireshark User Guide

1. Overview

1.1 What is Wireshark?  Wireshark (originally named “Ethereal”) is a network packet analyzer that captures network packets and displays the packet data as detailed as possible. It uses WinPcap as its interface to directly capture network traffic going through a network interface controller (NIC).

You could think of a network packet analyzer as a measuring device used to examine what is going on inside a network cable, just like a voltmeter is used by an electrician to examine what is going on inside an electric cable.

In the past, such tools were either very expensive, proprietary, or both. However, with the advent of Wireshark, all that has changed.

Wireshark is released under the terms of the GNU General Public License, which means you can use the software and the source code free of charge. It also allows you to modify and customize the source code.

Wireshark is, perhaps, one of the best open source packet analyzers available today.

1.2 Some Intended Purposes  Here are some examples of how Wireshark is typically used:

- Network administrators use it to troubleshoot network problems.
- Network security engineers use it to examine security problems.
- Developers use it to debug protocol implementations.
- People use it to learn more about network protocol internals.

Beside these examples, Wireshark can be used for many other purposes.

1.3 Features  The main features of Wireshark are as follows:

- Available for UNIX and Windows
- Captures live packet data from a network interface
- Displays packets along with detailed protocol information
- Opens/saves the captured packet data
- Imports/exports packets into a number of file formats, supported by other capture programs
- Advanced packet filtering
- Searches for packets based on multiple criteria
• Colorizes packets according to display filters
• Calculates statistics
• ...and a lot more!

1.4 Wireshark Can or Can’t Do

• **Live capture from different network media.**
  Wireshark can capture traffic from different network media, including wireless LAN.

• **Import files from many other capture programs.**
  Wireshark can import data from a large number of file formats, supported by other capture programs.

• **Export files for many other capture programs.**
  Wireshark can export data into a large number of file formats, supported by other capture programs.

• **Numerous protocol dissectors.**
  Wireshark can dissect, or decode, a large number of protocols.

• **Wireshark is not an intrusion detection system.**
  It will not warn you if there are any suspicious activities on your network. However, if strange things happen, Wireshark might help you figure out what is really going on.

• **Wireshark does not manipulate processes on the network, it can only perform “measurements” within it.**
  Wireshark does not send packets on the network or influence it in any other way, except for resolving names (converting numerical address values into a human readable format), but even that can be disabled.

2. Where to Get Wireshark

You can get Wireshark from the official website:  [https://www.wireshark.org/download.html](https://www.wireshark.org/download.html)

Wireshark can run on various operating systems. Please download the correct version according to the operating system you are using.


This demonstration uses Wireshark 2.2.6 on Linux.

a) Start Wireshark

On Linux, you can run the shell script provided below. It starts Wireshark, then configures NIC and the channel for packet capture.

```
ifconfig $1 down
iwconfig $1 mode monitor
iwconfig $1 channel $2
ifconfig $1 up
Wireshark&
```

In the above script, the parameter $1 represents NIC and $2 represents channel. For example, `wlan0 in ./xxx.sh wlan0 6`, specifies the NIC for packet capture, and 6 identifies the channel of an AP or Soft-AP.

b) Run the Shell Script to Open Wireshark and Display Capture Interface

c) Select the Interface to Start Packet Capture

As the red markup shows in the picture above, many interfaces are available. The first one is a local NIC and the second one is a wireless NIC.

Please select the NIC according to your requirements. This document will use the wireless NIC to demonstrate packet capture.

Double click `wlan0` to start packet capture.

d) Set up Filters

Since all packets in the channel will be captured, and many of them are not needed, you have to set up filters to get the packets that you need.

Please find the picture below with the red markup, indicating where the filters should be set up.
Chapter 4. API Guides

Fig. 67: Wireshark Capture Interface

Fig. 68: Setting up Filters in Wireshark
Chapter 4. API Guides

Click **Filter**, the top left blue button in the picture below. The *display filter* dialogue box will appear.

![Display Filter Dialogue Box](image)

Fig. 69: *Display Filter* Dialogue Box

Click the *Expression* button to bring up the *Filter Expression* dialogue box and set the filter according to your requirements.

**The quickest way:** enter the filters directly in the toolbar.

Click on this area to enter or modify the filters. If you enter a wrong or unfinished filter, the built-in syntax check turns the background red. As soon as the correct expression is entered, the background becomes green.

The previously entered filters are automatically saved. You can access them anytime by opening the drop down list.

For example, as shown in the picture below, enter two MAC addresses as the filters and click *Apply* (the blue arrow). In this case, only the packet data transmitted between these two MAC addresses will be captured.

e) **Packet List**

You can click any packet in the packet list and check the detailed information about it in the box below the list. For example, if you click the first packet, its details will appear in that box.

f) **Stop/Start Packet Capture**

As shown in the picture below, click the red button to stop capturing the current packet.

Click the top left blue button to start or resume packet capture.

g) **Save the Current Packet**

On Linux, go to *File -> Export Packet Dissections -> As Plain Text File* to save the packet.

Please note that *All packets, Displayed and All expanded* must be selected.

By default, Wireshark saves the captured packet in a libpcap file. You can also save the file in other formats, e.g. txt, to analyze it in other tools.

4.35 **Wi-Fi Security**

4.35.1 ESP32 Wi-Fi Security Features

- Support for Protected Management Frames (PMF)
- Support for WPA3-Personal
- Support for Opportunistic Wireless Encryption
Fig. 70: Filter Expression Dialogue Box

Fig. 71: Filter Toolbar

Fig. 72: Example of MAC Addresses applied in the Filter Toolbar
Chapter 4. API Guides

Fig. 73: Example of Packet List Details

Fig. 74: Stopping Packet Capture

Fig. 75: Starting or Resuming the Packets Capture
In addition to traditional security methods (WEP/WPA-TKIP/WPA2-CCMP), ESP32 Wi-Fi supports state-of-the-art security protocols, namely Protected Management, Wi-Fi Protected Access 3 and Enhanced Open based on Opportunistic Wireless Encryption. WPA3 provides better privacy and robustness against known attacks on traditional modes. Enhanced Open enhances security and privacy of users connecting to open (public) Wireless Network without authentication.

4.35.2 Protected Management Frames (PMF)

Introduction

In Wi-Fi, management frames such as beacons, probes, (de)authentication, (dis)association are used by non-AP stations to scan and connect to an AP. Unlike data frames, these frames are sent unencrypted. An attacker can use eavesdropping and packet injection to send spoofed (de)authentication/(dis)association frames at the right time, leading to attacks such as Denial-of-Service (DOS) and man-in-the-middle.

PMF provides protection against these attacks by encrypting unicast management frames and providing integrity checks for broadcast management frames. These include deauthentication, disassociation and robust management frames. It also provides Secure Association (SA) teardown mechanism to prevent spoofed association/authentication frames from disconnecting already connected clients.

There are 3 types of PMF configuration modes on both station and AP side -

- PMF Optional
- PMF Required
- PMF Disabled

API & Usage

ESP32 supports PMF in both Station and SoftAP mode. For both, the default mode is PMF Optional. For even higher security, PMF required mode can be enabled by setting the required flag in pmf_cfg while using the esp_wifi_set_config() API. This will result in the device only connecting to a PMF enabled device and rejecting others. PMF optional can be disabled using esp_wifi_disable_pmf_config() API. If softAP is started in WPA3 or WPA2/WPA3 mixed mode trying to disable PMF will result in error.
4.35.3 WiFi Enterprise

Introduction

Enterprise security is the secure authentication mechanism for enterprise wireless networks. It uses RADIUS server for authentication of network users before connecting to the Access Point. The authentication process is based on 802.1X policy and comes with different Extended Authentication Protocol (EAP) methods such as TLS, TTLS, PEAP and EAP-FAST. RADIUS server authenticates the users based on their credentials (username and password), digital certificates or both.

ESP32 supports WiFi Enterprise only in station mode.

ESP32 Supports WPA2-Enterprise and WPA3-Enterprise. WPA3-Enterprise builds upon the foundation of WPA2-Enterprise with the additional requirement of using Protected Management Frames (PMF) and server certificate validation on all WPA3 connections. **WPA3-Enterprise also offers an addition secure mode using 192-bit minimum-strength security protocols and cryptographic tools to better protect sensitive data.** The 192-bit security mode offered by WPA3-Enterprise ensures the right combination of cryptographic tools are used and sets a consistent baseline of security within a WPA3 network. WPA3-Enterprise 192-bit mode is only supported by modules having **SOC_WIFI_GCMP_SUPPORT** support. Enable **CONFIG_ESP_WIFI_SUITE_B_192** flag to support WPA3-Enterprise with 192-bit mode.

ESP32 supports the following EAP methods:

- **EAP-TLS:** This is a certificate-based method and only requires SSID and EAP-IDF.
- **PEAP:** This is a Protected EAP method. Username and password are mandatory.
- **EAP-TTLS:** This is a credential-based method. Only server authentication is mandatory while user authentication is optional. Username and Password are mandatory. It supports different Phase2 methods, such as:
  - **PAP:** Password Authentication Protocol.
  - **CHAP:** Challenge Handshake Authentication Protocol.
  - **MSCHAP and MSCHAP-V2.**
- **EAP-FAST:** This is an authentication method based on Protected Access Credentials (PAC) which also uses identity and password. Currently, **CONFIG_ESP_WIFI_MBEDTLS_TLS_CLIENT** flag should be disabled to use this feature.

Example wifi/wifi_enterprise demonstrates all the supported WiFi Enterprise methods except EAP-FAST. Please refer wifi/wifi_eap_fast for EAP-FAST example. EAP method can be selected from the Example Configuration menu in idf.py menuconfig. Refer to examples/wifi/wifi_enterprise/README.md for information on how to generate certificates and run the example.

4.35.4 WPA3-Personal

Introduction

Wi-Fi Protected Access-3 (WPA3) is a set of enhancements to Wi-Fi access security intended to replace the current WPA2 standard. It includes new features and capabilities that offer significantly better protection against different types of attacks. It improves upon WPA2-Personal in following ways:

- **WPA3 uses Simultaneous Authentication of Equals (SAE),** which is password-authenticated key agreement method based on Diffie-Hellman key exchange. Unlike WPA2, the technology is resistant to offline-dictionary attack, where the attacker attempts to determine shared password based on captured 4-way handshake without any further network interaction.
- **Disallows outdated protocols such as TKIP,** which is susceptible to simple attacks like MIC key recovery attack.
- **Mandates Protected Management Frames (PMF),** which provides protection for unicast and multicast robust management frames which include Disassoc and Deauth frames. This means that the attacker cannot disrupt...
an established WPA3 session by sending forged Assoc frames to the AP or Deauth/Disassoc frames to the Station.

- Provides forward secrecy, which means the captured data cannot be decrypted even if password is compromised after data transmission.

**ESP32 station also supports following additional Wi-Fi CERTIFIED WPA3™ features.**

- **Transition Disable**: WPA3 defines transition modes for client devices so that they can connect to a network even when some of the APs in that network do not support the strongest security mode. Client device implementations typically configure network profiles in a transition mode by default. However, such a client device could be subject to an active downgrade attack in which the attacker causes the client device to use a lower security mode in order to exploit a vulnerability with that mode. WPA3 has introduced the Transition Disable feature to mitigate such attacks, by enabling client devices to change from a transition mode to an “only” mode when connecting to a network, once that network indicates it fully supports the higher security mode. Enable `transition_disable` in `wifi_sta_config_t` to enable this feature for ESP32 station.

- **SAE PUBLIC-KEY (PK)**: As the password at small public networks is shared with multiple users it may be relatively easy for an attacker to find out the password, which is sufficient to launch an evil twin attack. Such attacks are prevented by an extension to WPA3-Personal called SAE-PK. The SAE-PK authentication exchange is very similar to the regular SAE exchange, with the addition of a digital signature sent by the AP to the client device. The client device validates the public key asserted by the AP based on the password fingerprint, and verifies the signature using the public key. So even if the attacker knows the password, it does not know the private key to generate a valid signature, and therefore the client device is protected against an evil twin attack. Enable `CONFIG_ESP_WIFI_ENABLE_SAE_PK` and `sae_pk_mode` in `wifi_sta_config_t` to add support of SAE PK for ESP32 station.

- **SAE PWE Methods**: ESP32 station as well as softAP supports SAE Password Element derivation method *Hunting And Pecking and Hash to Element (H2E).* H2E is computationally efficient as it uses less iterations than Hunt and Peck, also it mitigates side channel attacks. These can be configured using parameter `sae_pwe_h2e` from `wifi_sta_config_t` and `wifi_ap_config_t` for station and softAP respectively. Hunt and peck, H2E both can be enabled by using `WPA3_SAE_PWE_BOTH` configuration.

Please refer to Security section of Wi-Fi Alliance’s official website for further details.

### Setting up WPA3 Personal with ESP32

A config option `CONFIG_ESP_WIFI_ENABLE_WPA3_SAE` is provided to Enable/Disable WPA3 for station. By default it is kept enabled, if disabled ESP32 will not be able to establish a WPA3 connection. Also under Wi-Fi component a config option `CONFIG_ESP_WIFI_SOFTAP_SAE_SUPPORT` is provided to Enable/Disable WPA3 for softAP. Additionally, since PMF is mandated by WPA3 protocol, PMF Mode Optional is set by default for station and softAP. PMF Required can be configured using WiFi config. For WPA3 softAP, PMF required is mandatory and will be configured and stored in NVS implicitly if not specified by user.

Refer to Protected Management Frames (PMF) on how to set this mode.

After configuring all required settings for WPA3-Personal station, application developers need not worry about the underlying security mode of the AP. WPA3-Personal is now the highest supported protocol in terms of security, so it will be automatically selected for the connection whenever available. For example, if an AP is configured to be in WPA3 Transition Mode, where it will advertise as both WPA2 and WPA3 capable, Station will choose WPA3 for the connection with above settings. Note that Wi-Fi stack size requirement will increase 3kB when “Enable WPA3-Personal” is used.

After configuring all required setting for WPA3-Personal softAP, application developers have to set `WIFI_AUTH_WPA3_PSK` for `authmode` in `wifi_ap_config_t` to start AP in WPA3 security. SoftAP can be also configured to use `WIFI_AUTH_WPA2_WPA3_PSK` mixed mode. Note that binary size will be increased by ~6.5 kilobytes after enabling “`CONFIG_ESP_WIFI_SOFTAP_SAE_SUPPORT`.”

### 4.35.5 Wi-Fi Enhanced Open™
Introduction

Enhanced Open is used for providing security and privacy to users connecting to open (public) wireless networks, particularly in scenarios where user authentication is not desired or distribution of credentials impractical. Each user is provided with unique individual encryption keys that protect data exchange between a user device and the Wi-Fi network. Protected Management Frames further protects management traffic between the access point and user device. Enhanced Open is based on Opportunistic Wireless Encryption (OWE) standard. OWE Transition Mode enables a seamless transition from Open unencrypted WLANs to OWE WLANs without adversely impacting the end user experience.

ESP32 supports Wi-Fi Enhanced Open™ only in station mode.

Setting up OWE with ESP32

A config option `CONFIG_ESP_WIFI_ENABLE_WPA3_OWE_STA` and configuration parameter `owe_enabled` in `wifi_sta_config_t` is provided to enable OWE support for station. To use OWE transition mode, along with the config provided above, `authmode` from `wifi_scan_threshold_t` should be set to `WIFI_AUTH_OPEN`.
Chapter 5

Migration Guides

5.1 ESP-IDF 5.x Migration Guide

5.1.1 Migration from 4.4 to 5.0

Bluetooth Classic

Bluedroid

- `bt/host/bluedroid/api/include/api/esp_hf_defs.h`
  - In `esp_hf_cme_err_t`
    * ESP_HF_CME_MEMEORY_FULL renamed to ESP_HF_CME_MEMORY_FULL
    * ESP_HF_CME_MEMEORY_FAILURE renamed to ESP_HF_CME_MEMORY_FAILURE
  - `esp_bt_hf_init(esp_bd_addr_t remote_addr)` changes into `esp_hf_ag_init(void)`
  - `esp_bt_hf_deinit(esp_bd_addr_t remote_addr)` changes into `esp_hf_ag_deinit(void)`
    Along with this change, the `bt_bdaddr_t init` and `bt_bdaddr_t deinit` has been removed from `union btc_arg_t`.
  - `esp_bt_hf_register_callback` changes into `esp_hf_ag_register_callback`
  - `esp_bt_hf_connect` changes into `esp_hf_ag_slc_connect`
  - `esp_bt_hf_disconnect` changes into `esp_hf_ag_slc_disconnect`
  - `esp_BT_HF_CONNECT_AUDIO` changes into `esp_hf_ag_audio_connect`
  - `esp_BT_HF_DISCONNECT_AUDIO` changes into `esp_hf_ag_audio_disconnect`
  - `esp_BT_HF_VRA` changes into `esp_hf_ag_vra_control`
  - `esp_BT_HF_VOLUME_CONTROL` changes into `esp_hf_ag_volume_control`
  - `esp_BT_HF.Unknown_AT_response` changes into `esp_hf_ag_unknown_at_send`
  - `esp_BT_HF_CMEE_RESPONSE` changes into `esp_hf_ag_cmee_send`
  - `esp_BT_HF_IND_CHANGE_NOTIFICATION` changes into `esp_hf_ag_devices_status_indchange`
  - `esp_BT_HF_CIND_RESPONSE` changes into `esp_hf_ag_cind_response`
  - `esp_BT_HF_COPS_RESPONSE` changes into `esp_hf_ag_cops_response`
  - `esp_BT_HF_CLCC_RESPONSE` changes into `esp_hf_ag_clcc_response`
  - `esp_BT_HF_CNRM_RESPONSE` changes into `esp_hf_ag_cnum_response`
Chapter 5. Migration Guides

- esp_bt_hf_bsir changes into esp_hf_ag_bsir
- esp_bt_hf_answer_call changes into esp_hf_ag_answer_call
- esp_bt_hf_reject_call changes into esp_hf_ag_reject_call
- esp_bt_hf_out_call changes into esp_hf_ag_out_call
- esp_bt_hf_register_data_callback changes into esp_hf_ag_register_data_callback
- esp_hf_outgoing_data_ready changes into esp_hf_ag_outgoing_data_ready

Bluetooth Low Energy

Bluedroid

The following Bluedroid macros, types, and functions have been renamed:

- In esp_gap_ble_cb_event_t:
  - ESP_GAP_BLE_SET_PREFERED_DEFAULT_PHY_COMPLETE_EVT renamed to ESP_GAP_BLE_SET_PREFERRED_DEFAULT_PHY_COMPLETE_EVT
  - ESP_GAP_BLE_SET_PREFERED_PHY_COMPLETE_EVT renamed to ESP_GAP_BLE_SET_PREFERRED_PHY_COMPLETE_EVT
  - ESP_GAP_BLE_CHANNEL_SELECT_ALGORITHM_EVT renamed to ESP_GAP_BLE_CHANNEL_SELECT_ALGORITHM_EVT
- esp_ble_wl_opration_t renamed to esp_ble_wl_operation_t
- esp_ble_gap_cb_param_t.pkt_data_lenth_cmpl renamed to pkt_data_length_cmpl
- esp_ble_gap_cb_param_t.update_whitelist_cmpl.wl_opration renamed to wl_operation
- esp_ble_gap_set_prefered_default_phy renamed to esp_ble_gap_set_preferred_default_phy()
- esp_ble_gap_set_prefered_phy renamed to esp_ble_gap_set_preferred_phy()

- In esp_gatt_status_t:
  - ESP_GATT_ENCRYPED_MITM renamed to ESP_GATT_ENCRYPTED_MITM
  - ESP_GATT_ENCRYPTED_NO_MITM renamed to ESP_GATT_ENCRYPTED_NO_MITM

Nimble

The following Nimble APIs have been removed:

- Remove esp_err_t esp_nimble_hci_and_controller_init(void)
  - Controller initialization, enable and HCI initialization calls have been moved to nimble_port_init. This function can be deleted directly.
- Remove esp_err_t esp_nimble_hci_and_controller_deinit(void)
  - Controller deinitialization, disable and HCI deinitialization calls have been moved to nimble_port_deinit. This function can be deleted directly.

ESP-BLE-MESH

The following ESP-BLE-MESH macro has been renamed:

- In esp_ble_mesh_prov_cb_event_t:
  - ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT renamed to ESP_BLE_MESH_PROVISIONER_DIRECT_ERASE_SETTINGS_COMP_EVT
Build System

Migrating from GNU Make Build System  ESP-IDF v5.0 no longer supports GNU make-based projects. Please follow the build system guide for migration.

Update Fragment File Grammar  Please follow the migrate linker script fragment files grammar chapter for migrating v3.x grammar to the new one.

Specify Component Requirements Explicitly  In previous versions of ESP-IDF, some components were always added as public requirements (dependencies) to every component in the build, in addition to the common component requirements:

- driver
- efuse
- esp_timer
- lwip
- vfs
- esp_wifi
- esp_event
- esp_netif
- esp_eth
- esp_phy

This means that it was possible to include header files of those components without specifying them as requirements in idf_component_register. This behavior was caused by transitive dependencies of various common components.

In ESP-IDF v5.0, this behavior is fixed and these components are no longer added as public requirements by default. Every component depending on one of the components which isn’t part of common requirements has to declare this dependency explicitly. This can be done by adding REQUIRES <component_name> or PRIV_REQUIRES <component_name> in idf_component_register call inside component’s CMakeLists.txt. See Component Requirements for more information on specifying requirements.

Setting COMPONENT_DIRS and EXTRA_COMPONENT_DIRS Variables  ESP-IDF v5.0 includes a number of improvements to support building projects with space characters in their paths. To make that possible, there are some changes related to setting COMPONENT_DIRS and EXTRA_COMPONENT_DIRS variables in project CMakeLists.txt files.

Adding non-existent directories to COMPONENT_DIRS or EXTRA_COMPONENT_DIRS is no longer supported and will result in an error.

Using string concatenation to define COMPONENT_DIRS or EXTRA_COMPONENT_DIRS variables is now deprecated. These variables should be defined as CMake lists, instead. For example, use:

```cmake
set(EXTRA_COMPONENT_DIRS path1 path2)
lst(APPEND EXTRA_COMPONENT_DIRS path3)
```

instead of:

```cmake
set(EXTRA_COMPONENT_DIRS "path1 path2")
set(EXTRA_COMPONENT_DIRS "${EXTRA_COMPONENT_DIRS} path3")
```

Defining these variables as CMake lists is compatible with previous ESP-IDF versions.

Update Usage of target_link_libraries with project_elf  ESP-IDF v5.0 fixes CMake variable propagation issues for components. This issue caused compiler flags and definitions that were supposed to apply to one component to be applied to every component in the project.
As a side effect of this, user projects from ESP-IDF v5.0 onwards must use `target_link_libraries` with `project_elf` explicitly and custom CMake projects must specify `PRIVATE`, `PUBLIC`, or `INTERFACE` arguments. This is a breaking change and is not backward compatible with previous ESP-IDF versions.

For example:

```plaintext
target_link_libraries(${project_elf} PRIVATE "-Wl,--wrap=esp_panic_handler")
```

instead of:

```plaintext
target_link_libraries(${project_elf} "-Wl,--wrap=esp_panic_handler")
```

**Update CMake Version**  In ESP-IDF v5.0 minimal CMake version was increased to 3.16 and versions lower than 3.16 are not supported anymore. Run `tools/idf_tools.py install cmake` to install a suitable version if your OS version doesn’t have one.

This affects ESP-IDF users who use system-provided CMake and custom CMake.

**Reorder the Applying of the Target-Specific Config Files**  ESP-IDF v5.0 reorders the applying order of target-specific config files and other files listed in `SDKCONFIG_DEFAULTS`. Now, target-specific files will be applied right after the file brings it in, before all latter files in `SDKCONFIG_DEFAULTS`.

For example:

```plaintext
If `'`SDKCONFIG_DEFAULTS="sdkconfig.defaults;sdkconfig_devkit1"`', and there is a file `'`sdkconfig.defaults.esp32`' in the same folder, then the files will be applied in the following order: (1) sdkconfig.defaults (2) sdkconfig.defaults.esp32 (3) sdkconfig_devkit1.
```

If you have a key with different values in the target-specific files of the former item (e.g., `sdkconfig.defaults.esp32` above) and the latter item (e.g., `sdkconfig_devkit1` above), please note the latter will override the target-specific file of the former.

If you do want to have some target-specific config values, please put it into the target-specific file of the latter item (e.g., `sdkconfig_devkit1.esp32`).

**GCC**

**GCC Version**  The previous GCC version was GCC 8.4.0. This has now been upgraded to GCC 11.2.0 on all targets. Users that need to port their code from GCC 8.4.0 to 11.2.0 should refer to the series of official GCC porting guides listed below:

- Porting to GCC 9
- Porting to GCC 10
- Porting to GCC 11

**Warnings**  The upgrade to GCC 11.2.0 has resulted in the addition of new warnings, or enhancements to existing warnings. The full details of all GCC warnings can be found in GCC Warning Options. Users are advised to double-check their code, then fix the warnings if possible. Unfortunately, depending on the warning and the complexity of the user’s code, some warnings will be false positives that require non-trivial fixes. In such cases, users can choose to suppress the warning in multiple ways. This section outlines some common warnings that users are likely to encounter, and ways to suppress them.

**Warning:**  Users are advised to check that a warning is indeed a false positive before attempting to suppress it.
-Wstringop-overflow, -Wstringop-overread, -Wstringop-truncation, and -Warray-bounds  Users that use memory/string copy/compare functions will run into one of the -Wstringop warnings if the compiler cannot properly determine the size of the memory/string. The examples below demonstrate code that triggers these warnings and how to suppress them.

```c
#pragma GCC diagnostic push
#pragma GCC diagnostic ignored "-Wstringop-overflow"
#pragma GCC diagnostic ignored "-Warray-bounds"
    memset(RTC_SLOW_MEM, 0, CONFIG_ULP_COPROC_RESERVE_MEM); // <<-- This line leads to warnings
#pragma GCC diagnostic pop
```

- Waddress-of-packed-member  GCC will issue this warning when accessing an unaligned member of a packed struct due to the incurred penalty of unaligned memory access. However, all ESP chips (on both Xtensa and RISC-V architectures) allow for unaligned memory access and incur no extra penalty. Thus, this warning can be ignored in most cases.

```c
components/bt/host/bluedroid/btc/profile/std/gatt/btc_gatt_util.c: In function
    'btc_to_bta_gatt_id':
components/bt/host/bluedroid/btc/profile/std/gatt/btc_gatt_util.c:105:21: warning:
    taking address of packed member of 'struct <anonymous>' may result in an unaligned pointer value [-Waddress-of-packed-member]
105 |    btc_to_bta_uuid(&p_dest->uuid, &p_src->uuid);
     ^~~~~~~~~~~~~
```

If the warning occurs in multiple places across multiple source files, users can suppress the warning at the CMake level as demonstrated below.

```c
set_source_files_properties(
    "host/bluedroid/bta/gatt/bta_gatto_act.c"
    "host/bluedroid/bta/gatt/bta_gatto_cache.c"
    "host/bluedroid/btc/profile/std/gatt/btc_gatt_util.c"
    "host/bluedroid/btc/profile/std/gatt/btc_gatts.c"
    PROPERTIES COMPILE_FLAGS -Wno-address-of-packed-member)
```

However, if there are only one or two instances, users can suppress the warning directly in the source code itself as demonstrated below.

```c
#pragma GCC diagnostic push
    if __GNUC__ >= 9
        #pragma GCC diagnostic ignored "-Waddress-of-packed-member"  <<-- This key had been introduced since GCC 9
    #endif
    uint32_t* reg_ptr = (uint32_t*)src;
#pragma GCC diagnostic pop
```

llabs() for 64-bit Integers  The function abs() from stdlib.h takes int argument. Please use llabs() for types that are intended to be 64-bit. It is particularly important for time_t.
Espressif Toolchain Changes

**int32_t and uint32_t for Xtensa Compiler** The types int32_t and uint32_t have been changed from the previous int and unsigned int to long and unsigned long respectively for the Xtensa compiler. This change now matches upstream GCC which long integers for int32_t and uint32_t on Xtensa, RISC-V, and other architectures.

<table>
<thead>
<tr>
<th></th>
<th>2021r2 and older, GCC 8</th>
<th>2022r1, GCC 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xtensa</td>
<td>(unsigned) int</td>
<td>(unsigned) long</td>
</tr>
<tr>
<td>riscv32</td>
<td>(unsigned) long</td>
<td>(unsigned) long</td>
</tr>
</tbody>
</table>

The change mostly affects code that formats strings using types provided by `<inttypes.h>`. Users will need to replace placeholders such as %i and %x with PRIi32 and PRIxx respectively.

In other cases, it should be noted that enums have the int type.

In common, int32_t and int, as well as uint32_t and unsigned int, are different types.

If users do not make the aforementioned updates to format strings in their applications, the following error will be reported during compilation:

```c
/Users/name/esp/esp-rainmaker/components/esp-insights/components/esp_diagnostics/
~include/esp_diagnostics.h:238:29: error: format '%u' expects argument of type
~'unsigned int', but argument 3 has type 'uint32_t' {aka 'long unsigned int'} [-Werror=format]
238 | esp_diag_log_event(tag, "EV (%u) %s: " format, esp_log_timestamp(), tag,
| "~~~~~~~~~~~~~ ~~~~~~~~~~~~
| uint32_t {aka long_}
| unsigned int)
| uint32_t {aka long unsigned int}
```

**Removing CONFIG_COMPILER_DISABLE_GCC8_WARNINGS Build Option** The `CONFIG_COMPILER_DISABLE_GCC8_WARNINGS` option was introduced to allow building of legacy code dating from the rigid GCC 5 toolchain. However, enough time has passed to allow for the warnings to be fixed, thus this option has been removed.

For now in GCC 11, users are advised to review their code and fix the compiler warnings where possible.

**Networking**

**Wi-Fi**

**Callback function type esp_now_recv_cb_t** Previously, the first parameter of `esp_now_recv_cb_t` was of type `const uint8_t *mac_addr`, which only included the address of ESP-NOW peer device.

This now changes. The first parameter is of type `esp_now_recv_info_t`, which has members `src_addr`, `des_addr` and `rx_ctrl`. Therefore, the following updates are required:

- Redefine ESP-NOW receive callback function.
- `src_addr` can be used to replace original `mac_addr`.
- `des_addr` is the destination MAC address of ESP-NOW packet, which can be unicast or broadcast address. With `des_addr`, the user can distinguish unicast and broadcast ESP-NOW packets where broadcast ESP-NOW packets can be non-encrypted even when encryption policy is configured for the ESP-NOW.
- `rx_ctrl` is Rx control info of the ESP-NOW packet, which provides more information about the packet.
Please refer to the ESP-NOW example: `wifi/espnow/main/espnow_example_main.c`

### Ethernet

**esp Eth_ioctl() API** Previously, the *esp eth_ioctl()* API had the following issues:

- The third parameter (which is of type `void *`) would accept an `int/bool` type arguments (i.e., not pointers) as input in some cases. However, these cases were not documented properly.
- To pass `int/bool` type argument as the third parameter, the argument had to be "unnaturally" casted to a `void *` type, to prevent a compiler warning as demonstrated in the code snippet below. This casting could lead to misuse of the *esp eth_ioctl()* function.

```c
espeth_ioctl(eth_handle, ETH_CMD_S_FLOW_CTRL, (void *)true);
```

Therefore, the usage of *esp eth_ioctl()* is now unified. Arguments to the third parameter must be passed as pointers to a specific data type to/from where data will be stored/read by *esp eth_ioctl()*.

Usage example to set Ethernet configuration:

```c
eth_duplex_t new_duplex_mode = ETH_DUPLEX_HALF;
espeth_ioctl(eth_handle, ETH_CMD_S_DUPLEX_MODE, &new_duplex_mode);
```

Usage example to get Ethernet configuration:

```c
eth_duplex_t duplex_mode;
espeth_ioctl(eth_handle, ETH_CMD_G_DUPLEX_MODE, &duplex_mode);
```

### KSZ8041/81 and LAN8720 Driver Update

The KSZ8041/81 and LAN8720 drivers are updated to support more devices (i.e., generations) from their associated product families. The drivers can recognize particular chip numbers and their potential support by the driver.

As a result, the specific "chip number" functions calls are replaced by generic ones as follows:

- Removed *esp eth phy new ksz8041() and esp eth phy new ksz8081()*, and use
  *esp eth phy new ksz80xx()* instead
- Removed *esp eth phy new lan8720()*, and use *esp eth phy new lan87xx()* instead

### ESP NETIF Glue Event Handlers

*esp eth set default handlers()* and *esp eth clear default handlers()* functions are removed. Registration of the default IP layer handlers for Ethernet is now handled automatically. If you have already followed the suggestion to fully initialize the Ethernet driver and network interface before registering their Ethernet/IP event handlers, then no action is required (except for deleting the affected functions). Otherwise, you may start the Ethernet driver right after they register the user event handler.

### PHY Address Auto-detect

The Ethernet PHY address auto-detect function *esp eth detect phy addr()* is renamed to *esp eth phy 802_3 detect phy addr()* and its header declaration is moved to *esp eth/include/esp eth phy 802_3.h.*

### SPI-Ethernet Module Initialization

The SPI-Ethernet Module initialization is now simplified. Previously, you had to manually allocate an SPI device using *spi bus add device()* before instantiating the SPI-Ethernet MAC.

Now, you no longer need to call *spi bus add device()* as SPI devices are allocated internally. As a result, the *eth_dm9051 config t*, *eth w5500 config t*, and *eth ksz8851 snl config t* configuration structures are updated to include members for SPI device configuration (e.g., to allow fine tuning of SPI timing which may be dependent on PCB design). Likewise, the *ETH DM9051 DEFAULT_CONFIG*
ETH_W5500_DEFAULT_CONFIG, and ETH_KSZ8851SNL_DEFAULT_CONFIG configuration initialization macros are updated to accept new input parameters. Refer to Ethernet API Reference Guide for an example of SPI-Ethernet Module initialization.

TCP/IP Adapter The TCP/IP Adapter was a network interface abstraction component used in ESP-IDF prior to v4.1. This section outlines migration from tcpip_adapter API to its successor ESP-NETIF.

Updating Network Connection Code

Network Stack Initialization

- You may simply replace `tcpip_adapter_init()` with `esp_netif_init()`. However, please should note that the `esp_netif_init()` function now returns standard error codes. See ESP-NETIF for more details.
- The `esp_netif_deinit()` function is provided to de-initialize the network stack.
- You should also replace `#include "tcpip_adapter.h"` with `#include "esp_netif.h"`.

Network Interface Creation Previously, the TCP/IP Adapter defined the following network interfaces statically:

- WiFi Station
- WiFi Access Point
- Ethernet

This now changes. Network interface instance should be explicitly constructed, so that the ESP-NETIF can connect to the TCP/IP stack. For example, after the TCP/IP stack and the event loop are initialized, the initialization code for WiFi must explicitly call `esp_netif_create_default_wifi_sta()`, or `esp_netif_create_default_wifi_ap()`.

Please refer to the example initialization code for these three interfaces:

- WiFi Station: wifi/getting_started/station/main/station_example_main.c
- WiFi Access Point: wifi/getting_started/softAP/main/softap_example_main.c
- Ethernet: ethernet/basic/main/ethernet_example_main.c

Other tcpip_adapter API Replacement All the tcpip_adapter functions have their esp-netif counter-part. Please refer to the esp_netif.h grouped into these sections:

- Setters/Getters
- DHCP
- DNS
- IP address

Default Event Handlers Event handlers are moved from tcpip_adapter to appropriate driver code. There is no change from application code perspective, as all events should be handled in the same way. Please note that for IP-related event handlers, application code usually receives IP addresses in the form of an esp-netif specific struct instead of the LwIP structs. However, both structs are binary compatible.

This is the preferred way to print the address:

```
ESP_LOGI(TAG, "got ip: \n", IPSTR (event->ip_info.ip));
```

Instead of

```
ESP_LOGI(TAG, "got ip:%s\n", ip4addr_ntoa (event->ip_info.ip));
```

Since `ip4addr_ntoa()` is a LwIP API, the esp-netif provides `esp_ip4addr_ntoa()` as a replacement. However, the above method using `IPSTR()` is generally preferred.
**IP Addresses**  You are advised to use esp-netif defined IP structures. Please note that with default compatibility enabled, the LwIP structs will still work.

- esp-netif IP address definitions

**Peripherals**

**Peripheral Clock Gating**  As usual, peripheral clock gating is still handled by driver itself, users don’t need to take care of the peripheral module clock gating.

However, for advanced users who implement their own drivers based on hal and soc components, the previous clock gating include path has been changed from `driver/periph_ctrl.h` to `esp_private/periph_ctrl.h`.

**RTC Subsystem Control**  RTC control APIs have been moved from `driver/rtc_cntl.h` to `esp_private/rtc_ctrl.h`.

**ADC**

**ADC Oneshot & Continuous Mode drivers**  The ADC oneshot mode driver has been redesigned.

- The new driver is in `esp_adc` component and the include path is `esp_adc/adc_oneshot.h`.
- The legacy driver is still available in the previous include path `driver/adc.h`.

The ADC continuous mode driver has been moved from `driver` component to `esp_adc` component.

- The include path has been changed from `driver/adc.h` to `esp_adc/adc_continuous.h`.

Attempting to use the legacy include path `driver/adc.h` of either driver will trigger the build warning below by default. However, the warning can be suppressed by enabling the `CONFIG_ADC.Suppress_Deprecate_Warn` Kconfig option.

```
legacy adc driver is deprecated, please migrate to use esp_adc/adc_oneshot.h and
--esp_adc/adc_continuous.h for oneshot mode and continuous mode drivers...
```

**ADC Calibration Driver**  The ADC calibration driver has been redesigned.

- The new driver is in `esp_adc` component and the include path is `esp_adc/adc_cali.h` and `esp_adc/adc_cali_scheme.h`.

Legacy driver is still available by including `esp_adc_cali.h`. However, if users still would like to use the include path of the legacy driver, users should add `esp_adc` component to the list of component requirements in `CMakeLists.txt`.

Attempting to use the legacy include path `esp_adc_cali.h` will trigger the build warning below by default. However, the warning can be suppressed by enabling the `CONFIG_ADC_CALI.Suppress_Deprecate_Warn` Kconfig option.

```
legacy adc calibration driver is deprecated, please migrate to use esp_adc/adc_
--cali.h and esp_adc/adc_cali_scheme.h
```
API Changes

- The ADC power management APIs `adc_power_acquire` and `adc_power_release` have made private and moved to `esp_private/adc_share_hw_ctrl.h`.
  - The two APIs were previously made public due to a HW errata workaround.
  - Now, ADC power management is completely handled internally by drivers.
  - Users who still require this API can include `esp_private/adc_share_hw_ctrl.h` to continue using these functions.
- `driver/adc2_wifi_private.h` has been moved to `esp_private/adc_share_hw_ctrl.h`.
- Enums `ADC_UNIT_BOTH`, `ADC_UNIT_ALTER`, and `ADC_UNIT_MAX` in `adc_unit_t` have been removed.
- The following enumerations have been removed as some of their enumeration values are not supported on all chips. This would lead to the driver triggering a runtime error if an unsupported value is used.
  - `Enum ADC_CHANNEL_MAX`
  - `Enum ADC_ATTEN_MAX`
  - `Enum ADC_CONV_UNIT_MAX`
- The API `hall_sensor_read` on ESP32 has been removed. Hall sensor is no longer supported on ESP32.
- The API `adc_set_i2s_data_source` and `adc_i2s_mode_init` have been deprecated. Related enum `adc_i2s_source_t` has been deprecated. Please migrate to use `esp_adc/adc_continuous.h`.
- API `adc_digi_filter_reset`, `adc_digi_filter_set_config`, `adc_digi_filter_get_config`, and `adc_digi_filter_enable` have been removed. These APIs behaviours are not guaranteed. Enum `adc_digi_filter_idx_t`, `adc_digi_filter_mode_t`, and structure `adc_digi_iir_filter_t` have been removed as well.
- The API `esp_adc_cal_characterize` has been deprecated, please migrate to `adc_cali_create_scheme_curve_fitting` or `adc_cali_create_scheme_line_fitting` instead.
- The API `esp_adc_cal_raw_to_voltage` has been deprecated, please migrate to `adc_cali_raw_to_voltage` instead.
- The API `esp_adc_cal_get_voltage` has been deprecated, please migrate to `adc_oneshot_get_calibrated_result` instead.

GPIO

- The previous Kconfig option `RTCIO_SUPPORT_RTC_GPIO_DESC` has been removed, thus the `rtc_gpio_desc` array is unavailable. Please use `rtc_io_desc` array instead.
- The user callback of a GPIO interrupt should no longer read the GPIO interrupt status register to get the GPIO’s pin number of triggering the interrupt. You should use the callback argument to determine the GPIO’s pin number instead.
  - Previously, when a GPIO interrupt occurs, the GPIO’s interrupt status register is cleared after calling the user callbacks. Thus, it was possible for users to read the GPIO’s interrupt status register inside the callback to determine which GPIO was used to trigger the interrupt.
  - However, clearing the interrupt status register after calling the user callbacks can potentially cause edge-triggered interrupts to be lost. For example, if an edge-triggered interrupt (re)is triggered while the user callbacks are being called, that interrupt will be cleared without its registered user callback being handled.
  - Now, the GPIO’s interrupt status register is cleared before invoking the user callbacks. Thus, users can no longer read the GPIO interrupt status register to determine which pin has triggered the interrupt. Instead, users should use the callback argument to pass the pin number.

Sigma-Delta Modulator

The Sigma-Delta Modulator driver has been redesigned into `SDM`.

- The new driver implements a factory pattern, where the SDM channels are managed in a pool internally, thus users don’t have to fix a SDM channel to a GPIO manually.
- All SDM channels can be allocated dynamically.

Although it’s recommended to use the new driver APIs, the legacy driver is still available in the previous include path `driver/sigmadelta.h`. However, by default, including `driver/sigmadelta.h` will trigger the build warning below. The warning can be suppressed by Kconfig option `CONFIG_SDM_SUPPRESS_DEPRECATE_WARN`.
Chapter 5. Migration Guides

The legacy sigma-delta driver is deprecated, please use driver/sdm.h

The major breaking changes in concept and usage are listed as follows:

**Breaking Changes in Concepts**

- SDM channel representation has changed from `sigmadelta_channel_t` to `sdm_channel_handle_t`, which is an opaque pointer.
- SDM channel configurations are stored in `sdm_config_t` now, instead of the previous `sigmadelta_config_t`.
- In the legacy driver, users don’t have to set the clock source for SDM channel. But in the new driver, users need to set a proper one in the `sdm_config_t::clk_src`. The available clock sources are listed in the `soc_periph_sdm_clk_src_t`.
- In the legacy driver, users need to set a prescale for the channel, which reflects the frequency in which the modulator outputs a pulse. In the new driver, users should use `sdm_config_t::sample_rate_hz` to set the over sample rate.
- In the legacy driver, users set duty to decide the output analog value, it’s now renamed to a more appropriate name `density`.

**Breaking Changes in Usage**

- Channel configuration was done by channel allocation, in `sdm_new_channel()`. In the new driver, only the density can be changed at runtime, by `sdm_channel_set_pulse_density()`. Other parameters like `gpio number` and `prescale` are only allowed to set during channel allocation.
- Before further channel operations, users should enable the channel in advance, by calling `sdm_channel_enable()`. This function will help to manage some system level services, like `Power Management`.

**Timer Group Driver** Timer Group driver has been redesigned into `GPTimer`, which aims to unify and simplify the usage of general purpose timer.

Although it’s recommended to use the new driver APIs, the legacy driver is still available in the previous include path `driver/timer.h`. However, by default, including `driver/timer.h` will trigger the build warning below. The warning can be suppressed by the Kconfig option `CONFIG_GPTIMER_SUPPRESS_DEPRECATED_WARN`.

`legacy timer group driver is deprecated, please migrate to driver/gptimer.h`

The major breaking changes in concept and usage are listed as follows:

**Breaking Changes in Concepts**

- `timer_group_t` and `timer_idx_t` which used to identify the hardware timer are removed from user’s code. In the new driver, a timer is represented by `gptimer_handle_t`.
- Definition of timer clock source is moved to `gptimer_clock_source_t`, the previous `timer_src_clk_t` is not used.
- Definition of timer count direction is moved to `gptimer_count_direction_t`, the previous `timer_count_dir_t` is not used.
- Only level interrupt is supported, `timer_intr_t` and `timer_intr_mode_t` are not used.
- Auto-reload is enabled by set the `gptimer_alarm_config_t::auto_reload_on_alarm` flag. `timer_autoreload_t` is not used.

**Breaking Changes in Usage**

- Timer initialization is done by creating a timer instance from `gptimer_new_timer()`. Basic configurations like clock source, resolution and direction should be set in `gptimer_config_t`. Note that, specific configurations of alarm events are not needed during the installation stage of the driver.
Chapter 5. Migration Guides

- Alarm event is configured by `gptimer_set_alarm_action()`, with parameters set in the `gptimer_alarm_config_t`.
- Setting and getting count value are done by `gptimer_get_raw_count()` and `gptimer_set_raw_count()`. The driver doesn’t help convert the raw value into UTC time-stamp. Instead, the conversion should be done from user’s side as the timer resolution is also known to the user.
- The driver will install the interrupt service as well if `gptimer_event_callbacks_t::on_alarm` is set to a valid callback function. In the callback, users do not have to deal with the low level registers (like “clear interrupt status”, “re-enable alarm event” and so on). So functions like `timer_group_get_intr_status_in_isr` and `timer_group_get_auto_reload_in_isr` are not used anymore.
- To update the alarm configurations when alarm event happens, one can call `gptimer_set_alarm_action()` in the interrupt callback, then the alarm will be re-enabled again.
- Alarm will always be re-enabled by the driver if `gptimer_alarm_config_t::auto_reload_on_alarm` is set to true.

### UART

<table>
<thead>
<tr>
<th>Removed/Deprecated items</th>
<th>Replacement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>uart_isr_register()</code></td>
<td>None</td>
<td>UART interrupt handling is implemented by driver itself.</td>
</tr>
<tr>
<td><code>uart_isr_free()</code></td>
<td>None</td>
<td>UART interrupt handling is implemented by driver itself.</td>
</tr>
<tr>
<td><code>use_ref_tick</code> in <code>uart_config_t</code></td>
<td><code>uart_config_t::source_clk</code></td>
<td>Select the clock source.</td>
</tr>
<tr>
<td><code>uart_enable_pattern_det</code> in <code>uart_config_t</code></td>
<td><code>uart_enable_pattern_det_baud_intr()</code></td>
<td>Enable pattern detection interrupt.</td>
</tr>
</tbody>
</table>

### I2C

<table>
<thead>
<tr>
<th>Removed/Deprecated items</th>
<th>Replacement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>i2c_isr_register()</code></td>
<td>None</td>
<td>I2C interrupt handling is implemented by driver itself.</td>
</tr>
<tr>
<td><code>i2c_isr_register()</code></td>
<td>None</td>
<td>I2C interrupt handling is implemented by driver itself.</td>
</tr>
<tr>
<td><code>i2c_opmode_t</code></td>
<td>None</td>
<td>It’s not used anywhere in esp-idf.</td>
</tr>
</tbody>
</table>

### SPI

<table>
<thead>
<tr>
<th>Removed/Deprecated items</th>
<th>Replacement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>spi_cal_clock()</code></td>
<td><code>spi_get_actual_clock()</code></td>
<td>Get SPI real working frequency.</td>
</tr>
</tbody>
</table>

- The internal header file `spi_common_internal.h` has been moved to `esp_private/spi_common_internal.h`.

### SDMMC

<table>
<thead>
<tr>
<th>Removed/Deprecated items</th>
<th>Replacement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>sd_mmc_host_pullup_en()</code></td>
<td><code>set SDMMC_SLOT_FLAG_INTERNAL_PULLUP</code> flag in <code>sd_mmc_slot_config_t::flags</code></td>
<td>Enable internal pull up.</td>
</tr>
</tbody>
</table>

### LEDC

<table>
<thead>
<tr>
<th>Removed/Deprecated items</th>
<th>Replacement</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>bit_num</code> in <code>ledc_timer_config_t</code></td>
<td><code>ledc_timer_config_t::duty_resolution</code></td>
<td>Set resolution of the duty cycle.</td>
</tr>
</tbody>
</table>
**Pulse Counter Driver** Pulse counter driver has been redesigned (see PCNT), which aims to unify and simplify the usage of PCNT peripheral.

Although it’s recommended to use the new driver APIs, the legacy driver is still available in the previous include path `driver/pcnt.h`. However, including `driver/pcnt.h` will trigger the build warning below by default. The warning can be suppressed by the Kconfig option `CONFIG_PCNT_SUPPRESS_DEPRECATED_WARN`.

Legacy pcnt driver is deprecated, please migrate to use driver/pulse_cnt.h

The major breaking changes in concept and usage are listed as follows:

### Breaking Changes in Concepts

- `pcnt_port_t`, `pcnt_unit_t` and `pcnt_channel_t` which used to identify the hardware unit and channel are removed from user’s code. In the new driver, PCNT unit is represented by `pcnt_unit_handle_t`, likewise, PCNT channel is represented by `pcnt_channel_handle_t`. Both of them are opaque pointers.

- `pcnt_evt_type_t` is not used any more, they have been replaced by a universal **Watch Point Event**. In the event callback `pcnt_watch_cb_t`, it’s still possible to distinguish different watch points from `pcnt_watch_event_data_t`.

- `pcnt_count_mode_t` is replaced by `pcnt_channel_edge_action_t`, and `pcnt_ctrl_mode_t` is replaced by `pcnt_channel_level_action_t`.

### Breaking Changes in Usage

- Previously, the PCNT unit configuration and channel configuration were combined into a single function: `pcnt_unit_config`. They are now split into the two factory APIs: `pcnt_new_unit()` and `pcnt_new_channel()` respectively.
  - Only the count range is necessary for initializing a PCNT unit. GPIO number assignment has been moved to `pcnt_new_channel()`.
  - High/Low control mode and positive/negative edge count mode are set by stand-alone functions: `pcnt_channel_set_edge_action()` and `pcnt_channel_set_level_action()`.

- `pcnt_get_counter_value` is replaced by `pcnt_unit_get_count()`.

- `pcnt_counter_pause` is replaced by `pcnt_unit_stop()`.

- `pcnt_counter_resume` is replaced by `pcnt_unit_start()`.

- `pcnt_counter_clear` is replaced by `pcnt_unit_clear_count()`.

- `pcnt_intr_enable` and `pcnt_intr_disable` are removed. In the new driver, the interrupt is enabled by registering event callbacks `pcnt_unit_register_event_callbacks()`.

- `pcnt_event_enable` and `pcnt_event_disable` are removed. In the new driver, the PCNT events are enabled/disabled by adding/removing watch points `pcnt_unit_add_watch_point()`, `pcnt_unit_remove_watch_point()`.

- `pcnt_isr_register` and `pcnt_isr_unregister` are removed. Register of the ISR handler from user’s code is no longer permitted. Users should register event callbacks instead by calling `pcnt_unit_register_event_callbacks()`.

- `pcnt_set_pin` is removed and the new driver no longer allows the switching of the GPIO at runtime. If users want to change to other GPIOs, please delete the existing PCNT channel by `pcnt_del_channel()` and reinstall with the new GPIO number by `pcnt_new_channel()`.

- `pcnt_filter_enable`, `pcnt_filter_disable` and `pcnt_set_filter_value` are replaced by `pcnt_unit_set_glitch_filter()`. Meanwhile, `pcnt_get_filter_value` has been removed.

- `pcnt_set_mode` is replaced by `pcnt_channel_set_edge_action()` and `pcnt_channel_set_level_action()`.

- `pcnt_isr_service_install`, `pcnt_isr_service_uninstall`, `pcnt_isr_handler_add` and `pcnt_isr_handler_remove` are replaced by
pcnt_unit_register_event_callbacks(). The default ISR handler is lazy installed in the new driver.

**RMT Driver**  
RMT driver has been redesigned (see *RMT transceiver*), which aims to unify and extend the usage of RMT peripheral.

Although it’s recommended to use the new driver APIs, the legacy driver is still available in the previous include path `driver/rmt.h`. However, including `driver/rmt.h` will trigger the build warning below by default. The warning can be suppressed by the Kconfig option `CONFIG_RMT_SUPPRESS_DEPRECATE_WARN`.

The legacy RMT driver is deprecated, please use `driver/rmt_tx.h` and/or `driver/rmt_rx.h`.

The major breaking changes in concept and usage are listed as follows:

### Breaking Changes in Concepts

- `rmt_channel_t` which used to identify the hardware channel are removed from user space. In the new driver, RMT channel is represented by `rmt_channel_handle_t`. The channel is dynamically allocated by the driver, instead of designated by user.
- `rtm_item32_t` is replaced by `rmt_symbol_word_t`, which avoids a nested union inside a struct.
- `rtm_mem_t` is removed, as we don’t allow users to access RMT memory block (a.k.a an RMTMEM) directly. Direct access to RMTMEM doesn’t make sense but make mistakes, especially when the RMT channel also connected with a DMA channel.
- `rmt_mem_owner_t` is removed, as the ownership is controlled by driver, not by user anymore.
- `rtm_source_clk_t` is replaced by `rmt_clock_source_t`, and note they’re not binary compatible.
- `rtm_data_mode_t` is removed, the RMT memory access mode is configured to always use Non-FIFO and DMA mode.
- `rtm_mode_t` is removed, as the driver has stand alone install functions for TX and RX channels.
- `rtm_idle_level_t` is removed, setting IDLE level for TX channel is available in `rmt_transmit_config_t::eot_level`.
- `rtm_carrier_level_t` is removed, setting carrier polarity is available in `rmt_carrier_config_t::polarity_active_low`.
- `rtm_channel_status_t` and `rtm_channel_status_result_t` are removed, they’re not used anywhere.
- Transmitting by RMT channel doesn’t expect user to prepare the RMT symbols, instead, user needs to provide an RMT Encoder to tell the driver how to convert user data into RMT symbols.

### Breaking Changes in Usage

- Channel installation has been separated for TX and RX channels into `rmt_new_tx_channel()` and `rmt_new_rx_channel()`.
- `rtm_set_clk_div` and `rtm_get_clk_div` are removed. Channel clock configuration can only be done during channel installation.
- `rtm_set_rx_idle_thresh` and `rtm_get_rx_idle_thresh` are removed. In the new driver, the RX channel IDLE threshold is redesigned into a new concept `rmt_receive_config_t::signal_range_max_ns`.
- `rtm_set_mem_block_num` and `rtm_get_mem_block_num` are removed. In the new driver, the memory block number is determined by `rmt_tx_channel_config_t::mem_block_symbols` and `rmt_rx_channel_config_t::mem_block_symbols`.
- `rtm_set_tx_carrier` is removed, the new driver uses `rmt_apply_carrier()` to set carrier behavior.
- `rtm_set_mem_pd` and `rtm_get_mem_pd` are removed. The memory power is managed by the driver automatically.
- `rtm_memory_rw_rst`, `rtm_tx_memory_reset` and `rtm_rx_memory_reset` are removed. Memory reset is managed by the driver automatically.
- `rtm_tx_start` and `rtm_rx_start` are merged into a single function `rmt_enable()`, for both TX and RX channels.
• `rmt_tx_stop` and `rmt_rx_stop` are merged into a single function `rmt_disable()`, for both TX and RX channels.
• `rmt_set_memory_owner` and `rmt_get_memory_owner` are removed. RMT memory owner guard is added automatically by the driver.
• `rmt_set_tx_loop_mode` and `rmt_get_tx_loop_mode` are removed. In the new driver, the loop mode is configured in `rmt_transmit_config_t::loop_count`.
• `rmt_set_source_clk` and `rmt_get_source_clk` are removed. Configuring clock source is only possible during channel installation by `rmt_tx_channel_config_t::clk_src` and `rmt_rx_channel_config_t::clk_src`.
• `rmt_set_rx_filter` is removed. In the new driver, the filter threshold is redesigned into a new concept `rmt_receive_config_t::signal_range_min_ns`.
• `rmt_set_idle_level` and `rmt_get_idle_level` are removed. Setting IDLE level for TX channel is available in `rmt_transmit_config_t::eot_level`.
• `rmt_set_rx_intr_en`, `rmt_set_err_intr_en`, `rmt_set_tx_intr_en`, `rmt_set_tx_thr_intr_en` and `rmt_set_rx_thr_intr_en` are removed. The new driver doesn’t allow user to turn on/off interrupt from user space. Instead, it provides callback functions.
• `rmt_set_gpio` and `rmt_set_pin` are removed. The new driver doesn’t support to switch GPIO dynamically at runtime.
• `rmt_config` is removed. In the new driver, basic configuration is done during the channel installation stage.
• `rmt_isr_register` and `rmt_isr_deregister` are removed, the interrupt is allocated by the driver itself.
• `rmt_driver_install` is replaced by `rmt_new_tx_channel()` and `rmt_new_rx_channel()`.
• `rmt_driver_uninstall` is replaced by `rmt_del_channel()`.
• `rmt_fill_tx_items`, `rmt_write_items` and `rmt_write_sample` are removed. In the new driver, user needs to provide an encoder to “translate” the user data into RMT symbols.
• `rmt_get_counter_clock` is removed, as the channel clock resolution is configured by user from `rmt_tx_channel_config_t::resolution_hz`.
• `rmt_wait_tx_done` is replaced by `rmt_tx_wait_all_done()`.
• `rmt_translator_init`, `rmt_translator_set_context` and `rmt_translator_get_context` are removed. In the new driver, the translator has been replaced by the RMT encoder.
• `rmt_get_ringbuf_handle` is removed. The new driver doesn’t use Ringbuffer to save RMT symbols. Instead, the incoming data are saved to the user provided buffer directly. The user buffer can even be mounted to DMA link internally.
• `rmt_register_tx_end_callback` is replaced by `rmt_tx_register_event_callbacks()`, where user can register `rmt_tx_event_callbacks_t::on_trans_done` event callback.
• `rmt_set_intr_enable_mask` and `rmt_clr_intr_enable_mask` are removed, as the interrupt is handled by the driver, user doesn’t need to take care of it.
• `rmt_add_channel_to_group` and `rmt_remove_channel_from_group` are replaced by RMT sync manager. Please refer to `rmt_new_sync_manager()`.
• `rmt_set_tx_loop_count` is removed. The loop count in the new driver is configured in `rmt_transmit_config_t::loop_count`.
• `rmt_enable_tx_loop_autostop` is removed. In the new driver, TX loop auto stop is always enabled if available, it’s not configurable anymore.

**LCD**

The LCD panel initialization flow is slightly changed. Now the `esp_lcd_panel_init()` won’t turn on the display automatically. User needs to call `esp_lcd_panel_disp_on_off()` to manually turn on the display. Note, this is different from turning on backlight. With this breaking change, user can flash a predefined pattern to the screen before turning on the screen. This can help avoid random noise on the screen after a power on reset.

`esp_lcd_panel_disp_off()` is deprecated, please use `esp_lcd_panel_disp_on_off()` instead.

`dc_as_cmd_phase` is removed. The SPI LCD driver currently doesn’t support a 9-bit SPI LCD. Please always use a dedicated GPIO to control the LCD D/C line.

The way to register RGB panel event callbacks has been moved from the `esp_lcd_rgb_panel_config_t` into a separate API
Chapter 5. Migration Guides

- `esp_lcd_rgb_panel_register_event_callbacks()`. However, the event callback signature is not changed.
- Previous `relax_on_idle` flag in `esp_lcd_rgb_panel_config_t` has been renamed into `esp_lcd_rgb_panel_config_t::refresh_on_demand`, which expresses the same meaning but with a clear name.
- If the RGB LCD is created with the `refresh_on_demand` flag enabled, the driver will not start a refresh in the `esp_lcd_panel_draw_bitmap()`. Now users have to call `esp_lcd_rgb_panel_refresh()` to refresh the screen by themselves.
- `esp_lcd_color_space_t` is deprecated, please use `lcd_color_space_t` to describe the color space, and use `lcd_rgb_element_order_t` to describe the data order of RGB color.

**MCPWM** MCPWM driver was redesigned (see MCPWM), meanwhile, the legacy driver is deprecated.

The new driver’s aim is to make each MCPWM submodule independent to each other, and give the freedom of resource connection back to users.

Although it’s recommended to use the new driver APIs, the legacy driver is still available in the previous include path `driver/mcpwm.h`. However, using legacy driver will rigger the build warning below by default. This warning can be suppressed by the Kconfig option `CONFIG_MCPWM_SUPPRESS_DEPRECATE_WARN`.

```
legacy MCPWM driver is deprecated, please migrate to the new driver (include...
<driver/mcpwm_prelude.h)
```

The major breaking changes in concept and usage are listed as follows:

**Breaking Changes in Concepts** The new MCPWM driver is object-oriented, where most of the MCPWM submodule has a driver object associated with it. The driver object is created by factory function like `mcpwm_new_timer()`. IO control function always needs an object handle, in the first place.

The legacy driver has an inappropriate assumption, that is the MCPWM operator should be connected to different MCPWM timer. In fact, the hardware doesn’t have such limitation. In the new driver, a MCPWM timer can be connected to multiple operators, so that the operators can achieve the best synchronization performance.

The legacy driver presets the way to generate a PWM waveform into a so called `mcpwm_duty_type_t`. However, the duty cycle modes listed there are far from sufficient. Likewise, legacy driver has several preset `mcpwm_deadtime_type_t`, which also doesn’t cover all the use cases. What’s more, user usually gets confused by the name of the duty cycle mode and dead-time mode. In the new driver, there’s no such limitation, but user has to construct the generator behavior from scratch.

In the legacy driver, the ways to synchronize the MCPWM timer by GPIO, software and other timer module are not unified. It increased learning costs for users. In the new driver, the synchronization APIs are unified.

The legacy driver has mixed the concepts of “Fault detector” and “Fault handler”. Which make the APIs very confusing to users. In the new driver, the fault object just represents a failure source, and we introduced a new concept – brake to express the concept of “Fault handler”. What’s more, the new driver supports software fault.

The legacy driver only provides callback functions for the capture submodule. The new driver provides more useful callbacks for various MCPWM submodules, like timer stop, compare match, fault enter, brake, etc.

- `mcpwm_io_signals_t` and `mcpwm_pin_config_t` are not used. GPIO configuration has been moved into submodule’s configuration structure.
- `mcpwm_timer_t`, `mcpwm_generator_t` are not used. Timer and generator are represented by `mcpwm_timer_handle_t` and `mcpwm_gen_handle_t`.
- `mcpwm_fault_signal_t` and `mcpwm_sync_signal_t` are not used. Fault and sync source are represented by `mcpwm_fault_handle_t` and `mcpwm_sync_handle_t`.
- `mcpwm_capture_signal_t` is not used. A capture channel is represented by `mcpwm_cap_channel_handle_t`.

**Breaking Changes in Usage**
• `mcpwm_gpio_init` and `mcpwm_set_pin`: GPIO configurations are moved to submodule’s own configuration. e.g. set the PWM GPIO in `mcpwm_generator_config_t::gen_gpio_num`.
• `mcpwm_init`: To get an expected PWM waveform, users need to allocated at least one MCPWM timer and MCPWM operator, then connect them by calling `mcpwm_operator_connect_timer()`. After that, users should set the generator’s actions on various events by calling e.g. `mcpwm_generator_set_actions_on_timer_event()`, `mcpwm_generator_set_actions_on_compare_event()`.
• `mcpwm_group_set_resolution`: in the new driver, the group resolution is fixed to the maximum, usually it’s 80MHz.
• `mcpwm_timer_set_resolution`: MCPWM Timer resolution is set in `mcpwm_timer_config_t::resolution_hz`.
• `mcpwm_set_frequency`: PWM frequency is determined by `mcpwm_timer_config_t::resolution_hz`, `mcpwm_timer_config_t::count_mode` and `mcpwm_timer_config_t::period_ticks`.
• `mcpwm_set_duty`: To set the PWM duty cycle, users should call `mcpwm_comparator_set_compare_value()` to change comparator’s threshold.
• `mcpwm_set_duty_type`: There won’t be any preset duty cycle types, the duty cycle type is configured by setting different generator actions. e.g. `mcpwm_generator_set_actions_on_timer_event()`.
• `mcpwm_set_signal_high` and `mcpwm_set_signal_low` are replaced by `mcpwm_generator_set_force_level()`. In the new driver, it’s implemented by setting force action for the generator, instead of changing the duty cycle to 0% or 100% at the background.
• `mcpwm_start` and `mcpwm_stop` are replaced by `mcpwm_timer_start_stop()`. You have more modes to start and stop the MCPWM timer, see `mcpwm_timer_start_stop_cmd_t`.
• `mcpwm_carrier_init` is replaced by `mcpwm_operator_apply_carrier()`.
• `mcpwm_carrier_enable` and `mcpwm_carrier_disable`: Enabling and disabling carrier submodule is done automatically by checking whether the carrier configuration structure `mcpwm_carrier_config_t` is NULL.
• `mcpwm_carrier_set_period` is replaced by `mcpwm_carrier_config_t::frequency_hz`.
• `mcpwm_carrier_set_duty_cycle` is replaced by `mcpwm_carrier_config_t::duty_cycle`.
• `mcpwm_carrier_oneshot_mode_enable` is replaced by `mcpwm_carrier_config_t::first_pulse_duration_us`.
• `mcpwm_carrier_oneshot_mode_disable` is removed. Disabling the first pulse (a.k.a the one-shot pulse) in the carrier is never supported by the hardware.
• `mcpwm_carrier_output_invert` is replaced by `mcpwm_carrier_config_t::invert_before_modulate` and `mcpwm_carrier_config_t::invert_after_modulate`.
• `mcpwm_capture_enable` and `mcpwm_capture_disable` are removed. It’s duplicated to `mcpwm_capture_enable_channel()`.
• `mcpwm_capture_signal_get_value` and `mcpwm_capture_signal_get_edge` are provided in the capture event callback, via `mcpwm_capture_event_data_t`. Capture data are only valuable when capture event happens. Providing single API to fetch capture data is meaningless.
• `mcpwm_sync_enable` is removed. It’s duplicated to `mcpwm_syncConfigure()`.
• `mcpwmroscope_set_source`: MCPWM sync source is set in `mcpwm_timer_config_t::sync_src`
• `mcpwm_timer_start_sync_output` is replaced by `mcpwm_new_timer_sync_src()`.
• `mcpwm_timer_triggerソフト_sync` is replaced by `mcpwm_soft_sync_activate()`.
• `mcpwm_isr_register` is removed. You can register various event callbacks instead. For example, to register capture event callback, users can use `mcpwm_capture_channel_register_event_callbacks()`.
I2S driver  The I2S driver has been redesigned (see I2S Driver), which aims to rectify the shortcomings of the driver that were exposed when supporting all the new features of ESP32-C3 & ESP32-S3. The new driver’s APIs are available by including corresponding I2S mode’s header files driver/i2s/include/driver/i2s_std.h, driver/i2s/include/driver/i2s_pdm.h, or driver/i2s/include/driver/i2s_tdm.h.

Meanwhile, the old driver’s APIs in driver/deprecated/driver/i2s.h are still supported for backward compatibility. But there will be warnings if users keep using the old APIs in their projects, these warnings can be suppressed by the Kconfig option CONFIG_I2S_SUPPRESS_DEPRECATE_WARN.

Here is the general overview of the current I2S files:

Breaking changes in Concepts

Independent TX/RX channels  The minimum control unit in new I2S driver are now individual TX/RX channels instead of an entire I2S controller (that consists of multiple channels).

- The TX and RX channels of the same I2S controller can be controlled separately, meaning that they are configured such that they can be started or stopped separately.
- The c-type: i2s_chan_handle_t handle type is used to uniquely identify I2S channels. All the APIs will require the channel handle and users need to maintain the channel handles by themselves.
- On the ESP32-C3 and ESP32-S3, TX and RX channels in the same controller can be configured to different clocks or modes.
- However, on the ESP32 and ESP32-S2, the TX and RX channels of the same controller still share some hardware resources. Thus, configurations may cause one channel to affect another channel in the same controller.
- The channels can be registered to an available I2S controller automatically by setting i2s_port_t::I2S_NUM_AUTO as I2S port ID which will cause the driver to search for the available TX/RX channels. However, the driver also supports registering channels to a specific port.
- In order to distinguish between TX/RX channels and sound channels, the term ‘channel’ in the context of the I2S driver will only refer to TX/RX channels. Meanwhile, sound channels will be referred to as “slots”.

I2S Mode Categorization  I2S communication modes are categorized into the following three modes. Note that:

- **Standard mode**: Standard mode always has two slots, it can support Philips, MSB, and PCM (short frame sync) formats. Please refer to driver/i2s/include/driver/i2s_std.h for more details.
- **PDM mode**: PDM mode only supports two slots with 16-bit data width, but the configurations of PDM TX and PDM RX are slightly different. For PDM TX, the sample rate
can be set by `i2s_pdm_tx_clk_config_t::sample_rate`, and its clock frequency depends on the up-sampling configuration. For PDM RX, the sample rate can be set by `i2s_pdm_rx_clk_config_t::sample_rate`, and its clock frequency depends on the down-sampling configuration. Please refer to `driver/i2s/include/driver/i2s_pdm.h` for details.

- **TDM mode**: TDM mode can support up to 16 slots. It can work in Philips, MSB, PCM (short frame sync), and PCM (long frame sync) formats. Please refer to `driver/i2s/include/driver/i2s_tdm.h` for details.

When allocating a new channel in a specific mode, users should initialize that channel by its corresponding function. It is strongly recommended to use the helper macros to generate the default configurations in case the default values are changed in the future.

**Independent Slot and Clock Configuration**

The slot configurations and clock configurations can be configured separately.

- Call `i2s_channel_init_std_mode()`, `i2s_channel_init_pdm_rx_mode()`, `i2s_channel_init_pdm_tx_mode()`, or `i2s_channel_init_tdm_mode()` to initialize the slot/clock/gpio pin configurations.
- Calling `i2s_channel_reconfig_std_slot()`, `i2s_channel_reconfig_pdm_rx_slot()`, `i2s_channel_reconfig_pdm_tx_slot()`, or `i2s_channel_reconfig_tdm_slot()` can change the slot configurations after initialization.
- Calling `i2s_channel_reconfig_std_clock()`, `i2s_channel_reconfig_pdm_rx_clock()`, `i2s_channel_reconfig_pdm_tx_clock()`, or `i2s_channel_reconfig_tdm_clock()` can change the clock configurations after initialization.
- Calling `i2s_channel_reconfig_std_gpio()`, `i2s_channel_reconfig_pdm_rx_gpio()`, `i2s_channel_reconfig_pdm_tx_gpio()`, or `i2s_channel_reconfig_tdm_gpio()` can change the GPIO configurations after initialization.

**Misc**

- States and state-machine are adopted in the new I2S driver to avoid APIs called in wrong state.
- ADC and DAC modes are removed. They will only be supported in their own drivers and the legacy I2S driver.

**Breaking Changes in Usage**

To use the new I2S driver, please follow these steps:

1. **Call `i2s_new_channel()` to acquire channel handles.** We should specify the work role and I2S port in this step. Besides, the TX or RX channel handle will be generated by the driver. Inputting both two TX and RX channel handles is not necessary but at least one handle is needed. In the case of inputting both two handles, the driver will work at the duplex mode. Both TX and RX channels will be available on a same port, and they will share the MCLK, BCLK and WS signal. But if only one of the TX or RX channel handle is inputted, this channel will only work in the simplex mode.

2. **Call `i2s_channel_init_std_mode()`, `i2s_channel_init_pdm_rx_mode()`, `i2s_channel_init_pdm_tx_mode()` or `i2s_channel_init_tdm_mode()` to initialize the channel to the specified mode.** Corresponding slot, clock and GPIO configurations are needed in this step.

3. **(Optional) Call `i2s_channel_register_event_callback()` to register the ISR event callback functions.** I2S events now can be received by the callback function synchronously, instead of from the event queue asynchronously.

4. **Call `i2s_channel_enable()` to start the hardware of I2S channel.** In the new driver, I2S won’t start automatically after installed, and users are supposed to know clearly whether the channel has started or not.

5. **Read or write data by `i2s_channel_read()` or `i2s_channel_write()`**. Certainly, only the RX channel handle is supposed to be inputted in `i2s_channel_read()` and the TX channel handle in `i2s_channel_write()`.

6. **(Optional) The slot, clock and GPIO configurations can be changed by corresponding ‘reconfig’ functions, but `i2s_channel_disable()` must be called before updating the configurations.**

7. **Call `i2s_channel_disable()` to stop the hardware of I2S channel.**

8. **Call `i2s_del_channel()` to delete and release the resources of the channel if it is not needed any more, but the channel must be disabled before deleting it.**
TWAI Driver  The deprecated CAN peripheral driver is removed. Please use TWAI driver instead (i.e., include driver/twai.h in your application).

Register Access Macros  Previously, all register access macros could be used as expressions, so the following was allowed:

```c
uint32_t val = REG_SET_BITS(reg, mask);
```

In ESP-IDF v5.0, register access macros which write or read-modify-write the register can no longer be used as expressions, and can only be used as statements. This applies to the following macros: REG_WRITE, REG_SET_BIT, REG_CLR_BIT, REG_SET_BITS, REG_SET_FIELD, WRITE_PERI_REG, CLEAR_PERI_REG_MASK, SET_PERI_REG_MASK, SET_PERI_REG_BITS.

To store the value which would have been written into the register, split the operation as follows:

```c
uint32_t new_val = REG_READ(reg) | mask;
REG_WRITE(reg, new_val);
```

To get the value of the register after modification (which may be different from the value written), add an explicit read:

```c
REG_SET_BITS(reg, mask);
uint32_t new_val = REG_READ(reg);
```

Protocols

Mbed TLS  For ESP-IDF v5.0, Mbed TLS has been updated from v2.x to v3.1.0.

For more details about Mbed TLS’ s migration from version 2.x to version 3.0 or greater, please refer to the official guide.

Breaking Changes (Summary)

Most structure fields are now private

- Direct access to fields of structures (struct types) declared in public headers is no longer supported.
- Appropriate accessor functions (getter/setter) must be used for the same. A temporary workaround would be to use MBEDTLS_PRIVATE macro (not recommended).
- For more details, refer to the official guide.

SSL

- Removed support for TLS 1.0, 1.1, and DTLS 1.0
- Removed support for SSL 3.0

Deprecated Functions Were Removed from Cryptography Modules

- The functions mbedtls_*_ret () (related to MD, SHA, RIPEMD, RNG, HMAC modules) was renamed to replace the corresponding functions without _ret appended and updated return value.
- For more details, refer to the official guide.
Deprecated Config Options  Following are some of the important config options deprecated by this update. The configs related to and/or dependent on these have also been deprecated.

- **MBEDTLS_SSL_PROTO_SSL3**: Support for SSL 3.0
- **MBEDTLS_SSL_PROTO_TLS1**: Support for TLS 1.0
- **MBEDTLS_SSL_PROTO_TLS1_1**: Support for TLS 1.1
- **MBEDTLS_SSL_PROTO_DTLS**: Support for DTLS 1.1 (Only DTLS 1.2 is supported now)
- **MBEDTLS_DES_C**: Support for 3DES ciphersuites
- **MBEDTLS_RC4_MODE**: Support for RC4-based ciphersuites

**Note:** This list includes only major options configurable through `idf.py menuconfig`. For more details on deprecated options, refer to the [official guide](https://docs.espressif.com/en/develop/).  

Miscellaneous

Disabled Diffie-Hellman Key Exchange Modes  The Diffie-Hellman Key Exchange modes have now been disabled by default due to security risks (see warning text [here](https://docs.espressif.com/en/develop/)). Related configs are given below:

- **MBEDTLS_DHM_C**: Support for the Diffie-Hellman-Merkle module
- **MBEDTLS_KEY_EXCHANGE_DHE_PSK**: Support for Diffie-Hellman PSK (pre-shared-key) TLS authentication modes
- **MBEDTLS_KEY_EXCHANGE_DHE_RSA**: Support for cipher suites with the prefix `TLS-DHE-RSA-WITH-`

**Note:** During the initial step of the handshake (i.e. `client_hello`), the server selects a cipher from the list that the client publishes. As the DHE_PSK/DHE_RSA ciphers have now been disabled by the above change, the server would fall back to an alternative cipher; if in a rare case, it does not support any other cipher, the handshake would fail. To retrieve the list of ciphers supported by the server, one must attempt to connect with the server with a specific cipher from the client-side. Few utilities can help do this, e.g. `sslscan`.

Remove certs Module from X509 Library

- The `mbedtls/certs.h` header is no longer available in mbedts 3.1. Most applications can safely remove it from the list of includes.

Breaking Change for `esp_crt_bundle_set` API

- The `esp_crt_bundle_set()` API now requires one additional argument named `bundle_size`. The return type of the API has also been changed to `esp_err_t` from `void`.

Breaking Change for `esp_ds_rsa_sign` API

- The `esp_ds_rsa_sign()` API now requires one less argument. The argument `mode` is no longer required.

HTTPS Server

Breaking Changes (Summary)  Names of variables holding different certs in `httpd_ssl_config_t` structure have been updated.

- `httpd_ssl_config::servercert` variable inherits role of `cacert_pem` variable.
- `httpd_ssl_config::servercert_len` variable inherits role of `cacert_len` variable
- `httpd_ssl_config::cacert_pem` variable inherits role of `client_verify_cert_pem` variable
Chapter 5. Migration Guides

- `httpd_ssl_config::cacert_len` variable inherits role of `client_verify_cert_len` variable

The return type of the `httpd_ssl_stop()` API has been changed to `esp_err_t` from `void`.

ESP HTTPS OTA

Breaking Changes (Summary)

- The function `esp_https_ota()` now requires pointer to `esp_https_ota_config_t` as argument instead of pointer to `esp_http_client_config_t`.

ESP-TLS

Breaking Changes (Summary)

`esp_tls_t` Structure is Now Private  The `esp_tls_t` has now been made completely private. You cannot access its internal structures directly. Any necessary data that needs to be obtained from the ESP-TLS handle can be done through respective getter/setter functions. If there is a requirement of a specific getter/setter function, please raise an issue on ESP-IDF.

The list of newly added getter/setter function is as follows:

- `esp_tls_get_ssl_context()` - Obtain the ssl context of the underlying ssl stack from the ESP-TLS handle.

Function Deprecations And Recommended Alternatives  Following table summarizes the deprecated functions removed and their alternatives to be used from ESP-IDF v5.0 onwards.

<table>
<thead>
<tr>
<th>Deprecated Function</th>
<th>Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>esp_tls_conn_new()</code></td>
<td><code>esp_tls_conn_new_sync()</code></td>
</tr>
<tr>
<td><code>esp_tls_conn_delete()</code></td>
<td><code>esp_tls_conn_destroy()</code></td>
</tr>
</tbody>
</table>

- The function `esp_tls_conn_http_new()` has now been termed as deprecated. Please use the alternative function `esp_tls_conn_http_new_sync()` (or its asynchronous `esp_tls_conn_http_new_async()`). Note that the alternatives need an additional parameter `esp_tls_t`, which has to be initialized using the `esp_tls_init()` function.

HTTP Server

Breaking Changes (Summary)

- `http_server.h` header is no longer available in `esp_http_server`. Please use `esp_http_server.h` instead.

ESP HTTP Client

Breaking Changes (Summary)

- The functions `esp_http_client_read()` and `esp_http_client_fetch_headers()` now return an additional return value -ESP_ERR_HTTP_EAGAIN for timeout errors - call timed-out before any data was ready.
TCP Transport

Breaking Changes (Summary)

- The function `esp_transport_read()` now returns 0 for a connection timeout and < 0 for other errors. Please refer `esp_tcp_transport_err_t` for all possible return values.

MQTT Client

Breaking Changes (Summary)

- `esp_mqtt_client_config_t` have all fields grouped in sub structs.

Most common configurations are listed below:

- Broker address now is set in `esp_mqtt_client_config_t::broker::address::uri`
- Security related to broker verification in `esp_mqtt_client_config_t::broker::verification`
- Client username is set in `esp_mqtt_client_config_t::credentials::username`
- `esp_mqtt_client_config_t` no longer supports the `user_context` field. Please use `esp_mqtt_client_register_event()` instead for registering an event handler; the last argument `event_handler_arg` can be used to pass user context to the handler.

ESP-Modbus

Breaking Changes (Summary)  The ESP-IDF component `freemodbus` has been removed from ESP-IDF and is supported as a separate component. Additional information for the ESP-Modbus component can be found in the separate repository:

- ESP-Modbus component on GitHub

The main component folder of the new application shall include the component manager manifest file `idf_component.yml` as in the example below:

```yaml
dependencies:
  espresif/esp-modbus:
    version: "^1.0"
```

The `esp-modbus` component can be found in component manager registry. Refer to component manager documentation for more information on how to set up the component manager.

For applications targeting v4.x releases of ESP-IDF that need to use new `esp-modbus` component, adding the component manager manifest file `idf_component.yml` will be sufficient to pull in the new component. However, users should also exclude the legacy `freemodbus` component from the build. This can be achieved using the statement below in the project’s `CMakeLists.txt`:

```cmake
set(EXCLUDE_COMPONENTS freemodbus)
```

Provisioning

Protocomm  The `pop` field in the `protocomm_set_security()` API is now deprecated. Please use the `sec_params` field instead of `pop`. This parameter should contain the structure (including the security parameters) as required by the protocol version used.

For example, when using security version 2, the `sec_params` parameter should contain the pointer to the structure of type `protocomm_security2_params_t`. 
Wi-Fi Provisioning

- The `pop` field in the `wifi_prov_mgr_start_provisioning()` API is now deprecated. For backward compatibility, `pop` can be still passed as a string for security version 1. However, for security version 2, the `wifi_prov_sec_params` argument needs to be passed instead of `pop`. This parameter should contain the structure (containing the security parameters) as required by the protocol version used. For example, when using security version 2, the `wifi_prov_sec_params` parameter should contain the pointer to the structure of type `wifi_prov_security2_params_t`. For security 1, the behaviour and the usage of the API remain the same.

- The API `wifi_prov_mgr_is_provisioned()` does not return `ESP_ERR_INVALID_STATE` error any more. This API now works without any dependency on provisioning manager initialization state.

ESP Local Control

The `pop` field in the `esp_local_ctrl_proto_sec_cfg_t` API is now deprecated. Please use the `sec_params` field instead of `pop`. This field should contain the structure (containing the security parameters) as required by the protocol version used.

For example, when using security version 2, the `sec_params` field should contain pointer to the structure of type `esp_local_ctrl_security2_params_t`.

Removed or Deprecated Components

Components Moved to IDF Component Registry

Following components are removed from ESP-IDF and moved to IDF Component Registry:

- libsodium
- cbor
- jsmn
- esp_modem
- nghttp
- mdns
- esp_websocket_client
- asio
- freemodbus
- sh2lib
- expat
- coap
- esp-cryptoauthlib
- qrcode
- tjpgd
- esp_serial_slave_link
- tinyusb

Note: Please note that http parser functionality which was previously part of `nghttp` component is now part of `http_parser` component.

These components can be installed using `idf.py add-dependency` command.

For example, to install libsodium component with the exact version X.Y, run `idf.py add-dependency libsodium==X.Y`.

To install libsodium component with the latest version compatible to X.Y according to semver rules, run `idf.py add-dependency libsodium~X.Y`.

To find out which versions of each component are available, open `https://components.espressif.com`, search for the component by its name and check the versions listed on the component page.
Chapter 5. Migration Guides

Deprecated Components  The following components are removed since they were deprecated in IDF v4.x:

- tcpip_adapter. Please use the ESP-NETIF component instead; you can follow the TCP/IP Adapter.

**Note:** OpenSSL-API component is no longer supported. It is not available in the IDF Component Registry, either. Please use ESP-TLS or mbedtls API directly.

**Note:** esp_adc_cal component is no longer supported. New adc calibration driver is in esp_adc component. Legacy adc calibration driver has been moved into esp_adc component. To use legacy esp_adc_cal driver APIs, you should add esp_adc component to the list of component requirements in CMakeLists.txt. Also check Peripherals Migration Guide for more details.

The targets components are no longer necessary after refactoring and have been removed:

- esp32
- esp32s2
- esp32s3
- esp32c2
- esp32c3
- esp32h2

Storage

New Component for the Partition APIs  Breaking change: all the Partition API code has been moved to a new component esp_partition. For the complete list of affected functions and data-types, see header file esp_partition.h.

These API functions and data-types were previously a part of the spi_flash component, and thus possible dependencies on the spi_flash in existing applications may cause the build failure, in case of direct esp_partition_* APIs/data-types use (for instance, fatal error: esp_partition.h: No such file or directory at lines with #include "esp_partition.h"). If you encounter such an issue, please update your project’s CMakeLists.txt file as follows:

Original dependency setup:

```c
idf_component_register(...
  REQUIREES spi_flash)
```

Updated dependency setup:

```c
idf_component_register(...
  REQUIREES spi_flash esp_partition)
```

**Note:** Please update relevant REQUIREES or PRIV_REQUIREES section according to your project. The above-presented code snippet is just an example.

If the issue persists, please let us know and we will assist you with your code migration.

SDMMC/SDSPI  SD card frequency on SDMMC/SDSPI interface can be now configured through sdmmc_host_t.max_freq_khz to a specific value, not only SDMMC_FREQ_PROBING (400 kHz), SDMMC_FREQ_DEFAULT (20 MHz), or SDMMC_FREQ_HIGHSPEED (40 MHz). Previously, in case you have specified a custom frequency other than any of the above-mentioned values, the closest lower-or-equal one was selected anyway.

Now, the underlaying drivers calculate the nearest fitting value, given by available frequency dividers instead of an enumeration item selection. This could cause troubles in communication with your SD card without a change of the existing application code. If you encounter such an issue, please, keep trying different frequencies around your desired
value unless you find the one working well. To check the frequency value calculated and actually applied, use void
sdmmc_card_print_info(FILE* stream, const sdmmc_card_t* card) function.

**FatFs** FatFs is now updated to v0.14. As a result, the function signature of \f_mkfs() has changed. The new
signature is \FRESULT\ \f_mkfs(const TCHAR* path, const MKFS_PARM* opt, void* work, UINT len); which uses MKFS_PARM struct as a second argument.

**Partition Table** The partition table generator no longer supports misaligned partitions. When generating a partition
table, ESP-IDF only accepts partitions with offsets that align to 4 KB. This change only affects generating new
partition tables. Reading and writing to already existing partitions remains unchanged.

**VFS** The esp_vfs_semihost_register() function signature is changed as follows:
- The new signature is esp_err_t esp_vfs_semihost_register(const char* base_path);
- The host_path parameter of the old signature no longer exists. Instead, the OpenOCD command
ESP_SEMIHOST_BASEDIR should be used to set the full path on the host.

**Function Signature Changes** The following functions now return \esp_err_t instead of void or
nvs_iterator_t. Previously, when parameters were invalid or when something goes wrong internally, these
functions would assert() or return a nullptr. With an esp_err_t returned, you can get better error report-
ing.

- nvs_entry_find()
- nvs_entry_next()
- nvs_entry_info()

Because the esp_err_t return type changes, the usage patterns of nvs_entry_find() and
nvs_entry_next() become different. Both functions now modify iterators via parameters instead of
returning an iterator.

The old programming pattern to iterate over an NVS partition was as follows:

```
nvs_iterator_t it = nvs_entry_find(<nvs_partition_name>, <namespace>, NVS_TYPE_-
ANY);
while (it != NULL) {
    nvs_entry_info_t info;
    nvs_entry_info(it, &info);
    it = nvs_entry_next(it);
    printf("key '%s', type '%d'", info.key, info.type);
}
```

The new programming pattern to iterate over an NVS partition is now:

```
nvs_iterator_t it = nullptr;
esp_err_t res = nvs_entry_find(<nvs_partition_name>, <namespace>, NVS_TYPE_ANY, &-
it);
while (res == ESP_OK) {
    nvs_entry_info_t info;
    nvs_entry_info(it, &info); // Can omit error check if parameters are-
guaranteed to be non-NULL
    printf("key '%s', type '%d'", info.key, info.type);
    res = nvs_entry_next(&it);
}
nvs_release_iterator(it);
```

**Iterator Validity** Note that because the function signature changes, if there is a parameter error, you
may get an invalid iterator from nvs_entry_find(). Hence, it is important to initialize the iterator
to NULL before using nvs_entry_find(), so that you can avoid complex error checking before calling nvs_release_iterator(). A good example is the programming pattern above.

### Removed SDSPI Deprecated API

Structure sdspi_slot_config_t and function sdspi_host_init_slot() are removed, and replaced by structure sdspi_device_config_t and function sdspi_host_init_device() respectively.

### ROM SPI Flash

In versions before v5.0, ROM SPI flash functions were included via esp32**/rom/spi_flash.h. Thus, code written to support different ESP chips might be filled with ROM headers of different targets. Furthermore, not all of the APIs could be used on all ESP chips.

Now, the common APIs are extracted to esp_rom_spiflash.h. Although it is not a breaking change, you are strongly recommended to only use the functions from this header (i.e., prefixed with esp_rom_spiflash and included by esp_rom_spiflash.h) for better cross-compatibility between ESP chips.

To make ROM SPI flash APIs clearer, the following functions are also renamed:

- esp_rom_spiflash_lock() to esp_rom_spiflash_set_bp()
- esp_rom_spiflash_unlock() to esp_rom_spiflash_clear_bp()

### SPI Flash Driver

The esp_flash_speed_t enum type is now deprecated. Instead, you may now directly pass the real clock frequency value to the flash configuration structure. The following example demonstrates how to configure a flash frequency of 80MHz:

```c
esp_flash_spi_device_config_t dev_cfg = {
    // Other members
    .freq_mhz = 80,
    // Other members
};
```

### Legacy SPI Flash Driver

To make SPI flash drivers more stable, the legacy SPI flash driver is removed from v5.0. The legacy SPI flash driver refers to default spi_flash driver since v3.0, and the SPI flash driver with configuration option CONFIG_SPI_FLASH_USE_LEGACY_IMPL enabled since v4.0. The major breaking change here is that the legacy spi_flash driver is no longer supported from v5.0. Therefore, the legacy driver APIs and the CONFIG_SPI_FLASH_USE_LEGACY_IMPL configuration option are both removed. Please use the new spi_flash driver’s APIs instead.

<table>
<thead>
<tr>
<th>Removed items</th>
<th>Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>spi_flash_erase_sector()</td>
<td>esp_flash_erase_region()</td>
</tr>
<tr>
<td>spi_flash_erase_range()</td>
<td>esp_flash_erase_region()</td>
</tr>
<tr>
<td>spi_flash_write()</td>
<td>esp_flash_write()</td>
</tr>
<tr>
<td>spi_flash_read()</td>
<td>esp_flash_read()</td>
</tr>
<tr>
<td>spi_flash_write_encrypted()</td>
<td>esp_flash_write_encrypted()</td>
</tr>
<tr>
<td>spi_flash_read_encrypted()</td>
<td>esp_flash_read_encrypted()</td>
</tr>
</tbody>
</table>

**Note:** New functions with prefix esp_flash accept an additional esp_flash_t* parameter. You can simply set it to NULL. This will make the function to run the main flash (esp_flash_default_chip).

The esp_spi_flash.h header is deprecated as system functions are no longer public. To use flash memory mapping APIs, you may include spi_flash_mmap.h instead.

### System
Inter-Processor Call

IPC (Inter-Processor Call) feature is no longer a stand-alone component and has been integrated into the `esp_system` component.

Thus, any project presenting a `CMakeLists.txt` file with the parameters `PRIV_REQUIRES esp_ipc` or `REQUIRES esp_ipc` should be modified to simply remove these options as the `esp_system` component is included by default.

ESP Clock

The ESP Clock API (functions/types/macros prefixed with `esp_clk`) has been made into a private API. Thus, the previous include paths `#include "ESP32/clk.h"` and `#include "esp_clk.h"` have been removed. If users still require usage of the ESP Clock API (though this is not recommended), it can be included via `#include "esp_private/esp_clk.h"`.

Note: Private APIs are not stable and no are longer subject to the ESP-IDF versioning scheme’s breaking change rules. Thus, it is not recommended for users to continue calling private APIs in their applications.

Cache Error Interrupt

The Cache Error Interrupt API (functions/types/macros prefixed with `esp_cache_err`) has been made into a private API. Thus, the previous include path `#include "ESP32/cache_err_int.h"` has been removed. If users still require usage of the Cache Error Interrupt API (though this is not recommended), it can be included via `#include "esp_private/cache_err_int.h"`.

bootloader_support

- The function `bootloader_common_get_reset_reason()` has been removed. Please use the function `esp_rom_get_reset_reason()` in the ROM component.
- The functions `esp_secure_boot_verify_sbv2_signature_block()` and `esp_secure_boot_verify_rsa_signature_block()` have been removed without replacement. We do not expect users to use these directly. If they are indeed still necessary, please open a feature request on GitHub explaining why these functions are necessary to you.

Brownout

The Brownout API (functions/types/macros prefixed with `esp_brownout`) has been made into a private API. Thus, the previous include path `#include "brownout.h"` has been removed. If users still require usage of the Brownout API (though this is not recommended), it can be included via `#include "esp_private/brownout.h"`.

Trax

The Trax API (functions/types/macros prefixed with `trax_`) has been made into a private API. Thus, the previous include path `#include "trax.h"` has been removed. If users still require usage of the Trax API (though this is not recommended), it can be included via `#include "esp_private/trax.h"`.

ROM

The previously deprecated ROM-related header files located in `components/esp32/rom/` (old include path: `rom/*.h`) have been moved. Please use the new target-specific path from `components/esp_rom/include/ESP32/` (new include path: `ESP32/rom/*.h`).

esp_hw_support

- The header files `soc/cpu.h` have been deleted and deprecated CPU util functions have been removed. ESP-IDF developers should include `esp_cpu.h` instead for equivalent functions.
- The header files `hal/cpu_ll.h`, `hal/cpu_hal.h`, `hal/soc_ll.h`, `hal/soc_hal.h` and `interrupt_controller_hal.h` CPU API functions have been deprecated. ESP-IDF developers should include `esp_cpu.h` instead for equivalent functions.
- The header file `compare_set.h` have been deleted. ESP-IDF developers should use `esp_cpu_compare_and_set()` function provided in `esp_cpu.h` instead.
Chapter 5. Migration Guides

- `esp_cpu_get_ccount()`, `esp_cpu_set_ccount()` and `esp_cpu_in OCD debug_mode()` were removed from `esp_cpu.h`. ESP-IDF developers should use respectively `esp_cpu_get_cycle_count()`, `esp_cpu_set_cycle_count()` and `esp_cpu_dbgr_is_attached()` instead.

- The header file `esp_intr.h` has been deleted. Please include `esp_intr_alloc.h` to allocate and manipulate interrupts.

- The Panic API (functions/types/macros prefixed with `esp_panic`) has been made into a private API. Thus, the previous include path `#include "esp_panic.h"` has been removed. If users still require usage of the Trax API (though this is not recommended), it can be included via `#include "esp_private/panic_reason.h"`. Besides, developers should include `esp_debug_helpers.h` instead to use any debug-related helper functions, e.g., print backtrace.

- The header file `soc_log.h` is now renamed to `esp_hw_log.h` and has been made private. Users are encouraged to use logging APIs provided under `esp_log.h` instead.

- The header files `spinlock.h`, `clk_ctrl_os.h`, and `rtc_wdt.h` must now be included without the `soc` prefix. For example, `#include "spinlock.h"`.

- `esp_chip_info()` returns the chip version in the format = 100 * major eFuse version + minor eFuse version. Thus, the revision in the `esp_chip_info_t` structure is expanded to `uint16_t` to fit the new format.

**PSRAM**

- The target-specific header file `spiram.h` and the header file `esp_spiram.h` have been removed. A new component `esp_psram` is created instead. For PSRAM/SPIRAM-related functions, users now include `esp_psram.h` and set the `esp_psram` component as a component requirement in their `CMakeLists.txt` project files.

- `esp_spiram_get_chip_size` and `esp_spiram_get_size` have been deleted. You should use `esp_psram_get_size` instead.

**eFuse**

- The parameter type of function `esp_secure_boot_read_key_digests()` changed from `ets_secure_boot_key_digests_t*` to `esp_secure_boot_key_digests_t*`. The new type is the same as the old one, except that the `allow_key_revoke` flag has been removed. The latter was always set to `true` in current code, not providing additional information.

- Added eFuse wafer revisions: major and minor. The `esp_efuse_get_chip_ver()` API is not compatible with these changes, so it was removed. Instead, please use the following APIs: `efuse_hal_get_major_chip_version()`, `efuse_hal_get_minor_chip_version()` or `efuse_hal_chip_revision()`.

**esp_common**  
`EXT_RAM_ATTR` is deprecated. Use the new macro `EXT_RAM_BSS_ATTR` to put `.bss` on PSRAM.

**esp_system**

- The header files `esp_random.h`, `esp_mac.h`, and `esp_chip_info.h`, which were all previously indirectly included via the header file `esp_system.h`, must now be included directly. These indirect inclusions from `esp_system.h` have been removed.

- The Backtrace Parser API (functions/types/macros prefixed with `esp_eh_frame_`) has been made into a private API. Thus, the previous include path `#include "eh_frame_parser.h"` has been removed. If users still require usage of the Backtrace Parser API (though this is not recommended), it can be included via `#include "esp_private/eh_frame_parser.h"`.

- The Interrupt Watchdog API (functions/types/macros prefixed with `esp_int_wdt_`) has been made into a private API. Thus, the previous include path `#include "esp_int_wdt.h"` has been removed. If users still require usage of the Interrupt Watchdog API (though this is not recommended), it can be included via `#include "esp_private/esp_int_wdt.h"`.

Espressif Systems  2679  Release v5.1.2

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SOC Dependency

- Public API headers listed in the Doxyfiles will not expose unstable and unnecessary soc header files, such as `soc/soc.h` and `soc/rtc.h`. That means the user has to explicitly include them in their code if these “missing” header files are still wanted.
- Kconfig option `LEGACY_INCLUDE_COMMON_HEADERS` is also removed.
- The header file `soc/soc_memory_types.h` has been deprecated. Users should use the `esp_memory_utils.h` instead. Including `soc/soc_memory_types.h` will bring a build warning like `soc_memory_types.h is deprecated, please migrate to esp_memory_utils.h`.

APP Trace

One of the timestamp sources has changed from the legacy timer group driver to the new `GPTimer`. Kconfig choices like `APPTTRACE_SV_TS_SOURCE_TIMER00` has been changed to `APPTTRACE_SV_TS_SOURCE_GPTIMER`. User no longer need to choose the group and timer ID.

esp_timer

The FRC2-based legacy implementation of esp_timer available on ESP32 has been removed. The simpler and more efficient implementation based on the LAC timer is now the only option.

ESP Image

The image SPI speed enum definitions have been renamed.

- Enum `ESP_IMAGE_SPI_SPEED_80M` has been renamed to `ESP_IMAGE_SPI_SPEED_DIV_1`.
- Enum `ESP_IMAGE_SPI_SPEED_40M` has been renamed to `ESP_IMAGE_SPI_SPEED_DIV_2`.
- Enum `ESP_IMAGE_SPI_SPEED_26M` has been renamed to `ESP_IMAGE_SPI_SPEED_DIV_3`.
- Enum `ESP_IMAGE_SPI_SPEED_20M` has been renamed to `ESP_IMAGE_SPI_SPEED_DIV_4`.

Task Watchdog Timers

- The API for `esp_task_wdt_init()` has changed as follows:
  - Configuration is now passed as a configuration structure.
  - The function will now handle subscribing of the idle tasks if configured to do so.
- The former `CONFIG_ESP_TASK_WDT` configuration option has been renamed to `CONFIG_ESP_TASK_WDT_INIT` and a new `CONFIG_ESP_TASK_WDT_EN` option has been introduced.

FreeRTOS

Legacy API and Data Types

Previously, the `configENABLE_BACKWARD_COMPATIBILITY` option was set by default, thus allowing pre FreeRTOS v8.0.0 function names and data types to be used. The `configENABLE_BACKWARD_COMPATIBILITY` is now disabled by default, thus legacy FreeRTOS names/types are no longer supported by default. Users should do one of the followings:

- Update their code to remove usage of legacy FreeRTOS names/types.
- Enable the `CONFIG_FREERTOS_ENABLE_BACKWARD_COMPATIBILITY` to explicitly allow the usage of legacy names/types.

Tasks Snapshot

The header `task_snapshot.h` has been removed from `freertos/task.h`. ESP-IDF developers should include `freertos/task_snapshot.h` if they need tasks snapshot API.

The function `vTaskGetSnapshot()` now returns `BaseType_t`. Return value shall be `pdTRUE` on success and `pdFALSE` otherwise.

FreeRTOS Asserts

Previously, FreeRTOS asserts were configured separately from the rest of the system using the `FREERTOS_ASSERT` kconfig option. This option has now been removed and the configuration is now done through `COMPILER_OPTIMIZATION_ASSERTION_LEVEL`. 
Port Macro API  The file portmacro_deprecated.h which was added to maintain backward compatibility for deprecated APIs is removed. Users are advised to use the alternate functions for the deprecated APIs as listed below:

- `portENTER_CRITICAL_NESTED()` is removed. Users should use the `port_SET_INTERRUPT_MASK_FROM_ISR()` macro instead.
- `portEXIT_CRITICAL_NESTED()` is removed. Users should use the `port_CLEAR_INTERRUPT_MASK_FROM_ISR()` macro instead.
- `vPortCPUInitializeMutex()` is removed. Users should use the `spinlock_initialize()` function instead.
- `vPortCPUAcquireMutex()` is removed. Users should use the `spinlock_acquire()` function instead.
- `vPortCPUAcquireMutexTimeout()` is removed. Users should use the `spinlock_acquire()` function instead.
- `vPortCPUReleaseMutex()` is removed. Users should use the `spinlock_release()` function instead.

App Update

- The functions `esp_ota_get_app_description()` and `esp_ota_get_app_elf_sha256()` have been termed as deprecated. Please use the alternative functions `esp_app_get_description()` and `esp_app_get_elf_sha256()` respectively. These functions have now been moved to a new component `esp_app_format`. Please refer to the header file `esp_app_desc.h`.

Bootloader Support

- The `esp_app_desc_t` structure, which used to be declared in `esp_app_format.h`, is now declared in `esp_app_desc.h`.
- The function `bootloader_common_get_partition_description()` has now been made private. Please use the alternative function `esp_ota_get_partition_description()`. Note that this function takes `esp_partition_t` as its first argument instead of `esp_partition_pos_t`.

Chip Revision  The bootloader checks the chip revision at the beginning of the application loading. The application can only be loaded if the version is `>= CONFIG_ESP32_REV_MIN and < CONFIG_ESP32_REV_MAX Full`. During the OTA upgrade, the version requirements and chip revision in the application header are checked for compatibility. The application can only be updated if the version is `>= CONFIG_ESP32_REV_MIN and < CONFIG_ESP32_REV_MAX_FULL`.

Tools

IDF Monitor  IDF Monitor makes the following changes regarding baud-rate:

- IDF monitor now uses the custom console baud-rate (`CONFIG_ESP_CONSOLE_UART_BAUDRATE`) by default instead of 115200.
- Setting a custom baud from menuconfig is no longer supported.
- A custom baud-rate can be specified from command line with the `idf.py monitor -b <baud>` command or through setting environment variables.
- Please note that the baud-rate argument has been renamed from `-B to `-b` in order to be consistent with the global baud-rate `idf.py -b <baud>`.

Run `idf.py monitor --help` for more information.
**Deprecated Commands**  
`idf.py` sub-commands and `cmake` target names have been unified to use hyphens (-) instead of underscores (_). Using a deprecated sub-command or target name will produce a warning. Users are advised to migrate to using the new sub-commands and target names. The following changes have been made:

<table>
<thead>
<tr>
<th>Old Name</th>
<th>New Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>efuse_common_table</td>
<td>efuse-common-table</td>
</tr>
<tr>
<td>efuse_custom_table</td>
<td>efuse-custom-table</td>
</tr>
<tr>
<td>erase_flash</td>
<td>erase-flash</td>
</tr>
<tr>
<td>partition_table</td>
<td>partition-table</td>
</tr>
<tr>
<td>partition_table-flash</td>
<td>partition-table-flash</td>
</tr>
<tr>
<td>post Debug</td>
<td>post-debug</td>
</tr>
<tr>
<td>show_efuse_table</td>
<td>show-efuse-table</td>
</tr>
<tr>
<td>erase_otadata</td>
<td>erase-otadata</td>
</tr>
<tr>
<td>read_otadata</td>
<td>read-otadata</td>
</tr>
</tbody>
</table>

**Esptool**  
The `CONFIG_ESPTOOLPY_FLASHSIZE_DETECT` option has been renamed to `CONFIG_ESPTOOLPY_HEADER_FLASHSIZE_UPDATE` and has been disabled by default. New and existing projects migrated to ESP-IDF v5.0 will have to set `CONFIG_ESPTOOLPY_FLASHSIZE`. If this is not possible due to an unknown flash size at build time, then `CONFIG_ESPTOOLPY_HEADER_FLASHSIZE_UPDATE` can be enabled. However, once enabled, to keep the digest valid, a SHA256 digest will no longer be appended to the image when updating the binary header with the flash size during flashing.

**Windows Environment**  
The Msys/Mingw-based Windows environment support got deprecated in ESP-IDF v4.0 and was entirely removed in v5.0. Please use ESP-IDF Tools Installer to set up a compatible environment. The options include Windows Command Line, Power Shell and the graphical user interface based on Eclipse IDE. In addition, a VS Code-based environment can be set up with the supported plugin: https://github.com/espressif/vscode-esp-idf-extension.

### 5.1.2 Migration from 5.0 to 5.1

**GCC**

**GCC Version**  
The previous GCC version was GCC 11.2.0. This has now been upgraded to GCC 12.2.0 on all targets. Users that need to port their code from GCC 11.2.0 to 12.2.0 should refer to the series of official GCC porting guides listed below:

- Porting to GCC 12

**Warnings**  
The upgrade to GCC 12.2.0 has resulted in the addition of new warnings, or enhancements to existing warnings. The full details of all GCC warnings can be found in GCC Warning Options. Users are advised to double-check their code, then fix the warnings if possible. Unfortunately, depending on the warning and the complexity of the user’s code, some warnings will be false positives that require non-trivial fixes. In such cases, users can choose to suppress the warning in multiple ways. This section outlines some common warnings that users are likely to encounter and ways to fix them.
Chapter 5. Migration Guides

- **Wuse-after-free** Typically, this warning should not produce false-positives for release-level code. But this may appear in test cases. There is an example of how it was fixed in IDF’s test_realloc.c.

```c
void *x = malloc(64);
void *y = realloc(x, 48);
TEST_ASSERT_EQUAL_PTR(x, y);
```

Pointers may be converted to int to avoid warning -Wuse-after-free.

```c
int x = (int) malloc(64);
int y = (int) realloc((void *) x, 48);
TEST_ASSERT_EQUAL_UINT32((uint32_t) x, (uint32_t) y);
```

- **Waddress** GCC 12.2.0 introduces an enhanced version of the -Waddress warning option, which is now more eager in detecting the checking of pointers to an array in if-statements.

The following code will trigger the warning:

```c
char array[8];
...
if (array)
    memset(array, 0xff, sizeof(array));
```

Eliminating unnecessary checks resolves the warning.

```c
char array[8];
...
memset(array, 0xff, sizeof(array));
```

**RISC-V Builds Outside of IDF** The RISC-V extensions zicsr and zifencei have been separated from the I extension. GCC 12 reflects this change, and as a result, when building for RISC-V ESP32 chips outside of the IDF framework, you must include the _zicsr_zifencei postfix when specifying the -march option in your build system.

Example:

```bash
riscv32-esp-elf-gcc main.c -march=rv32imac
```

Now is replaced with:

```bash
riscv32-esp-elf-gcc main.c -march=rv32imac_zicsr_zifencei
```

**Peripherals**

**DAC** DAC driver has been redesigned (see DAC API Reference), which aims to unify the interface and extend the usage of DAC peripheral. Although it is recommended to use the new driver APIs, the legacy driver is still available in the previous include path driver/dac.h. However, by default, including driver/dac.h will bring a build warning like The legacy DAC driver is deprecated, please use 'driver/dac_oneshot.h', 'driver/dac_cosine.h' or 'driver/dac_continuous.h' instead. The warning can be suppressed by the Kconfig option CONFIG_DAC.Suppress.Deprecate.Warn.

The major breaking changes in concept and usage are listed as follows:
Breaking Changes in Concepts

- `dac_channel_t` which was used to identify the hardware channel are removed from user space. The channel index now starts from 0, so please use `DAC_CHAN_0` and `DAC_CHAN_1` instead. And in the new driver, DAC channels can be selected by using `dac_channel_mask_t`. And these channels can be allocated in a same channel group which is represented by `dac_channels_handle_t`.
- `dac_cw_scale_t` is replaced by `dac_cosine_atten_t` to decouple the legacy driver and the new driver.
- `dac_cw_phase_t` is replaced by `dac_cosine_phase_t`. The enumerate value is now the phase angle directly.
- `dac_cw_config_t` is replaced by `dac_cosine_config_t`, but the `en_ch` field is removed because it should be specified while allocating the channel group.

Breaking Changes in Usage

- `dac_pad_get_io_num` is removed.
- `dac_output_voltage` is replaced by `dac_oneshot_output_voltage()`.
- `dac_output_enable` is removed. For oneshot mode, it will be enabled after the channel is allocated.
- `dac_output_disable` is removed. For oneshot mode, it will be disabled before the channel is deleted.
- `dac_cw_generator_enable` is replaced by `dac_cosine_start()`.
- `dac_cw_generator_disable` is replaced by `dac_cosine_stop()`.
- `dac_cw_generator_config` is replaced by `dac_cosine_new_channel()`.
- `dac_i2s_enable` is replaced by `dac_continuous_enable()`, but it needs to allocate the continuous DAC channel first by `dac_continuous_new_channels()`.
- `dac_i2s_disable` is replaced by `dac_continuous_disable()`.

**GP SPI**

Following items are deprecated. Since ESP-IDF v5.1, GP SPI clock source is configurable.

- `spi_get_actual_clock` is deprecated, you should use `spi_device_get_actual_freq()` instead.

**LEDC**

- `soc_periph_ledc_clk_src_legacy_t::LEDC_USE_RTC8M_CLK` is deprecated. Please use `LEDC_USE_RC_FAST_CLK` instead.

**Storage**

**FatFs**

`esp_vfs_fat_sdmmc_unmount()` is now deprecated, you can use `esp_vfs_fat_sdcard_unmount()` instead. This API is deprecated in previous IDF versions, but without deprecation warning and migration guide. Since IDF v5.1, calling this `esp_vfs_fat_sdmmc_unmount()` API will generate deprecation warning.

**SPI_FLASH**

- `spi_flash_get_counters()` is deprecated, please use `esp_flash_get_counters()` instead.
- `spi_flash_dump_counters()` is deprecated, please use `esp_flash_dump_counters()` instead.
- `spi_flash_reset_counters()` is deprecated, please use `esp_flash_reset_counters()` instead.
Networking

SNTP  SNTP module now provides thread safe APIs to access lwIP functionality. It’s recommended to use ESP_NETIF API. Please refer to the chapter SNTP API for more details.

System

FreeRTOS

Dynamic Memory Allocation  Previously, most FreeRTOS dynamic allocation would eventually call to malloc(). Thus, if an application was configured to allow malloc() to allocate from external RAM (i.e., CONFIG_SPIRAM_USE was set CONFIG_SPIRAM_USE_MALLOC), then there was a possibility that FreeRTOS could allocate dynamic memory from external RAM, with the exact placement being decided by the heap allocator.

Note: Dynamic memory allocation for tasks (which are likely to consume the most memory) were an exception to the scenario above. FreeRTOS would use a separate memory allocation function to guarantee that dynamic memory allocate for a task was always placed in internal RAM.

Allowing FreeRTOS objects (such as queues and semaphores) to be placed in external RAM becomes an issue if those objects are accessed while the cache is disabled (such as during SPI Flash write operations) and would lead to a cache access errors (see Fatal Errors for more details).

Therefore, FreeRTOS has been updated to always use internal memory (i.e., DRAM) for dynamic memory allocation. Calling FreeRTOS creation functions (e.g., xTaskCreate(), xQueueCreate()) will guarantee that the memory allocated for those tasks/objects is from internal memory (see FreeRTOS Heap for more details).

Warning: For users that previously relied on CONFIG_SPIRAM_USE to place FreeRTOS objects into external memory, this change will lead to increased usage of internal memory due the FreeRTOS objects now being allocated there.

Users that want to place a FreeRTOS task/object into external memory will now need to do so explicitly. Users can use one of the following methods:

• Allocate the task/object using one of the ...CreateWithCaps() API such as xTaskCreateWithCaps() and xQueueCreateWithCaps() (see IDF Additional API for more details).
• Manually allocate external memory for those objects using heap_caps_malloc(), then create the objects from the allocated memory using one of the ...CreateStatic() FreeRTOS functions.

Power Management

• esp_pm_config.esp32xx_t is deprecated, use esp_pm_config_t instead.
• esp32xx/pm.h is deprecated, use esp_pm.h instead.

WiFi

WiFi Enterprise security  APIs defined in esp_wpa2.h have been deprecated. Please use newer APIs from esp_eap_client.h.
Chapter 6

Libraries and Frameworks

6.1 Cloud Frameworks

ESP32 supports multiple cloud frameworks using agents built on top of ESP-IDF. Here are the pointers to various supported cloud frameworks’ agents and examples:

6.1.1 ESP RainMaker

ESP RainMaker is a complete solution for accelerated AIoT development. ESP RainMaker on GitHub.

6.1.2 AWS IoT

https://github.com/espressif/esp-aws-iot is an open source repository for ESP32 based on Amazon Web Services’ aws-iot-device-sdk-embedded-C.

6.1.3 Azure IoT

https://github.com/espressif/esp-azure is an open source repository for ESP32 based on Microsoft Azure’s azure-iot-sdk-c SDK.

6.1.4 Google IoT Core

https://github.com/espressif/esp-google-iot is an open source repository for ESP32 based on Google’s iot-device-sdk-embedded-c SDK.

6.1.5 Aliyun IoT

https://github.com/espressif/esp-aliyun is an open source repository for ESP32 based on Aliyun’s iotkit-embedded SDK.

6.1.6 Joylink IoT

https://github.com/espressif/esp-joylink is an open source repository for ESP32 based on Joylink’s joylink_dev_sdk SDK.
6.1.7 Tencent IoT

https://github.com/espressif/esp-welink is an open source repository for ESP32 based on Tencent’s welink SDK.

6.1.8 Tencentyun IoT

https://github.com/espressif/esp-qcloud is an open source repository for ESP32 based on Tencentyun’s qcloud-iot-sdk-embedded-c SDK.

6.1.9 Baidu IoT

https://github.com/espressif/esp-baidu-iot is an open source repository for ESP32 based on Baidu’s iot-sdk-c SDK.

6.2 Espressif’s Frameworks

Here you will find a collection of the official Espressif libraries and frameworks.

6.2.1 Espressif Audio Development Framework

The ESP-ADF is a comprehensive framework for audio applications including:

- CODEC’s HAL
- Music Players and Recorders
- Audio Processing
- Bluetooth Speakers
- Internet Radios
- Hands-free devices
- Speech Recognition

This framework is available at GitHub: ESP-ADF.

6.2.2 ESP-CSI

ESP-CSI is an experimental implementation that uses the Wi-Fi Channel State Information to detect the presence of a human body.

See ESP-CSI project for more information about it.

6.2.3 Espressif DSP Library

The library provides algorithms optimized specifically for digital signal processing applications. This library supports:

- Matrix multiplication
- Dot product
- FFT (Fast Fourier Transform)
- IIR (Infinite Impulse Response)
- FIR (Finite Impulse Response)
- Vector math operations

This library is available here: ESP-DSP library.
6.2.4 ESP-WIFI-MESH Development Framework

This framework is based on the ESP-WIFI-MESH protocol with the following features:

- Fast network configuration
- Stable upgrade
- Efficient debugging
- LAN control
- Various application demos

ESP-MDF.

6.2.5 ESP-WHO

The ESP-WHO is a face detection and recognition framework using the ESP32 and camera. To know more about the project, see ESP-WHO on GitHub.

6.2.6 ESP RainMaker

ESP RainMaker is a complete solution for accelerated AIoT development. Using ESP RainMaker, you can create AIoT devices from the firmware to the integration with voice-assistant, phone apps and cloud backend.

ESP RainMaker on GitHub.

6.2.7 ESP-IoT-Solution

ESP-IoT-Solution contains commonly used device drivers and code frameworks when developing IoT systems. The device drivers and code frameworks within the ESP-IoT-Solution are organized as separate components, allowing them to be easily integrated into an ESP-IDF project.

ESP-IoT-Solution includes:

- Device drivers for sensors, display, audio, GUI, input, actuators, etc.
- Framework and documentation for low power, security, storage, etc.
- Guide for Espressif open source solutions from practical application point.

ESP-IoT-Solution on GitHub.

6.2.8 ESP-Protocols

ESP-Protocols repository contains collection of protocol components for ESP-IDF. The code within the ESP-Protocols is organized into separate components, allowing them to be easily integrated into an ESP-IDF project. In addition to that, each component is available in IDF Component Registry.

ESP-Protocols components:

- esp_modem enables connectivity with GSM/LTE modems using AT commands or PPP protocol, see the esp_modem documentation.
- mDNS (mDNS) is a multicast UDP service that is used to provide local network service and host discovery, see the mDNS documentation.
- asio is a cross-platform C++ library, see [https://think-async.com/Asio/](https://think-async.com/Asio/). It provides a consistent asynchronous model using a modern C++ approach. , see the asio documentation.
6.2.9 ESP-BSP

ESP-BSP repository contains Board Support Packages (BSPs) for various Espressif’s and 3rd party development boards. BSPs are useful for quick start on a supported board. Usually they contain pinout definition and helper functions, that will initialize peripherals for the specific board. Additionally, the BSP would contain drivers for external chips populated on the development board, such as sensors, displays, audio codecs etc.

6.2.10 ESP-IDF-CXX

ESP-IDF-CXX contains C++ wrappers for part of ESP-IDF. The focus is on ease of use, safety, automatic resource management and shifting checks to compile time instead of failing at run time. There are C++ classes for ESP-Timer, I2C, SPI, GPIO and other peripherals or features of ESP-IDF. ESP-IDF-CXX is available as a component from the component registry. Please check the project’s README.md for more information.
Chapter 7

Contributions Guide

We welcome contributions to the esp-idf project!

7.1 How to Contribute

Contributions to esp-idf - fixing bugs, adding features, adding documentation - are welcome. We accept contributions via Github Pull Requests.

7.2 Before Contributing

Before sending us a Pull Request, please consider this list of points:

• Is the contribution entirely your own work, or already licensed under an Apache License 2.0 compatible Open Source License? If not then we unfortunately cannot accept it. Please check the Copyright Header Guide for additional information.
• Does any new code conform to the esp-idf Style Guide?
• Have you installed the pre-commit hook for esp-idf project?
• Does the code documentation follow requirements in Documenting Code?
• Is the code adequately commented for people to understand how it is structured?
• Is there documentation or examples that go with code contributions? There are additional suggestions for writing good examples in examples readme.
• Are comments and documentation written in clear English, with no spelling or grammar errors?
• Example contributions are also welcome. Please check the Creating Examples guide for these.
• If the contribution contains multiple commits, are they grouped together into logical changes (one major change per pull request)? Are any commits with names like “fixed typo” squashed into previous commits?
• If you’re unsure about any of these points, please open the Pull Request anyhow and then ask us for feedback.

7.3 Pull Request Process

After you open the Pull Request, there will probably be some discussion in the comments field of the request itself. Once the Pull Request is ready to merge, it will first be merged into our internal git system for in-house automated testing.

If this process passes, it will be merged into the public GitHub repository.
Chapter 7. Contributions Guide

7.4 Legal Part

Before a contribution can be accepted, you will need to sign our Contributor Agreement. You will be prompted for this automatically as part of the Pull Request process.

7.5 Related Documents

7.5.1 Espressif IoT Development Framework Style Guide

About This Guide

Purpose of this style guide is to encourage use of common coding practices within the ESP-IDF.

Style guide is a set of rules which are aimed to help create readable, maintainable, and robust code. By writing code which looks the same way across the code base we help others read and comprehend the code. By using same conventions for spaces and newlines we reduce chances that future changes will produce huge unreadable diffs. By following common patterns for module structure and by using language features consistently we help others understand code behavior.

We try to keep rules simple enough, which means that they can not cover all potential cases. In some cases one has to bend these simple rules to achieve readability, maintainability, or robustness.

When doing modifications to third-party code used in ESP-IDF, follow the way that particular project is written. That will help propose useful changes for merging into upstream project.

C Code Formatting

Naming

- Any variable or function which is only used in a single source file should be declared static.
- Public names (non-static variables and functions) should be namespaced with a per-component or per-unit prefix, to avoid naming collisions. i.e esp_vfs_register() or esp_console_run(). Starting the prefix with esp_ for Espressif-specific names is optional, but should be consistent with any other names in the same component.
- Static variables should be prefixed with s_ for easy identification. For example, static bool s_invert.
- Avoid unnecessary abbreviations (i.e shortening data to dat), unless the resulting name would otherwise be very long.

Indentation  Use 4 spaces for each indentation level. Don’t use tabs for indentation. Configure the editor to emit 4 spaces each time you press tab key.

Vertical Space  Place one empty line between functions. Don’t begin or end a function with an empty line.

```c
void function1()
{
  do_one_thing();
  do_another_thing();
}  // INCORRECT, don't place empty line here

void function2()
{
  // INCORRECT, don't use an empty line here
  int var = 0;
  while (var < SOME_CONSTANT) {
    do_stuff(&var);
  }
}  // place empty line here
```

(continues on next page)
The maximum line length is 120 characters as long as it doesn’t seriously affect the readability.

**Horizontal Space** Always add single space after conditional and loop keywords:

```c
if (condition) { // correct
    // ...
}
switch (n) {    // correct
    case 0:
        // ...
}
for(int i = 0; i < CONST; ++i) { // INCORRECT
    // ...
}
```

Add single space around binary operators. No space is necessary for unary operators. It is okay to drop space around multiply and divide operators:

```c
const int y = y0 + (x - x0) * (y1 - y0) / (x1 - x0); // correct
const int y = y0 + (x - x0) * (y1 - y0) / (x1 - x0); // also okay
int y_cur = -y;
++y_cur;
const int y = y0 + (x - x0) * (y1 - y0) / (x1 - x0); // INCORRECT
```

No space is necessary around . and -> operators.

Sometimes adding horizontal space within a line can help make code more readable. For example, you can add space to align function arguments:

```c
esp_rom_gpio_connect_in_signal(PIN_CAM_D6, I2S0I_DATA_IN14_IDX, false);
esp_rom_gpio_connect_in_signal(PIN_CAM_D7, I2S0I_DATA_IN15_IDX, false);
esp_rom_gpio_connect_in_signal(PIN_CAM_HREF, I2S0I_H_ENABLE_IDX, false);
esp_rom_gpio_connect_in_signal(PIN_CAM_PCLK, I2S0I_DATA_IN15_IDX, false);
```

Note however that if someone goes to add new line with a longer identifier as first argument (e.g. `PIN_CAM_VSYNC`), it will not fit. So other lines would have to be realigned, adding meaningless changes to the commit.

Therefore, use horizontal alignment sparingly, especially if you expect new lines to be added to the list later.

Never use TAB characters for horizontal alignment.

Never add trailing whitespace at the end of the line.

**Braces**

- Function definition should have a brace on a separate line:

```c
// This is correct:
void function(int arg)
{
    
}
```

(continues on next page)
• Within a function, place opening brace on the same line with conditional and loop statements:

```c
if (condition) {
    do_one();
} else if (other_condition) {
    do_two();
}
```

**Comments**

Use `//` for single line comments. For multi-line comments it is okay to use either `//` on each line or a `/* */` block.

Although not directly related to formatting, here are a few notes about using comments effectively.

• Don’t use single comments to disable some functionality:

```c
void init_something() {
    setup_dma();
    // load_resources(); // WHY is this thing commented, asks the reader?
    start_timer();
}
```

• If some code is no longer required, remove it completely. If you need it you can always look it up in git history of this file. If you disable some call because of temporary reasons, with an intention to restore it in the future, add explanation on the adjacent line:

```c
void init_something() {
    setup_dma();
    // TODO: we should load resources here, but loader is not fully integrated yet.
    // load_resources();
    start_timer();
}
```

• Same goes for `#if 0 ... #endif` blocks. Remove code block completely if it is not used. Otherwise, add comment explaining why the block is disabled. Don’t use `#if 0 ... #endif` or comments to store code snippets which you may need in the future.

• Don’t add trivial comments about authorship and change date. You can always look up who modified any given line using git. E.g. this comment adds clutter to the code without adding any useful information:

```c
void init_something() {
    setup_dma();
    // XXX add 2016-09-01
    init_dma_list();
    fill_dma_item(0);
    // end XXX add
    start_timer();
}
```

**Line Endings**

Commits should only contain files with LF (Unix style) endings.

Windows users can configure git to check out CRLF (Windows style) endings locally and commit LF endings by setting the `core.autocrlf` setting. Github has a document about setting this option [here](https://github.com)
If you accidentally have some commits in your branch that add LF endings, you can convert them to Unix by running this command in an MSYS2 or Unix terminal (change directory to the IDF working directory and check the correct branch is currently checked out, beforehand):

```bash
    git rebase --exec 'git diff-tree --no-commit-id --name-only -r HEAD | xargs --dos2unix && git commit -a --amend --no-edit --allow-empty' master
```

(Notaethatthislinerebasesonmaster,change thesebranchname at the end to rebase on another branch.)

For updating a single commit, it’s possible to run `dos2unix FILENAME` and then run `git commit --amend`

**Formatting Your Code** You can use an astyle program to format your code according to the above recommendations.

If you are writing a file from scratch, or doing a complete rewrite, feel free to re-format the entire file. If you are changing a small portion of file, don’t re-format the code you didn’t change. This will help others when they review your changes.

To re-format a file, run:

`tools/format.sh components/my_component/file.c`

**Type Definitions** Should be snake_case, ending with _t suffix:

```c
    typedef int signed_32_bit_t;
```

**Enum** Enums should be defined through the typedef and be namespaced:

```c
    typedef enum
    {
        MODULE_FOO_ONE,
        MODULE_FOO_TWO,
        MODULE_FOO_THREE
    } module_foo_t;
```

**Assertions** The standard C assert() function, defined in assert.h should be used to check conditions that should be true in source code. In the default configuration, an assertion that returns false or 0 will call abort() and trigger a Fatal Error.

assert() should only be used to detect unrecoverable errors due to a serious internal logic bug or corruption, where it’s not possible for the program to continue. For recoverable errors, including errors that are possible due to invalid external input, an error value should be returned.

**Note:** When asserting a value of type esp_err_t is equal to ESP_OK, use the ESP_ERROR_CHECK macro instead of an assert().

It’s possible to configure ESP-IDF projects with assertions disabled (see CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL). Therefore, functions called in an assert() statement should not have side-effects.

It’s also necessary to use particular techniques to avoid “variable set but not used” warnings when assertions are disabled, due to code patterns such as:

```c
    int res = do_something();
    assert(res == 0);
```
Once the `assert` is optimized out, the `res` value is unused and the compiler will warn about this. However the function `do_something()` must still be called, even if assertions are disabled.

When the variable is declared and initialized in a single statement, a good strategy is to cast it to `void` on a new line. The compiler will not produce a warning, and the variable can still be optimized out of the final binary:

```c
int res = do_something();
assert(res == 0);
(void)res;
```

If the variable is declared separately, for example if it is used for multiple assertions, then it can be declared with the GCC attribute `__attribute__((unused))`. The compiler will not produce any unused variable warnings, but the variable can still be optimized out:

```c
int res __attribute__((unused));
res = do_something();
assert(res == 0);
res = do_something_else();
assert(res != 0);
```

**Header file guards**

All public facing header files should have preprocessor guards. A `#pragma` is preferred:

```c
#pragma once
```

over the following pattern:

```c
ifndef FILE_NAME_H
#define FILE_NAME_H
...
endif // FILE_NAME_H
```

In addition to guard macros, all C header files should have `extern "C"` guards to allow the header to be used from C++ code. Note that the following order should be used: `#pragma once`, then any `#include` statements, then `extern "C"` guards:

```c
#pragma once
#include <stdint.h>
#ifndef __cplusplus
extern "C" {
#define __cplusplus
/* declarations go here */
#undef __cplusplus
}
#endif
```

**Include statements**

When writing `#include` statements, try to maintain the following order:

- C standard library headers.
- Other POSIX standard headers and common extensions to them (such as `sys/queue.h`)
- Common IDF headers (`esp_log.h`, `esp_system.h`, `esp_timer.h`, `esp_sleep.h`, etc.)
• Headers of other components, such as FreeRTOS.
• Public headers of the current component.
• Private headers.

Use angle brackets for C standard library headers and other POSIX headers (#include <stdio.h>).
Use double quotes for all other headers (#include "esp_log.h").

**C++ Code Formatting**

The same rules as for C apply. Where they are not enough, apply the following rules.

**File Naming** C++ Header files have the extension .hpp. C++ source files have the extension .cpp. The latter is important for the compiler to distinguish them from normal C source files.

**Naming**

• **Class and struct** names shall be written in CamelCase with a capital letter as beginning. Member variables and methods shall be in snake_case. An exception from CamelCase is if the readability is severely decreased, e.g. in GPIOOutput, then an underscore _ is allowed to make it more readable: GPIO_Output.
• **Namespaces** shall be in lower snake_case.
• **Templates** are specified in the line above the function declaration.
• Interfaces in terms of Object-Oriented Programming shall be named without the suffix ...Interface. Later, this makes it easier to extract interfaces from normal classes and vice versa without making a breaking change.

**Member Order in Classes** In order of precedence:

• First put the public members, then the protected, then private ones. Omit public, protected or private sections without any members.
• First put constructors/destructors, then member functions, then member variables.

For example:

```cpp
class ForExample {
  public:
    // first constructors, then default constructor, then destructor
    ForExample(double example_factor_arg);
    ForExample();
    ~ForExample();

    // then remaining public methods
    set_example_factor(double example_factor_arg);

    // then public member variables
    uint32_t public_data_member;

  private:
    // first private methods
    void internal_method();

    // then private member variables
    double example_factor;
};
```

**Spacing**

• Don’t indent inside namespaces.
• Put public, protected and private labels at the same indentation level as the corresponding class label.

**Simple Example**

```cpp
// file spaceship.h
#ifndef SPACESHIP_H_
#define SPACESHIP_H_
#include <cstdlib>
namespace spaceships {
  class SpaceShip {
    public:
      SpaceShip(size_t crew);
      size_t get_crew_size() const;
    private:
      const size_t crew;
  };
  class SpaceShuttle : public SpaceShip {
    public:
      SpaceShuttle();
  };
  class Sojuz : public SpaceShip {
    public:
      Sojuz();
  };
  template <typename T>
  class CargoShip {
    public:
      CargoShip(const T &cargo);
    private:
      T cargo;
  };
} // namespace spaceships
#endif // SPACESHIP_H_

// file spaceship.cpp
#include "spaceship.h"
namespace spaceships {
  // Putting the curly braces in the same line for constructors is OK if it only initializes
  // values in the initializer list
  SpaceShip::SpaceShip(size_t crew) : crew(crew) {
  }
  size_t SpaceShip::get_crew_size() const {
    return crew;
  }
  SpaceShuttle::SpaceShuttle() : SpaceShip(7) {
    // doing further initialization
  }
} // namespace spaceships
```

(continues on next page)
CMake Code Style

- Indent with four spaces.
- Maximum line length 120 characters. When splitting lines, try to focus on readability where possible (for example, by pairing up keyword/argument pairs on individual lines).
- Don’t put anything in the optional parentheses after `endforeach()`, `endif()`, etc.
- Use lowercase (with underscores) for command, function, and macro names.
- For locally scoped variables, use lowercase (with underscores).
- For globally scoped variables, use uppercase (`WITH_UNDERSCORES`).
- Otherwise follow the defaults of the `cmake-lint` project.

Configuring the Code Style for a Project Using EditorConfig

EditorConfig helps developers define and maintain consistent coding styles between different editors and IDEs. The EditorConfig project consists of a file format for defining coding styles and a collection of text editor plugins that enable editors to read the file format and adhere to defined styles. EditorConfig files are easily readable and they work nicely with version control systems.

For more information, see EditorConfig Website.

Third Party Component Code Styles

ESP-IDF integrates a number of third party components where these components may have differing code styles.

FreeRTOS  The code style adopted by FreeRTOS is described in the FreeRTOS style guide. Formatting of FreeRTOS source code is automated using Uncrustify, thus a copy of the FreeRTOS code style’s Uncrustify configuration (`uncrustify.cfg`) is stored within ESP-IDF FreeRTOS component.

If a FreeRTOS source file is modified, the updated file can be formatted again by following the steps below:

1. Ensure that Uncrustify (v0.69.0) is installed on your system
2. Run the following command on the update FreeRTOS source file (where `source.c` is the path to the source file that requires formatting).

   ```
   uncrustify -c $IDF_PATH/components/freertos/FreeRTOS-Kernel/uncrustify.cfg --replace source.c --no-backup
   ```

Documenting Code

Please see the guide here: Documenting Code.
Chapter 7. Contributions Guide

Structure
To be written.

Language Features
To be written.

7.5.2 Install pre-commit Hook for ESP-IDF Project

Required Dependency
Python 3.7.* or above. This is our recommended python version for IDF developers.
If you still have python versions not compatible, update your python versions before installing the pre-commit hook.

Install pre-commit

Run `pip install pre-commit`

Install pre-commit hook

1. Go to the IDF Project Directory
2. Run `pre-commit install --allow-missing-config`. Install hook by this approach will let you commit successfully even in branches without the `.pre-commit-config.yaml`
3. pre-commit hook will run automatically when you’re running `git commit`

Uninstall pre-commit

Run `pre-commit uninstall`

What’s More?

For detailed usage, please refer to the documentation of `pre-commit`.

Common Problems For Windows Users

If you’re in Git Bash, please check the python executable location by run `which python`.
If the executable is under `/AppData/Local/Microsoft/WindowsApps/`, then it’s a link to Windows AppStore, not a real one.
Please install python manually and update this in your PATH environment variable.

Your `%USERPROFILE%` contains non-ASCII characters
`pre-commit` may fail when initializing an environment for a particular hook when the path of `pre-commit`’s cache contains non-ASCII characters. The solution is to set `PRE_COMMIT_HOME` to a path containing only standard characters before running pre-commit.

- **CMD:** `set PRE_COMMIT_HOME=C:\somepath\pre-commit`
- **PowerShell:** `$Env:PRE_COMMIT_HOME = "C:\somepath\pre-commit"`
- **git bash:** `export PRE_COMMIT_HOME="/c/somepath/pre-commit"`
7.5.3 Documenting Code

The purpose of this description is to provide quick summary on documentation style used in espressif/esp-idf repository and how to add new documentation.

Introduction

When documenting code for this repository, please follow Doxygen style. You are doing it by inserting special commands, for instance @param, into standard comments blocks, for example:

```c
/**
 * @param ratio this is oxygen to air ratio
 */
```

Doxygen is phrasing the code, extracting the commands together with subsequent text, and building documentation out of it.

Typical comment block, that contains documentation of a function, looks like below.

![Typical comment block](image)

Doxygen supports couple of formatting styles. It also gives you great flexibility on level of details to include in documentation. To get familiar with available features, please check data rich and very well organized Doxygen Manual.

Why we need it?

The ultimate goal is to ensure that all the code is consistently documented, so we can use tools like Sphinx and Breathe to aid preparation and automatic updates of API documentation when the code changes.

With these tools the above piece of code renders like below:
Go for it!

When writing code for this repository, please follow guidelines below.

1. Document all building blocks of code: functions, structs, typedefs, enums, macros, etc. Provide enough information about purpose, functionality and limitations of documented items, as you would like to see them documented when reading the code by others.

2. Documentation of function should describe what this function does. If it accepts input parameters and returns some value, all of them should be explained.

3. Do not add a data type before parameter or any other characters besides spaces. All spaces and line breaks are compressed into a single space. If you like to break a line, then break it twice.

4. If function has void input or does not return any value, then skip @param or @return
5. When documenting a `define` as well as members of a `struct` or `enum`, place specific comment like below after each member.

```
/*!
  * < how to documented members */
```

6. To provide well formatted lists, break the line after command (like `@return` in example below).

```
* @return
  * - ESP_OK if erase operation was successful
  * - ESP_ERR_NVS_INVALID_HANDLE if handle has been closed or is NULL
  * - ESP_ERR_NVS_READ_ONLY if handle was opened as read only
  * - ESP_ERR_NVS_NOT_FOUND if the requested key doesn't exist
  * - other error codes from the underlying storage driver
```

7. Overview of functionality of documented header file, or group of files that make a library, should be placed in a separate README.rst file of the same directory. If this directory contains header files for different APIs, then the file name should be apiname-readme.rst.

Go one extra mile

Here are a couple of tips on how you can make your documentation even better and more useful to the reader and writer.

When writing codes, please follow the guidelines below:

1. Add code snippets to illustrate implementation. To do so, enclose snippet using `@code{c}` and `@endcode` commands.

```
/*
 * @code{c}
 * // Example of using nvs_get_i32:
 * int32_t max_buffer_size = 4096; // default value
 * esp_err_t err = nvs_get_i32(my_handle, "max_buffer_size", &max_buffer_size);
 * assert(err == ESP_OK || err == ESP_ERR_NVS_NOT_FOUND);
 * // if ESP_ERR_NVS_NOT_FOUND was returned, max_buffer_size will still
 * // have its default value.
*/
```

(continues on next page)
The code snippet should be enclosed in a comment block of the function that it illustrates.

2. To highlight some important information use command `@attention` or `@note`.

```plaintext
* @attention
* 1. This API only impact WIFI_MODE_STA or WIFI_MODE_APSTA mode
* 2. If the ESP32 is connected to an AP, call esp_wifi_disconnect to disconnect.
```

Above example also shows how to use a numbered list.

3. To provide common description to a group of similar functions, enclose them using `/**@{*/` and `/**}@*/` markup commands:

```plaintext
/**@{*/
/**
* @brief common description of similar functions
* /
*/
void first_similar_function (void);
void second_similar_function (void);
/**}@*/
```

For practical example see `nvs_flash/include/nvs.h`.

4. You may want to go even further and skip some code like repetitive defines or enumerations. In such case, enclose the code within `/** @cond */` and `/** @endcond */` commands. Example of such implementation is provided in `driver/gpio/include/driver/gpio.h`.

5. Use markdown to make your documentation even more readable. You will add headers, links, tables and more.

```plaintext
```

**Note:** Code snippets, notes, links, etc. will not make it to the documentation, if not enclosed in a comment block associated with one of documented objects.

6. Prepare one or more complete code examples together with description. Place description to a separate file `README.md` in specific folder of `examples` directory.

**Standardize Document Format**

When it comes to text, please follow guidelines below to provide well formatted Markdown (.md) or reST (.rst) documents.

1. Please ensure that one paragraph is written in one line. Don’t break lines like below. Breaking lines to enhance readability is only suitable for writing codes. To make the text easier to read, it is recommended to place an empty line to separate the paragraph.

2. Please make the line number of CN and EN documents consistent like below. The benefit of this approach is that it can save time for both writers and translators. When non-bilingual writers need to update text, they only need to update the same line in the corresponding CN or EN document. For translators, if documents are updated in English, then translators can quickly locate where to update in the corresponding CN document later. Besides, by comparing the total number of lines in EN and CN documents, you can quickly find out whether the CN version lags behind the EN version.
Fig. 1: One line for one paragraph (click to enlarge)

Fig. 2: No line breaks within the same paragraph (click to enlarge)

Fig. 3: Keep the line number for EN and CN documents consistent (click to enlarge)
Building Documentation

The documentation is built with the esp-docs Python package, which is a wrapper around Sphinx.

To install it simply do:

```
pip install esp-docs
```

After a successful install then the documentation can be built from the docs folder with:

```
budget-docs build
```

or for specific target and language with:

```
budget-docs -t esp32 -l en build
```

For more in-depth documentation about esp-docs features please see the documentation at esp-docs.

Wrap up

We love good code that is doing cool things. We love it even better, if it is well documented, so we can quickly make it run and also do the cool things.

Go ahead, contribute your code and documentation!

Related Documents

- API Documentation Template

7.5.4 Creating Examples

Each ESP-IDF example is a complete project that someone else can copy and adapt the code to solve their own problem. Examples should demonstrate ESP-IDF functionality, while keeping this purpose in mind.

Structure

- The main directory should contain a source file named (something)_example_main.c with the main functionality.
- If the example has additional functionality, split it logically into separate C or C++ source files under main and place a corresponding header file in the same directory.
- If the example has a lot of additional functionality, consider adding a components directory to the example project and make some example-specific components with library functionality. Only do this if the components are specific to the example, if they’re generic or common functionality then they should be added to ESP-IDF itself.
- The example should have a README.md file. Use the template example README and adapt it for your particular example.
- Examples should have a pytest_<example name>.py file for running an automated example test. If submitting a GitHub Pull Request which includes an example, it’s OK not to include this file initially. The details can be discussed as part of the Pull Request. Please refer to IDF Tests with Pytest Guide for details.

General Guidelines

Example code should follow the Espressif IoT Development Framework Style Guide.
Chapter 7. Contributions Guide

Checklist

Checklist before submitting a new example:

• Example project name (in README.md) uses the word “example”. Use “example” instead of “demo”, “test” or similar words.
• Example does one distinct thing. If the example does more than one thing at a time, split it into two or more examples.
• Example has a README.md file which is similar to the template example README.
• Functions and variables in the example are named according to naming section of the style guide. (For non-static names which are only specific to the example’s source files, you can use example or something similar as a prefix.)
• All code in the example is well structured and commented.
• Any unnecessary code (old debugging logs, commented-out code, etc.) is removed from the example.
• Options in the example (like network names, addresses, etc) are not hard-coded. Use configuration items if possible, or otherwise declare macros or constants)
• Configuration items are provided in a KConfig.projbuild file with a menu named “Example Configuration”. See existing example projects to see how this is done.
• All original example code has a license header saying it is “in the public domain / CC0”, and a warranty disclaimer clause. Alternatively, the example is licensed under Apache License 2.0. See existing examples for headers to adapt from.
• Any adapted or third party example code has the original license header on it. This code must be licensed compatible with Apache License 2.0.

7.5.5 API Documentation Template

Note: INSTRUCTIONS

1. Use this file (docs/en/api-reference/template.rst) as a template to document API.
2. Change the file name to the name of the header file that represents documented API.
3. Include respective files with descriptions from the API folder using ..include::
   • README.rst
   • example.rst
   • ...
4. Optionally provide description right in this file.
5. Once done, remove all instructions like this one and any superfluous headers.

Overview

Note: INSTRUCTIONS

1. Provide overview where and how this API may be used.
2. Where applicable include code snippets to illustrate functionality of particular functions.
3. To distinguish between sections, use the following heading levels:
   • # with overline, for parts
   • * with overline, for chapters
   • =, for sections
   • –, for subsections
   • ^, for subsubsections
   • “, for paragraphs
Application Example

**Note: INSTRUCTIONS**

1. Prepare one or more practical examples to demonstrate functionality of this API.
2. Each example should follow pattern of projects located in esp-idf/examples/ folder.
3. Place example in this folder complete with README.md file.
4. Provide overview of demonstrated functionality in README.md.
5. With good overview reader should be able to understand what example does without opening the source code.
6. Depending on complexity of example, break down description of code into parts and provide overview of functionality of each part.
7. Include flow diagram and screenshots of application output if applicable.
8. Finally add in this section synopsis of each example together with link to respective folder in esp-idf/examples/.

API Reference

**Note: INSTRUCTIONS**

1. This repository provides for automatic update of API reference documentation using code markup retrieved by Doxygen from header files.
2. Update is done on each documentation build by invoking Sphinx extension :esp_extensions/run_doxygen.py for all header files listed in the INPUT statement of docs/doxygen/Doxyfile.
3. Each line of the INPUT statement (other than a comment that begins with ##) contains a path to header file *.h that will be used to generate corresponding *.inc files:
   ```
   ## Wi-Fi - API Reference
   ../components/esp32/include/esp_wifi.h \
   ../components/esp32/include/esp_smartconfig.h \
   ```
4. When the headers are expanded, any macros defined by default in sdkconfig.h as well as any macros defined in SOC-specific include/soc/*_caps.h headers will be expanded. This allows the headers to include/exclude material based on the IDF_TARGET value.
5. The *.inc files contain formatted reference of API members generated automatically on each documentation build. All *.inc files are placed in Sphinx _build directory. To see directives generated for e.g. esp_wifi.h, run `python gen-dxd.py esp32/include/esp_wifi.h`.
6. To show contents of *.inc file in documentation, include it as follows:
   ```
   .. include-build-file:: inc/esp_wifi.inc
   ```
   For example see docs/en/api-reference/network/esp_wifi.rst
   Below is the list of common .. doxygen...:: directives:
   • Functions .-.. doxygenfunction:: name_of_function
   • Unions .-.. doxygenuion:: name_of_union
   • Structures .-.. doxygenstruct:: name_of_structure together with :members:
   • Macros .-.. doxygendifine:: name_of_define
   • Type Definitions .-.. doxygentypedef:: name_of_type
   • Enumerations .-.. doxygennum:: name_of Enumeration
   See Breathe documentation for additional information.
   To provide a link to header file, use the link custom role directive as follows:
   ```
   * :component_file:`path_to/header_file.h`
   ```
8. In any case, to generate API reference, the file `docs/doxygen/Doxyfile` should be updated with paths to `*.h` headers that are being documented.

9. When changes are committed and documentation is build, check how this section has been rendered. Correct annotations in respective header files, if required.

### 7.5.6 Contributor Agreement

**Individual Contributor Non-Exclusive License Agreement including the Traditional Patent License OPTION**

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8.3 If any provision of this Agreement is found void and unenforceable, such provision will be replaced to the extent possible with a provision that comes closest to the meaning of the original provision and that is enforceable. The terms and conditions set forth in this Agreement shall apply notwithstanding any failure of essential purpose of this Agreement or any limited remedy to the maximum extent possible under law.
8.4 You agree to notify Us of any facts or circumstances of which you become aware that would make this Agreement inaccurate in any respect.
7.5.7 Copyright Header Guide

ESP-IDF is released under the Apache License 2.0 with some additional third-party copyrighted code released under various licenses. For further information please refer to the list of copyrights and licenses.

This page explains how the source code should be properly marked with a copyright header. ESP-IDF uses The Software Package Data Exchange (SPDX) format which is short and can be easily read by humans or processed by automated tools for copyright checks.

How to Check the Copyright Headers

Please make sure you have installed the pre-commit hooks which contain a copyright header checker as well. The checker can suggest a header if it is not able to detect a properly formatted SPDX header.

What if the Checker’s Suggestion is Incorrect?

No automated checker (no matter how good is) can replace humans. So the developer’s responsibility is to modify the offered header to be in line with the law and the license restrictions of the original code on which the work is based on. Certain licenses are not compatible between each other. Such corner cases will be covered by the following examples.

The checker can be configured with the tools/ci/check_copyright_config.yaml configuration file. Please check the options it offers and consider updating it in order to match the headers correctly.

Common Examples of Copyright Headers

The simplest case is when the code is not based on any licensed previous work, e.g. it was written completely from scratch. Such code can be decorated with the following copyright header and put under the license of ESP-IDF:

```
/*
 * SPDX-FileCopyrightText: 2015-2023 Espressif Systems (Shanghai) CO LTD
 * *
 * SPDX-License-Identifier: Apache-2.0
 */
```
Less restrictive parts of ESP-IDF  Some parts of ESP-IDF are deliberately under less restrictive licenses in order to ease their re-use in commercial closed source projects. This is the case for ESP-IDF examples which are in Public domain or under the Creative Commons Zero Universal (CC0) license. The following header can be used in such source files:

```c
/*
 * SPDX-FileCopyrightText: 2015-2023 Espressif Systems (Shanghai) CO LTD
 * SPDX-License-Identifier: Unlicense OR CC0-1.0
 */
```

The option allowing multiple licenses joined with the OR keyword from the above example can be achieved with the definition of multiple allowed licenses in the tools/ci/check_copyright_config.yaml configuration file. Please use this option with care and only selectively for a limited part of ESP-IDF.

Third party licenses  Code licensed under different licenses, modified by Espressif Systems and included in ESP-IDF cannot be licensed under Apache License 2.0 not even if the checker suggests it. It is advised to keep the original copyright header and add an SPDX before it.

The following example is a suitable header for a code licensed under the “GNU General Public License v2.0 or later” held by John Doe with some additional modifications done by Espressif Systems:

```c
/*
 * SPDX-FileCopyrightText: 1991 John Doe
 * SPDX-License-Identifier: GPL-2.0-or-later
 * SPDX-FileContributor: 2019-2023 Espressif Systems (Shanghai) CO LTD
 */
```

The licenses can be identified and the short SPDX identifiers can be found in the official SPDX license list. Other very common licenses are the GPL-2.0-only, the BSD-3-Clause, and the BSD-2-Clause.

In exceptional case, when a license is not present on the SPDX license list, it can be expressed by using the LicenseRef-[idString] custom license identifier, for example LicenseRef-Special-License. The full license text must be added into the LICENSES directory under Special-License filename.

```c
/*
 * SPDX-FileCopyrightText: 2015-2023 Espressif Systems (Shanghai) CO LTD
 * SPDX-License-Identifier: LicenseRef-Special-License
 */
```

Dedicated LicenseRef-Included custom license identifier can be used to express a situation when the custom license is included directly in the source file.

```c
/*
 * SPDX-FileCopyrightText: 2015-2023 Espressif Systems (Shanghai) CO LTD
 * SPDX-License-Identifier: LicenseRef-Included
 * <Full custom license text>
 */
```

The configuration stored in tools/ci/check_copyright_config.yaml offers features useful for third party licenses:

- A different license can be defined for the files part of a third party library.
- The check for a selected set of files can be permanently disabled. Please use this option with care and only in cases when none of the other options are suitable.
7.5.8 ESP-IDF Tests with Pytest Guide

This documentation is a guide that introduces the following aspects:

1. The basic idea of different test types in ESP-IDF
2. How to apply the pytest framework to the test python scripts to make sure the apps are working as expected.
3. ESP-IDF CI target test process
4. Run ESP-IDF tests with pytest locally
5. Tips and tricks on pytest

Disclaimer

In ESP-IDF, we use the following plugins by default:

- pytest-embedded with default services esp, idf
- pytest-rerunfailures

All the introduced concepts and usages are based on the default behavior in ESP-IDF. Not all of them are available in vanilla pytest.

Installation

All dependencies could be installed by running the install script with the `--enable-pytest` argument, e.g.,

```
$ install.sh --enable-pytest
```

Common Issues During Installation

**No Package ‘dbus-1’ found** If you’re facing an error message like:

```
configure: error: Package requirements (dbus-1 >= 1.8) were not met:
No package 'dbus-1' found
Consider adjusting the PKG_CONFIG_PATH environment variable if you
installed software in a non-standard prefix.
```

If you’re running under ubuntu system, you may need to run:

```
sudo apt-get install libdbus-glib-1-dev
```

or

```
sudo apt-get install libdbus-1-dev
```

For other linux distros, you may Google the error message and find the solution. This issue could be solved by installing the related header files.

**Invalid command ‘bdist_wheel’** If you’re facing an error message like:

```
error: invalid command 'bdist_wheel'
```

You may need to run:

```
python -m pip install -U pip
```

Or
python -m pip install wheel

Before running the pip commands, please make sure you’re using the IDF python virtual environment.

Basic Concepts

Component-based Unit Tests  Component-based unit tests are our recommended way to test your component. All the test apps should be located under `${IDF_PATH}/components/<COMPONENT_NAME>/test_apps`. For example:

```
components/
  └── my_component/
      ├── include/
      │   └── ...
      ├── test_apps/
      │   └── test_app_1
      │       └── main/
      │           └── ...
      │           └── CMakeLists.txt
      │           └── pytest_my_component_app_1.py
      │       └── test_app_2
      │           └── ...
      │           └── pytest_my_component_app_2.py
      │       └── parent_folder
      │           └── test_app_3
      │               └── ...
      │               └── pytest_my_component_app_3.py
      │               └── ...
      └── my_component.c
```

Example Tests  Example Tests are tests for examplesthat are intended to demonstrate parts of the ESP-IDF functionality to our customers. All the test apps should be located under `${IDF_PATH}/examples`. For more information please refer to the Examples Readme.

For example:

```
examples/
  └── parent_folder/
      └── example_1/
          └── main/
              └── ...
          └── CMakeLists.txt
          └── pytest_example_1.py
```

Custom Tests  Custom Tests are tests that aim to run some arbitrary test internally. They are not intended to demonstrate the ESP-IDF functionality to our customers in any way. All the test apps should be located under `${IDF_PATH}/tools/test_apps`. For more information please refer to the Custom Test Readme.

Pytest in ESP-IDF

Pytest Execution Process
1. Bootstrapping Phase
   Create session-scoped caches:
   - port-target cache
   - port-app cache

2. Collection Phase
   1. Get all the python files with the prefix pytest_
   2. Get all the test functions with the prefix test_
   3. Apply the params, and duplicate the test functions.
   4. Filter the test cases with CLI options. Introduced detailed usages here.

3. Test Running Phase
   1. Construct the fixtures. In ESP-IDF, the common fixtures are initialized in this order:
      1. pexpect_proc: pexpect instance
      2. app: IdfApp instance
         The information of the app, like sdkconfig, flash_files, partition_table, etc., would be parsed at this phase.
      3. serial: IdfSerial instance
         The port of the host which connected to the target type parsed from the app would be auto-detected.
         The flash files would be auto flashed.
      4. dut: IdfDut instance
   2. Run the real test function
   3. Deconstruct the fixtures in this order:
      1. dut
         1. close the serial port
      2. (Only for apps with unity test framework) generate junit report of the unity test cases
      3. serial
      4. app
      4. pexpect_proc: Close the file descriptor
   4. (Only for apps with unity test framework)
      Raise AssertionError when detected unity test failed if you call dut.
      expect_from Unity_output() in the test function.

4. Reporting Phase
   1. Generate junit report of the test functions
   2. Modify the junit report test case name into ESP-IDF test case ID format: <target>.<config>.<test function name>

5. Finalizing Phase (Only for apps with unity test framework)
   Combine the junit reports if the junit reports of the unity test cases are generated.

Getting Started Example  This code example is taken from pytest_console_basic.py.

```python
@pytest.mark.esp32
@pytest.mark.esp32c3
@ pytest.mark.generic
@ pytest.mark.parametrize('config', [ 'history', 'nohistory', ], indirect=True)
def test_console_advanced(config: str, dut: IdfDut) -> None:
    if config == 'history':
        dut.expect('Command history enabled')
    elif config == 'nohistory':
        dut.expect('Command history disabled')
```

Let’s go through this simple test case line by line in the following subsections.

Use Markers to Specify the Supported Targets

```python
@ pytest.mark.esp32  # <-- support esp32
@ pytest.mark.esp32c3  # <-- support esp32c3
```

(continues on next page)
The above lines indicate that this test case supports target esp32 and esp32c3, the target board type should be “generic”. If you want to know what is the “generic” type refers to, you may run pytest --markers to get the detailed information of all markers.

**Note:** If the test case supports all officially ESP-IDF supported targets (You may check the value via `idf.py ⚶ list-targets`), you can use a special marker `supported_targets` to apply all of them in one line.

### Use Params to Specify the sdkconfig Files
You can use `pytest.mark.parametrize` with “config” to apply the same test to different apps with different sdkconfig files. For more information about `sdkconfig.ci.xxx` files, please refer to the Configuration Files section under this readme.

```python
@pytest.mark.parametrize('config', [
    'history', # <-- run with app built by sdkconfig.ci.history
    'nohistory', # <-- run with app built by sdkconfig.ci.nohistory
], indirect=True) # <-- `indirect=True` is required
```

Overall, this test function would be replicated to 4 test cases:

- esp32.history.test_console_advanced
- esp32.nohistory.test_console_advanced
- esp32c3.history.test_console_advanced
- esp32c3.nohistory.test_console_advanced

### Expect From the Serial output

```python
def test_console_advanced(config: str, dut: IdfDut) -> None:
    # The value of argument `config` is assigned by the parametrization.
    if config == 'history':
        dut.expect('Command history enabled')
    elif config == 'nohistory':
        dut.expect('Command history disabled')
```

When we’re using `dut.expect(...)`, the string would be compiled into regex at first, and then seeks through the serial output until the compiled regex is matched, or a timeout is exceeded. You may have to pay extra attention when the string contains regex keyword characters, like parentheses, or square brackets.

Actually using `dut.expect_exact(...)` here is better, since it would seek until the string is matched. For further reading about the different types of `expect` functions, please refer to the pytest-embedded Expecting documentation.

### Advanced Examples

#### Multi Dut Tests with the Same App

```python
@pytest.mark.esp32s2
@pytest.mark.esp32s3
@pytest.mark.usb_host
@pytest.mark.parametrize('count', [2], indirect=True)
def test_usb_host(dut: Tuple[IdfDut, IdfDut]) -> None:
    device = dut[0] # <-- assume the first dut is the device
    host = dut[1] # <-- and the second dut is the host
```
Chapter 7. Contributions Guide

After setting the param `count` to 2, all these fixtures are changed into tuples.

**Multi Dut Tests with Different Apps**  This code example is taken from `pytest_wifi_getting_started.py`.

```python
@pytest.mark.esp32
@ pytest.mark.multi_dut_generic
@pytest.mark.parametrize(
    'count, app_path', [
        (2,
         f'os.path.join(os.path.dirname(__file__), "softAP")||os.path.join(os.
         path.dirname(__file__), "station"))',
    ], indirect=True)

def test_wifi_getting_started(dut: Tuple[IdfDut, IdfDut]) -> None:
    softap = dut[0]
    station = dut[1]
```

Here the first dut was flashed with the app `softap`, and the second dut was flashed with the app `station`.

**Note:** Here the `app_path` should be set with absolute path. the `__file__` macro in python would return the absolute path of the test script itself.

**Multi Dut Tests with Different Apps, and Targets** This code example is taken from `pytest_wifi_getting_started.py`. As the comment says, for now it’s not running in the ESP-IDF CI.

```python
@ pytest.mark.parametrize(
    'count, app_path, target', [
        (2,
         f'os.path.join(os.path.dirname(__file__), "softAP")||os.path.join(os.
         path.dirname(__file__), "station"))',
    'esp32|esp32s2'),
],)

def test_wifi_getting_started(dut: Tuple[IdfDut, IdfDut]) -> None:
    softap = dut[0]
    station = dut[1]
```

Overall, this test function would be replicated to 2 test cases:

- softap with esp32 target, and station with esp32s2 target
- softap with esp32s2 target, and station with esp32 target

**Support different targets with different sdkconfig files** This code example is taken from `pytest_panic.py` as an advanced example.

```python
CONFIGS = [
    pytest.param('coredump_flash_bin_crc', marks=[pytest.mark.esp32, pytest.mark.
    esp32s2]),
    pytest.param('coredump_flash_elf_sha', marks=[pytest.mark.esp32]),  # sha256
    only supported on esp32
    pytest.param('coredump_uart_bin_crc', marks=[pytest.mark.esp32, pytest.mark.
    esp32s2]),
]
```

(continues on next page)
Use Custom Class  Usually, you can write a custom class in these conditions:

1. Add more reusable functions for a certain number of DUTs
2. Add custom setup and teardown functions in different phases described here

This code example is taken from panic/conftest.py

```python
class PanicTestDut(IdfDut):

@ pytest.fixture(scope='module')
def monkeypatch_module(request: FixtureRequest) -> MonkeyPatch:
  mp = MonkeyPatch()
  request.addfinalizer(mp.undo)
  return mp

@ pytest.fixture(scope='module', autouse=True)
def replace_dut_class(monkeypatch_module: MonkeyPatch) -> None:
  monkeypatch_modulesetattr('pytest_embedded_idf.dut.IdfDut', PanicTestDut)

monkeypatch_module provide a module-scoped monkeypatch fixture.
replace_dut_class is a module-scoped autouse fixture. This function replaces the IdfDut class with your custom class.

Mark Flaky Tests  Sometimes, our test is based on ethernet or wifi. The network may cause the test flaky. We could mark the single test case within the code repo.

This code example is taken from pytest_esp_eth.py

```python
@ pytest.mark.flaky(reruns=3, reruns_delay=5)
def test_esp_eth_ip101(dut: IdfDut) -> None:

This flaky marker means that if the test function failed, the test case would rerun for a maximum of 3 times with 5 seconds delay.

Mark Known Failure Cases  Sometimes a test couldn’t pass for the following reasons:

- Has a bug
- The success ratio is too low because of environment issue, such as network issue. Retry couldn’t help

Now you may mark this test case with marker xfail with a user-friendly readable reason.

This code example is taken from pytest_panic.py

```python
@ pytest.mark.xfail('config.getvalue("target") == "esp32s2"', reason='raised _IllegalInstruction instead')
def test_cache_error(dut: PanicTestDut, config: str, test_func_name: str) -> None:

This marker means that if the test would be a known failure one on esp32s2.
**Mark Nightly Run Test Cases**  Some test cases are only triggered in nightly run pipelines due to a lack of runners.

```python
@ pytest.mark.nightly_run
```

This marker means that the test case would only be run with env var NIGHTLY_RUN or INCLUDE_NIGHTLY_RUN.

**Mark Temp Disabled in CI**  Some test cases which can pass locally may need to be temporarily disabled in CI due to a lack of runners.

```python
@ pytest.mark.temp_skip_ci(targets=['esp32', 'esp32s2'], reason='lack of runners')
```

This marker means that the test case could still be run locally with pytest --target esp32, but will not run in CI.

**Run Unity Test Cases**  For component-based unit test apps, one line could do the trick to run all single-board test cases, including normal test cases and multi-stage test cases:

```python
def test_component_ut(dut: IdfDut):
    dut.run_all_single_board_cases()
```

It would also skip all the test cases with [ignore] mark.

If you need to run a group of test cases, you may run:

```python
def test_component_ut(dut: IdfDut):
    dut.run_all_single_board_cases(group='psram')
```

It would trigger all test cases with module name [psram].

You may also see that there are some test scripts with the following statements, which are deprecated. Please use the suggested one as above.

```python
def test_component_ut(dut: IdfDut):
    dut.expect_exact('Press ENTER to see the list of tests')
    dut.write('*')
    dut.expect_unity_test_output()
```

For further reading about our unit testing in ESP-IDF, please refer to our unit testing guide.

**Run the Tests in CI**

The workflow in CI is simple, build jobs -> target test jobs.

**Build Jobs**

**Build Job Names**

- Component-based Unit Tests: `build_pytest_components_<target>`
- Example Tests: `build_pytest_examples_<target>`
- Custom Tests: `build_pytest_test_apps_<target>`

**Build Job Commands**  The command used by CI to build all the relevant tests is: `python $IDF_PATH/tools/ci/ci_build_apps.py <parent_dir> --target <target> -vv --pytest-apps`

All apps which supported the specified target would be built with all supported sdkconfig files under `build_<target>_<config>`.
For example, if you run `python $IDF_PATH/tools/ci/ci_build_apps.py $IDF_PATH/examples/system/console/basic --target esp32 --pytest-apps` the folder structure would be like this:

```
basic
|-- build_esp32_history/
|   |-- ...
|-- build_esp32_nohistory/
|   |-- ...
|-- main/
|   |-- CMakeLists.txt
|   |-- pytest_console_basic.py
|   |-- ...
```

All the binaries folders would be uploaded as artifacts under the same directories.

**Target Test Jobs**

**Target Test Job Names**

- Component-based Unit Tests: `component_ut_pytest_<target>_<test_env>`
- Example Tests: `example_test_pytest_<target>_<test_env>`
- Custom Tests: `test_app_test_pytest_<target>_<test_env>`

**Target Test Job Commands** The command used by CI to run all the relevant tests is: `pytest <parent_dir> --target <target> -m <test_env_marker>`

All test cases with the specified target marker and the test env marker under the parent folder would be executed.

The binaries in the target test jobs are downloaded from build jobs, the artifacts would be placed under the same directories.

**Run the Tests Locally**

First you need to install ESP-IDF with additional python requirements:

```
$ cd $IDF_PATH
$ bash install.sh --enable-pytest
$ . ./export.sh
```

By default, the `pytest` script will look for the build directory in this order:

- `build_<target>_<sdkconfig>`
- `build_<target>`
- `build_<sdkconfig>`
- `build`

Which means, the simplest way to run `pytest` is calling `idf.py build`.

For example, if you want to run all the esp32 tests under the `$IDF_PATH/examples/get-started/hello_world` folder, you should run:

```
$ cd examples/get-started/hello_world
$ idf.py build
$ pytest --target esp32
```

If you have multiple `sdkconfig` files in your test app, like those `sdkconfig.ci.*` files, the simple `idf.py build` won’t apply the extra `sdkconfig` files. Let’s take `$IDF_PATH/examples/system/console/basic` as an example.

If you want to test this app with config history, and build with `idf.py build`, you should run
If you want to build and test with all sdkconfig files at the same time, you should use our CI script as an helper script:

```
$ cd examples/system/console/basic
$ python $IDF_PATH/tools/ci/ci_build_apps.py --target esp32 -vv --pytest-apps

The app with sdkconfig.ci.history will be built in build_esp32_history, and the app with sdkconfig.ci.nohistory will be built in build_esp32_nohistory. pytest --target esp32 will run tests on both apps.
```

**Tips and Tricks**

**Filter the Test Cases**

- filter by target with `pytest --target <target>`
  - pytest would run all the test cases that support specified target.
- filter by sdkconfig file with `pytest --sdkconfig <sdkconfig>`
  - if `<sdkconfig>` is default, pytest would run all the test cases with the sdkconfig file `sdkconfig.defaults`.
  - In other cases, pytest would run all the test cases with sdkconfig file `sdkconfig.ci.<sdkconfig>`.

**Add New Markers**

We’re using two types of custom markers, target markers which indicate that the test cases should support this target, and env markers which indicate that the test case should be assigned to runners with these tags in CI.

You can add new markers by adding one line under the `${IDF_PATH}/conftest.py`. If it’s a target marker, it should be added into `TARGET_MARKERS`. If it’s a marker that specifies a type of test environment, it should be added into `ENV_MARKERS`. The grammar should be: `<marker_name>: <marker_description>`.

**Generate JUnit Report**

You can call pytest with `--junitxml <filepath>` to generate the JUnit report. In ESP-IDF, the test case name would be unified as “<target>.<config>.<function_name>”.

**Skip Auto Flash Binary**

Skipping auto-flash binary every time would be useful when you’re debugging your test script.

You can call pytest with `--skip-autoflash y` to achieve it.

**Record Statistics**

Sometimes you may need to record some statistics while running the tests, like the performance test statistics.

You can use `record_xml_attribute` fixture in your test script, and the statistics would be recorded as attributes in the JUnit report.

**Logging System**

Sometimes you may need to add some extra logging lines while running the test cases.

You can use `python logging module` to achieve this.

**Useful Logging Functions (as Fixture)**
**log_performance**

```python
def test_hello_world(
    dut: IdfDut,
    log_performance: Callable[[str, object], None],
) -> None:
    log_performance('test', 1)
```

The above example would log the performance item with pre-defined format: “[performance][test]: 1” and record it under the *properties* tag in the junit report if --junitxml <filepath> is specified. The junit test case node would look like:

```xml
<testcase
classname="examples.get-started.hello_world.pytest_hello_world"
file="examples/get-started/hello_world/pytest_hello_world.py"
line="13"
name="esp32.
default.test_hello_world"
time="8.389">
    <properties>
        <property
            name="test"
            value="1">
    </properties>
</testcase>
```

**check_performance** We provide C macros TEST_PERFORMANCE_LESS_THAN and TEST_PERFORMANCE_GREATER_THAN to log the performance item and check if the value is in the valid range. Sometimes the performance item value could not be measured in C code, so we also provide a python function for the same purpose. Please note that using C macros is the preferred approach, since the python function couldn’t recognize the threshold values of the same performance item under different ifdef blocks well.

```python
def test_hello_world(
    dut: IdfDut,
    check_performance: Callable[[str, float, str], None],
) -> None:
    check_performance('RSA_2048KEY_PUBLIC_OP', 123, 'esp32')
    check_performance('RSA_2048KEY_PUBLIC_OP', 19001, 'esp32')
```

The above example would first get the threshold values of the performance item RSA_2048KEY_PUBLIC_OP from components/idf_test/include/idf_performance.h and the target-specific one components/idf_test/include/esp32/idf_performance_target.h, then check if the value reached the minimum limit or exceeded the maximum limit.

Let’s assume the value of IDF_PERFORMANCE_MAX_RSA_2048KEY_PUBLIC_OP is 19000. so the first check_performance line would pass and the second one would fail with warning: [Performance] RSA_2048KEY_PUBLIC_OP value is 19001, doesn’t meet pass standard 19000.0

**Further Readings**

- pytest documentation: https://docs.pytest.org/en/latest/contents.html
- pytest-embedded documentation: https://docs.espressif.com/projects/pytest-embedded/en/latest/
Chapter 8

ESP-IDF Versions

The ESP-IDF GitHub repository is updated regularly, especially the master branch where new development takes place.

For production use, there are also stable releases available.

8.1 Releases

The documentation for the current stable release version can always be found at this URL:

Documentation for the latest version (master branch) can always be found at this URL:

The full history of releases can be found on the GitHub repository Releases page. There you can find release notes, links to each version of the documentation, and instructions for obtaining each version.

8.2 Which Version Should I Start With?

- For production purposes, use the current stable version. Stable versions have been manually tested, and are updated with “bugfix releases” which fix bugs without changing other functionality (see Versioning Scheme for more details). Every stable release version can be found on the Releases page.
- For prototyping, experimentation or for developing new ESP-IDF features, use the latest version (master branch in Git). The latest version in the master branch has all the latest features and has passed automated testing, but has not been completely manually tested ( “bleeding edge” ).
- If a required feature is not yet available in a stable release, but you do not want to use the master branch, it is possible to check out a pre-release version or a release branch. It is recommended to start from a stable version and then follow the instructions for Updating to a Pre-Release Version or Updating to a Release Branch.
- If you plan to use another project which is based on ESP-IDF, please check the documentation of that project to determine the version(s) of ESP-IDF it is compatible with.

See Updating ESP-IDF if you already have a local copy of ESP-IDF and wish to update it.

8.3 Versioning Scheme

ESP-IDF uses Semantic Versioning. This means that:
• Major Releases, like v3.0, add new functionality and may change functionality. This includes removing deprecated functionality.
  If updating to a new major release (for example, from v2.1 to v3.0), some of your project’s code may need updating and functionality may need to be re-tested. The release notes on the Releases page include lists of Breaking Changes to refer to.
• Minor Releases like v3.1 add new functionality and fix bugs but will not change or remove documented functionality, or make incompatible changes to public APIs.
  If updating to a new minor release (for example, from v3.0 to v3.1), your project’s code does not require updating, but you should re-test your project. Pay particular attention to the items mentioned in the release notes on the Releases page.
• Bugfix Releases like v3.0.1 only fix bugs and do not add new functionality.
  If updating to a new bugfix release (for example, from v3.0 to v3.0.1), you do not need to change any code in your project, and you only need to re-test the functionality directly related to bugs listed in the release notes on the Releases page.

8.4 Support Periods

Each ESP-IDF major and minor release version has an associated support period. After this period, the release is End of Life and no longer supported.

The ESP-IDF Support Period Policy explains this in detail, and describes how the support periods for each release are determined.

Each release on the Releases page includes information about the support period for that particular release.

As a general guideline:

• If starting a new project, use the latest stable release.
• If you have a GitHub account, click the “Watch” button in the top-right of the Releases page and choose “Releases only”. GitHub will notify you whenever a new release is available. Whenever a bug fix release is available for the version you are using, plan to update to it.
• If possible, periodically update the project to a new major or minor ESP-IDF version (for example, once a year.) The update process should be straightforward for Minor updates, but may require some planning and checking of the release notes for Major updates.
• Always plan to update to a newer release before the release you are using becomes End of Life.

Each ESP-IDF major and minor release (V4.1, V4.2, etc) is supported for 30 months after the initial stable release date.

Supported means that the ESP-IDF team will continue to apply bug fixes, security fixes, etc to the release branch on GitHub, and periodically make new bugfix releases as needed.

Support period is divided into “Service” and “Maintenance” period:

<table>
<thead>
<tr>
<th>Period</th>
<th>Duration</th>
<th>Recommended for new projects?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service</td>
<td>12 months</td>
<td>Yes</td>
</tr>
<tr>
<td>Maintenance</td>
<td>18 months</td>
<td>No</td>
</tr>
</tbody>
</table>

During the Service period, bugfixes releases are more frequent. In some cases, support for new features may be added during the Service period (this is reserved for features which are needed to meet particular regulatory requirements or standards for new products, and which carry a very low risk of introducing regressions.)

During the Maintenance period, the version is still supported but only bugfixes for high severity issues or security issues will be applied.

Using an “In Service” version is recommended when starting a new project.

Users are encouraged to upgrade all projects to a newer ESP-IDF release before the support period finishes and the release becomes End of Life (EOL). It is our policy to not continue fixing bugs in End of Life releases.
Pre-release versions (betas, previews, -rc and -dev versions, etc) are not covered by any support period. Sometimes a particular feature is marked as “Preview” in a release, which means it is also not covered by the support period. The ESP-IDF Programming Guide has information about the different versions of ESP-IDF (major, minor, bugfix, etc).

8.5 Checking the Current Version

The local ESP-IDF version can be checked by using `idf.py`:

```
idf.py --version
```

The ESP-IDF version is also compiled into the firmware and can be accessed (as a string) via the macro `IDF_VER`. The default ESP-IDF bootloader will print the version on boot (the version information is not always updated if the code in the GitHub repo is updated, it only changes if there is a clean build or if that particular source file is recompiled).

If writing code that needs to support multiple ESP-IDF versions, the version can be checked at compile time using compile-time macros.

Examples of ESP-IDF versions:
### Chapter 8. ESP-IDF Versions

#### Version String | Meaning
--- | ---
`v3.2-dev-306-gbeb3611ca` | Master branch pre-release. 
- `v3.2-dev` - in development for version 3.2. 
- `306` - number of commits after v3.2 development started. 
- `gbeb3611ca` - commit identifier. 

`v3.0.2` | Stable release, tagged v3.0.2. 

`v3.1-beta1-75-g346d6b0ea` | Beta version in development (on a release branch). 
- `v3.1-beta1` - pre-release tag. 
- `75` - number of commits after the pre-release beta tag was assigned. 
- `g346d6b0ea` - commit identifier. 

`v3.0.1-dirty` | Stable release, tagged v3.0.1. 
- `dirty` means that there are modifications in the local ESP-IDF directory. 

### 8.6 Git Workflow

The development (Git) workflow of the Espressif ESP-IDF team is as follows:

- New work is always added on the master branch (latest version) first. The ESP-IDF version on master is always tagged with `-dev` (for “in development”), for example `v3.1-dev`. 
- Changes are first added to an internal Git repository for code review and testing but are pushed to GitHub after automated testing passes. 
- When a new version (developed on master) becomes feature complete and “beta” quality, a new branch is made for the release, for example `release/v3.1`. A pre-release tag is also created, for example `v3.1-beta1`. You can see a full list of branches and a list of tags on GitHub. Beta pre-releases have release notes which may include a significant number of Known Issues. 
- As testing of the beta version progresses, bug fixes will be added to both the master branch and the release branch. New features for the next release may start being added to master at the same time. 
- Once testing is nearly complete a new release candidate is tagged on the release branch, for example `v3.1-rc1`. This is still a pre-release version. 
- If no more significant bugs are found or reported, then the final Major or Minor Version is tagged, for example `v3.1`. This version appears on the Releases page. 
- As bugs are reported in released versions, the fixes will continue to be committed to the same release branch. 
- Regular bugfix releases are made from the same release branch. After manual testing is complete, a bugfix release is tagged (i.e. `v3.1.1`) and appears on the Releases page. 

### 8.7 Updating ESP-IDF

Updating ESP-IDF depends on which version(s) you wish to follow:

- *Updating to Stable Release* is recommended for production use.
Chapter 8. ESP-IDF Versions

- *Updating to Master Branch* is recommended for the latest features, development use, and testing.
- *Updating to a Release Branch* is a compromise between the first two.

**Note:** These guides assume that you already have a local copy of ESP-IDF cloned. To get one, check Step 2 in the *Getting Started* guide for any ESP-IDF version.

### 8.7.1 Updating to Stable Release

To update to a new ESP-IDF release (recommended for production use), this is the process to follow:

- Check the [Releases page](https://esp-idf.espressif.com) regularly for new releases.
- When a bugfix release for the version you are using is released (for example, if using v3.0.1 and v3.0.2 is released), check out the new bugfix version into the existing ESP-IDF directory.
- In Linux or macOS system, please run the following commands to update the local branch to vX.Y.Z:

```bash
cd $IDF_PATH
git fetch
git checkout vX.Y.Z
git submodule update --init --recursive
```

- In the Windows system, please replace `cd $IDF_PATH` with `cd %IDF_PATH%`.
- When major or minor updates are released, check the Release Notes on the releases page and decide if you want to update or to stay with your current release. Updating is via the same Git commands shown above.

**Note:** If you installed the stable release via zip file instead of using git, it might not be possible to update versions using the commands. In this case, update by downloading a new zip file and replacing the entire IDF_PATH directory with its contents.

### 8.7.2 Updating to a Pre-Release Version

It is also possible to `git checkout` a tag corresponding to a pre-release version or release candidate, the process is the same as *Updating to Stable Release*.

Pre-release tags are not always found on the [Releases page](https://esp-idf.espressif.com). Consult the list of tags on GitHub for a full list. Caveats for using a pre-release are similar to *Updating to a Release Branch*.

### 8.7.3 Updating to Master Branch

**Note:** Using Master branch means living “on the bleeding edge” with the latest ESP-IDF code.

To use the latest version on the ESP-IDF master branch, this is the process to follow:

- In Linux or macOS system, please run the following commands to check out to the master branch locally:

```bash
cd $IDF_PATH
git checkout master
git pull
git submodule update --init --recursive
```

- In the Windows system, please replace `cd $IDF_PATH` with `cd %IDF_PATH%`.
- Periodically, re-run `git pull` to pull the latest version of master. Note that you may need to change your project or report bugs after updating your master branch.
Chapter 8. ESP-IDF Versions

- To switch from master to a release branch or stable version, run `git checkout` as shown in the other sections.

**Important:** It is strongly recommended to regularly run `git pull` and then `git submodule update --init --recursive` so a local copy of master does not get too old. Arbitrary old master branch revisions are effectively unsupportable “snapshots” that may have undocumented bugs. For a semi-stable version, try *Updating to a Release Branch* instead.

### 8.7.4 Updating to a Release Branch

In terms of stability, using a release branch is part-way between using the master branch and only using stable releases. A release branch is always beta quality or better, and receives bug fixes before they appear in each stable release.

You can find a list of branches on GitHub.

For example, in Linux or macOS system, you can execute the following commands to follow the branch for ESP-IDF v3.1, including any bugfixes for future releases like v3.1.1, etc:

```
cd $IDF_PATH
git fetch
git checkout release/v3.1
git pull
git submodule update --init --recursive
```

In the Windows system, please replace `cd $IDF_PATH` with `cd %IDF_PATH%`.

Each time you `git pull` this branch, ESP-IDF will be updated with fixes for this release.

**Note:** There is no dedicated documentation for release branches. It is recommended to use the documentation for the closest version to the branch which is currently checked out.
Chapter 9

Resources

9.1 PlatformIO

PlatformIO is a cross-platform embedded development environment with out-of-the-box support for ESP-IDF.

Since ESP-IDF support within PlatformIO is not maintained by the Espressif team, please report any issues with PlatformIO directly to its developers in the official PlatformIO repositories.

A detailed overview of the PlatformIO ecosystem and its philosophy can be found in the official PlatformIO documentation.

9.1.1 What is PlatformIO?

PlatformIO is a cross-platform embedded development environment with out-of-the-box support for ESP-IDF.

9.1.2 Installation

- **PlatformIO IDE** is a toolset for embedded C/C++ development available on Windows, macOS and Linux platforms
- **PlatformIO Core (CLI)** is a command-line tool that consists of multi-platform build system, platform and library managers and other integration components. It can be used with a variety of code development environments and allows integration with cloud platforms and web services
9.1.3 Configuration

Please go through the official PlatformIO configuration guide for ESP-IDF.

9.1.4 Tutorials

• ESP-IDF and ESP32-DevKitC: debugging, unit testing, project analysis

9.1.5 Project Examples

Please check ESP-IDF page in the official PlatformIO documentation

9.1.6 Next Steps

Here are some useful links for exploring the PlatformIO ecosystem:

• Learn more about integrations with other IDEs/Text Editors
• Get help from PlatformIO community

9.2 Useful Links

• The esp32.com forum is a place to ask questions and find community resources.
• Check the Issues section on GitHub if you find a bug or have a feature request. Please check existing Issues before opening a new one.
• A comprehensive collection of solutions, practical applications, components and drivers based on ESP-IDF is available in ESP IoT Solution repository. In most of cases descriptions are provided both in English and in 中文.
• To develop applications using Arduino platform, refer to Arduino core for the ESP32, ESP32-S2 and ESP32-C3.
• Several books have been written about ESP32 and they are listed on Espressif web site.
• If you’re interested in contributing to ESP-IDF, please check the Contributions Guide.
• For additional ESP32 product related information, please refer to documentation section of Espressif site.
• Download latest and previous versions of this documentation in PDF and HTML format.
Chapter 10

Copyrights and Licenses

10.1 Software Copyrights

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Some examples use external components which are not Apache licensed, please check the copyright description in each example source code.

10.1.1 Firmware Components

These third party libraries can be included into the application (firmware) produced by ESP-IDF.

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- Xtensa header files are Copyright (C) 2013 Tensilica Inc and are licensed under the MIT License as reproduced in the individual header files.
- Original parts of FreeRTOS (components/freertos) are Copyright (C) 2017 Amazon.com, Inc. or its affiliates are licensed under the MIT License, as described in license.txt.
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- wpa_supplicant Copyright (c) 2003-2022 Jouni Malinen <j@w1.fi> and contributors and licensed under the BSD license.
- Fast PBKDF2 Copyright (c) 2015 Joseph Birr-Pixton and licensed under CC0 Public Domain Dedication license.
- FreeBSD net80211 Copyright (c) 2004-2008 Sam Leffler, Erno Consulting and licensed under the BSD license.
- argtable3 argument parsing library Copyright (C) 1998-2001,2003-2011,2013 Stewart Heitmann and licensed under 3-clause BSD license. argtable3 also includes the following software components. For details, please see argtable3 LICENSE file.
  - C Hash Table library, Copyright (c) 2002, Christopher Clark and licensed under 3-clause BSD license.
  - The Better String library, Copyright (c) 2014, Paul Hsieh and licensed under 3-clause BSD license.
  - TCL library, Copyright the Regents of the University of California, Sun Microsystems, Inc., Scriptics Corporation, ActiveState Corporation and other parties, and licensed under TCL/TK License.
- linenoise line editing library Copyright (c) 2010-2014 Salvatore Sanfilippo, Copyright (c) 2010-2013 Pieter Noordhuis, licensed under 2-clause BSD license.
- FatFS library, Copyright (C) 2017 ChaN, is licensed under a BSD-style license.
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- **Mbed TLS** library, Copyright (C) 2006-2018 ARM Limited, is licensed under Apache License 2.0 as described in LICENSE file.
- **SPIFFS** library, Copyright (c) 2013-2017 Peter Andersson, is licensed under MIT license as described in LICENSE file.
- **SD/MMC driver** is derived from OpenBSD SD/MMC driver, Copyright (c) 2006 Uwe Stuehler, and is licensed under BSD license.
- **ESP-MQTT** MQTT Package (contiki-mqtt) - Copyright (c) 2014, Stephen Robinson, MQTT-ESP - Tuan PM <tuanpm at live dot com> is licensed under Apache License 2.0 as described in LICENSE file.
- **BLE Mesh** is adapted from Zephyr Project, Copyright (c) 2017-2018 Intel Corporation and licensed under Apache License 2.0.
- **mynewt-nimble** Apache Mynewt NimBLE, Copyright 2015-2018, The Apache Software Foundation, is licensed under Apache License 2.0 as described in LICENSE file.
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- **openthread** Copyright (c) The OpenThread Authors, is licensed under BSD License as described in LICENSE file.
- **UBSAN runtime** — Copyright (c) 2016, Linaro Limited and Jiří Zárevůcky, licensed under the BSD 2-clause license.
- **HTTP Parser** Based on src/http/ngx_http_parse.c from NGINX copyright Igor Sysoev. Additional changes are licensed under the same terms as NGINX and Joyent, Inc. and other Node contributors. For details please check LICENSE file.
- **SEGGER SystemView** target-side library, Copyright (c) 1995-2021 SEGGER Microcontroller GmbH, is licensed under BSD 1-clause license.

### 10.1.2 Documentation

- HTML version of the ESP-IDF Programming Guide uses the Sphinx theme sphinx_idf_theme, which is Copyright (c) 2013-2020 Dave Snider, Read the Docs, Inc. & contributors, and Espressif Systems (Shanghai) CO., LTD. It is based on sphinx_rtd_theme. Both are licensed under MIT license.

### 10.2 ROM Source Code Copyrights

ESP32, ESP32-S and ESP32-C Series SoCs mask ROM hardware includes binaries compiled from portions of the following third party software:

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- **Xtensa libhal**, Copyright (c) Tensilica Inc and licensed under the MIT license (see below).
- **TinyBasic Plus**, Copyright Mike Field & Scott Lawrence and licensed under the MIT license (see below).
- **miniz**, by Rich Geldreich - placed into the public domain.
- **wpa_supplicant** Copyright (c) 2003-2022 Jouni Malinen <j@w1.fi> and contributors and licensed under the BSD license.
- **TJpgDec** Copyright (C) 2011, ChaN, all right reserved. See below for license.

### 10.3 Xtensa libhal MIT License

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10.5 TJpgDec License

TJpgDec - Tiny JPEG Decompressor R0.01 (C)ChaN, 2011 The TJpgDec is a generic JPEG decompressor module for tiny embedded systems. This is a free software that opened for education, research and commercial developments under license policy of following terms.

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Chapter 11

About

This is documentation of ESP-IDF, the framework to develop applications for ESP32 chip by Espressif.

The ESP32 is 2.4 GHz Wi-Fi and Bluetooth combo, which integrates one or two Xtensa® 32-bit LX6 CPU, with up to 600 DMIPS processing power.

![Fig. 1: Espressif IoT Integrated Development Framework](image)

The ESP-IDF, Espressif IoT Development Framework, provides toolchain, API, components and workflows to develop applications for ESP32 using Windows, Linux and macOS operating systems.
Chapter 12

Switch Between Languages

The ESP-IDF Programming Guide is now available in two languages. Please refer to the English version if there is any discrepancy.

- English
- Chinese

You can easily change from one language to another by clicking the language link you can find at the top of every document that has a translation.
Symbols

_index__ESP_LOG_EARLY_ENABLED (C macro), 2161
_ip_addr (C++ struct), 1026
_ip_addr::ip4 (C++ member), 1026
_ip_addr::ip6 (C++ member), 1026
_ip_addr::type (C++ member), 1027
_ip_addr::u_addr (C++ member), 1026
[anonymous] (C++ enum), 492, 528, 606, 1351, 2220
[anonymous]::ESP_BLE_MESH_SERVER_FLAG_MAX (C++ enumerator), 606
[anonymous]::ESP_BLE_MESH_SERVER_TRANS_TIMER_START (C++ enumerator), 606
[anonymous]::ESP_BLE_SCA_100PPM (C++ enumerator), 528
[anonymous]::ESP_BLE_SCA_150PPM (C++ enumerator), 528
[anonymous]::ESP_BLE_SCA_20PPM (C++ enumerator), 529
[anonymous]::ESP_BLE_SCA_250PPM (C++ enumerator), 528
[anonymous]::ESP_BLE_SCA_30PPM (C++ enumerator), 528
[anonymous]::ESP_BLE_SCA_50PPM (C++ enumerator), 528
[anonymous]::ESP_BLE_SCA_50PPM (C++ enumerator), 528
[anonymous]::ESP_BLE_SCA_75PPM (C++ enumerator), 528
[anonymous]::ESP_ERR_FLASH_NO_RESPONSE (C++ enumerator), 1351
[anonymous]::ESP_ERR_FLASH_SIZE_NOT_MATCH (C++ enumerator), 1351
[anonymous]::ESP_ERR_SLEEP_REJECT (C++ enumerator), 2220
[anonymous]::ESP_ERR_SLEEP_TOO_SHORT_SLEEP_FUNCTION (C++ enumerator), 2220
[anonymous]::ESP_HIDD_BOOT_REPORT_SIZE_KEYBOARD (C++ enumerator), 492
[anonymous]::ESP_HIDD_BOOT_REPORT_SIZE_MOUSE (C++ enumerator), 492

A

adc_atten_t (C++ enum), 1040
adc_atten_t::ADC_ATTEN_DB_0 (C++ enumerator), 1040

C

CHIPE_NTE BLE (C macro), 2172
CHIPEreature BT (C macro), 2172
CHIPEeature EMB FLASH (C macro), 2172
CHIPEeature EMB PSRAM (C macro), 2172
CHIPEeature IEEE802154 (C macro), 2172
CHIPEeature WIFI BG (C macro), 2172
CONFIG_ESPTOOLPY_FLASHSIZE, 1329
CONFIG_FEATURE_CACHE_TX_BUF_BIT
(C macro), 895
CONFIG_FEATURE_FTM_INITIATOR_BIT
(C macro), 895
CONFIG_FEATURE_FTM_RESPONDER_BIT
(C macro), 895
CONFIG_FEATURE_WPA3_SAE_BIT (C macro), 895
CONFIG_HEAP_TRACING_STACK_DEPTH
(C macro), 2136

D

dac_channel_mask t (C enum), 1078

dac_channel_mask t::DAC_CHANNEL_MASK_ALL
(C enum), 1078

dac_channel_mask t::DAC_CHANNEL_MASK_CH0
(C enum), 1078

dac_channel_mask t::DAC_CHANNEL_MASK_CH1
(C enum), 1078

dac_channel_t (C enum), 1079

dac_channel_t::DAC_CHAN_0 (C enum), 1079

dac_channel_t::DAC_CHAN_1 (C enum), 1079

dac_channel_t::DAC_CHANNEL_1 (C enum), 1079

dac_channel_t::DAC_CHANNEL_2 (C enum), 1079

dac_continuous_channel_mode t (C enum), 1078

dac_continuous_channel_mode t::DAC_CHANNEL_MODE_ACTIVE
(C enum), 1079

dac_continuous_channel_mode t::DAC_CHANNEL_MODE_SLEEP
(C enum), 1079

dac_continuous_config t (C struct), 1076

dac_continuous_config t::buf_size
(C member), 1076

dac_continuous_config t::chan_mask
(C member), 1076

dac_continuous_config t::chan_mode
(C member), 1077

dac_continuous_config t::clk_src (C member), 1077

dac_continuous_config t::desc_num
(C member), 1076

dac_continuous_config t::freq_hz (C member), 1076

dac_continuous_config t::offset (C member), 1077

dac_continuous_del_channels (C function), 1073

dac_continuous_digi_clk_src t (C type), 1078

dac_continuous_disable (C function), 1073

dac_continuous_enable (C function), 1073

dac_continuous_handle t (C type), 1078

dac_continuous_new_channels (C function), 1073

dac_continuous_register_event_callback
(C function), 1075

dac_continuous_start_async writing
(C function), 1075

dac_continuous_stop_async writing
(C function), 1075

dac_continuous_write (C function), 1074

dac_continuous_write_asynchronously
(C function), 1075

dac_continuous_write_cyclically
(C function), 1074

dac_cosine_atten t (C enum), 1079

dac_cosine_atten t::DAC_COSINE_ATTEN_DB_0
(C macro), 1078

dac_continuous_write (C function), 1074

dac_continuous_write_asynchronously
(C function), 1075

dac_continuous_write_cyclically
(C function), 1074

dac_channel_mask t (C enum), 1078

dac_channel_mask_t::DAC_CHANNEL_MASK_ALL
(C enum), 1078

dac_channel_mask_t::DAC_CHANNEL_MASK_CH0
(C enum), 1078

dac_channel_mask_t::DAC_CHANNEL_MASK_CH1
(C enum), 1078

dac_channel_t (C enum), 1079

dac_channel_t::DAC_CHAN_0 (C enum), 1079

dac_channel_t::DAC_CHAN_1 (C enum), 1079

dac_channel_t::DAC_CHANNEL_1 (C enum), 1079

dac_channel_t::DAC_CHANNEL_2 (C enum), 1079

dac_continuous_channel_mode t (C enum), 1078

dac_continuous_channel_mode t::DAC_CHANNEL_MODE_A
(C enum), 1079

dac_continuous_channel_mode t::DAC_CHANNEL_MODE_SLEEP
(C enum), 1079

dac_continuous_config t (C struct), 1076

dac_continuous_config t::buf_size
(C member), 1076

dac_continuous_config t::chan_mask
(C member), 1076

dac_continuous_config t::chan_mode
(C member), 1077

dac_continuous_config t::clk_src (C member), 1077

dac_continuous_config t::desc_num
(C member), 1076

dac_continuous_config t::freq_hz (C member), 1076

dac_continuous_config t::offset (C member), 1077

dac_continuous_del_channels (C function), 1073

dac_continuous_digi_clk_src t (C type), 1078

dac_continuous_disable (C function), 1073

dac_continuous_enable (C function), 1073

dac_continuous_handle t (C type), 1078

dac_continuous_new_channels (C function), 1073

dac_continuous_register_event_callback
(C function), 1075

dac_continuous_start_async writing
(C function), 1075

dac_continuous_stop_async writing
(C function), 1075

dac_continuous_write (C function), 1074

dac_continuous_write_asynchronously
(C function), 1075

dac_continuous_write_cyclically
(C function), 1074

dac_cosine_atten t (C enum), 1079

dac_cosine_atten t::DAC_COSINE_ATTEN_DB_0
(C macro), 1078

bridge_config::max_fdb_sta_entries
(C member), 1019
bridge_config::max_ports (C member), 1019
bridge_config_t (C type), 1022
BT_CONTROLLER_INIT_CONFIG_DEFAULT (C macro), 528
BT_OCTET32 (C type), 596
BT_OCTET32_LEN (C macro), 577
BT_SPP_DEFAULT_CONFIG (C macro), 440
BTH_MAX_DSC_LEN (C macro), 504
btm_query_reason (C enum), 947
btm_query_reason::REASON_BANDWIDTH
(C enum), 947
btm_query_reason::REASON_DELAY (C enum), 947
btm_query_reason::REASON_FRAME_LOSS
(C enum), 948
btm_query_reason::REASON_GRAY_ZONE
(C enum), 948
btm_query_reason::REASON_INTERFERENCE
(C enum), 948
btm_query_reason::REASON_LOAD_BALANCE
(C enum), 947
btm_query_reason::REASON_PREMIUM_AP
(C enum), 948
btm_query_reason::REASON_RETRANSMISSIONS
(C enum), 948
btm_query_reason::REASON_RSSI (C enum), 948
btm_query_reason::REASON_UNSPECIFIED
(C enum), 947
BX_JUMP_TYPE_DIRECT (C macro), 2261
BX_JUMP_TYPE_OVF (C macro), 2262
BX_JUMP_TYPE_ZERO (C macro), 2261

C

CHIP_FEATURE_BLE (C macro), 2172
CHIP_FEATURE_BT (C macro), 2172
CHIP_FEATURE_EMB_FLASH (C macro), 2172
CHIP_FEATURE_EMB_PSRAM (C macro), 2172
CHIP_FEATURE_IEEE802154 (C macro), 2172
CHIP_FEATURE_WIFI_BG (C macro), 2172
CONFIG_ESPTOOLPY_FLASHSIZE, 1329
CONFIG_FEATURE_CACHE_TX_BUF_BIT
(C macro), 895
CONFIG_FEATURE_FTM_INITIATOR_BIT
(C macro), 895
CONFIG_FEATURE_FTM_RESPONDER_BIT
(C macro), 895
CONFIG_FEATURE_WPA3_SAE_BIT (C macro), 895
CONFIG_HEAP_TRACING_STACK_DEPTH
(C macro), 2136
dac_oneshot_new_channel (C++ enumerator), 1079
dac_oneshot_del_channel (C++ function), 1077
dac_oneshot_config_t::chan_id (C++ member), 1072
default_http_buf_size (C macro), 173
default_dev_addr_flag (C macro), 578
default_dev_uuid_flag (C macro), 578
dpp_bootstrap_type (C++ enumerator), 951
dpp_bootstrap_type::dpp_bootstrap_nfc_uri (C++ enumerator), 951
dpp_bootstrap_type::dpp_bootstrap_pke (C++ enumerator), 951
dpp_bootstrap_type::dpp_bootstrap_qr_code (C++ enumerator), 951
dac_oneshot_config_t::atten (C++ member), 1072
dac_cosine_phase_t::DAC_COSINE_PHASE_180 (C++ function), 1886
dac_cosine_del_channel (C++ function), 1079
dac_cosine_config_t::phase (C++ member), 1079
dac_cosine_config_t::flags (C++ member), 1072
dac_cosine_config_t::force_set_freq (C++ member), 1072
dac_cosine_config_t::freq_hz (C++ member), 1072
dac_cosine_config_t::offset (C++ member), 1072
dac_cosine_config_t::phase (C++ member), 1072
dac_cosine_del_channel (C++ function), 1071
dac_cosine_handle_t (C++ type), 1073
dac_cosine_new_channel (C++ function), 1071
dac_cosine_phase_t (C++ enum), 1079
dac_cosine_phase_t::DAC_COSINE_PHASE_0 (C++ enumerator), 1080
dac_cosine_phase_t::DAC_COSINE_PHASE_180 (C++ enumerator), 1080
dac_cosine_start (C++ function), 1071
dac_cosine_stop (C++ function), 1072
dac_event_callbacks_t::on_convert_done (C++ member), 1077
dac_event_callbacks_t::on_stop (C++ member), 1077
dac_event_data_t::buf (C++ member), 1077
dac_event_data_t::buf_size (C++ member), 1077
dac_event_data_t::write_bytes (C++ member), 1077
dac_isr_callback_t (C++ type), 1078
dac_oneshot_config_t::struct (C++ type), 1071
dac_oneshot_config_t::chan_id (C++ member), 1071
dac_oneshot_del_channel (C++ function), 1070
dac_oneshot_handle_t (C++ type), 1071
dac_oneshot_new_channel (C++ function), 1070
dac_oneshot_output_voltage (C++ function), 1070
effect_action::eSetValueWithOverwrite (C++ enum), 2002
effect_action::eSetValueWithoutOverwrite (C++ enum), 2002
effect_action::eSetBits (C++ enum), 2002
effect_action::eSetValueWithoutOverwrite (C++ enum), 2003
effect_action::eSetValueWithOverwrite (C++ enum), 2003
Index

eSleepModeStatus::eStandardSleep (C++ struct), 404
esp_a2d_cb_param_t::a2d_prof_stat_param::init_state (C++ member), 405
esp_a2d_cb_param_t::a2d_prof_stat_param::init_prof_stat_param (C++ struct), 405
esp_a2d_cb_events::ESP_A2D_PROF_STATE_EVT (C++ member), 405
esp_a2d_cb_events::ESP_A2D_AUDIO_STATE_EVT (C++ member), 405
esp_a2d_cb_events::ESP_A2D_AUDIO_CFG_EVT (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_DISCONNECTED (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_DISCONNECTING (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_CONNECTED (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_CONNECTING (C++ member), 405
esp_a2d_discovery_rsn::ESP_A2D_DISC_RSN_NORMAL (C++ member), 405
esp_a2d_discovery_rsn::ESP_A2D_DISC_RSN_ABNORMAL (C++ member), 405
esp_a2d_disc_rsn::ESP_A2D_DISC_RSN_ABNORMAL (C++ member), 405
esp_a2d_disc_rsn::ESP_A2D_DISC_RSN_NORMAL (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_DISCONNECTED (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_DISCONNECTING (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_CONNECTED (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_CONNECTING (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_SBC (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_M24 (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_M12 (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_ATRAC (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_M24 (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_M12 (C++ member), 405
esp_a2d_connection::ESP_A2D_CIE_LEN_SBC (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_DISCONNECTED (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_DISCONNECTING (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_CONNECTED (C++ member), 405
esp_a2d_connection_state::ESP_A2D_CONNECTION_STATE_CONNECTING (C++ member), 405

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esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_CHAN_DOWN
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_ANGLE
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_9
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_8
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_7
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_6
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_5
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_4
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_3
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_2
esp_avrc_pt_cmd_t::ESP_AVRC_PT_CMD_0
(esp_avrc_pt_cmd_state_t::ESP_AVRC_PT_CMD_STATE_RELEASED)
(esp_avrc_pt_cmd_state_t::ESP_AVRC_PT_CMD_STATE_PRESSED)
(esp_avrc_psth_filter_t::ESP_AVRC_PSTH_FILTER_SUPPORTED_CMD)
(esp_avrc_psth_filter_t::ESP_AVRC_PSTH_FILTER_ALLOWED_CMD)
(esp_avrc_psth_bit_mask_t::bits)
(esp_avrc_psth_bit_mask_operation)
(esp_avrc_ps_shf_value_ids_t::ESP_AVRC_PS_SHUFFLE_OFF)
(esp_avrc_ps_shf_value_ids_t::ESP_AVRC_PS_SHUFFLE_GROUP)
(esp_avrc_ps_scn_value_ids_t::ESP_AVRC_PS_SCAN_OFF)
(esp_avrc_ps_scn_value_ids_t::ESP_AVRC_PS_SCAN_GROUP)
(esp_avrc_ps_scn_value_ids_t::ESP_AVRC_PS_SCAN_ALL)

Index
(C++ struct), 418
esp_avrc_tg_cb_param_t::avrc_tg_reg_ntf_param::event_id (C++ member), 418
esp_avrc_tg_cb_param_t::avrc_tg_reg_ntf_param (C++ struct), 418
esp_avrc_tg_cb_param_t::avrc_tg_psth_cmd_param::key_state (C++ member), 418
esp_avrc_tg_cb_param_t::avrc_tg_psth_cmd_param::key_code (C++ member), 418
esp_avrc_tg_cb_param_t::avrc_tg_conn_stat_param::remote_bda (C++ member), 418
esp_avrc_tg_cb_event_t::ESP_AVRC_TG_SET_PLAYER_APP_VALUE_EVT (C++ function), 413
esp_avrc_tg_cb_event_t::ESP_AVRC_TG_SET_ABSOLUTE_VOLUME_CMD_EVT (C++ function), 412
esp_avrc_tg_cb_event_t::ESP_AVRC_TG_REMOTE_FEATURES_EVT (C++ function), 412
esp_avrc_tg_reg_ntf_cap (C++ function), 412
esp_avrc_tg_deinit (C++ function), 412
esp_avrc_tg_init (C++ function), 412
esp_avrc_tg_set_abs_vol (C++ function), 413
esp_avrc_tg_set_app_value (C++ function), 413
esp_avrc_tg_send_rn_rsp (C++ function), 414
esp_avrc_tg_conn_stat (C++ member), 417
esp_avrc_tg_set_psth_cmd_filter (C++ function), 413
esp_avrc_tg_get_psth_cmd_filter (C++ function), 412
esp_avrc_tg_rmt_feats (C++ member), 417
esp_avrc_tg_set_abs_vol (C++ member), 417
esp_avrc_tg_set_app_value (C++ member), 417
esp_avrc_tg_t (C++ type), 420
esp_avrc_tg_deinit (C++ function), 412

Index
esp_ble_adv_data_type::ESP_BLE_AD_TYPE_NAME_SHORT
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_LE_SUPPORT_FEATURE
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_LE_SECURE_RANDOM
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_LE_SECURE_CONFIRM
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_LE_DEV_ADDR
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_INT_RANGE
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_INDOOR_POSITION
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_DEV_CLASS
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_CHAN_MAP_UPDATE
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_32SRV_PART
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_32SRV_CMPL
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_32SOL_SRV_UUID
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_32SERVICE_DATA
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_16SRV_PART
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_16SRV_CMPL
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_128SRV_PART
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_128SRV_CMPL
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_128SOL_SRV_UUID
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_128SERVICE_DATA
 esp_ble_adv_data_type::ESP_BLE_AD_MANUFACTURER_SPECIFIC_TYPE

esp_ble_adv_data_t::set_scan_rsp

esp_ble_adv_params_t::peer_addr_type
 esp_ble_adv_params_t::peer_addr

esp_ble_adv_filter_t::ADV_FILTER_ALLOW_SCAN_WLST_CON_WLST
 esp_ble_adv_filter_t::ADV_FILTER_ALLOW_SCAN_WLST_CON_ANY
 esp_ble_adv_filter_t::ADV_FILTER_ALLOW_SCAN_ANY_CON_ANY

esp_ble_adv_data_type::ESP_BLE_AD_TYPE_URI
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_TX_PWR
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_TRANS_DISC_DATA
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_SPAIR_C256
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_SOL_SRV_UUID
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_SM_TK
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_SERVICE_DATA
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_RANDOM_TARGET
 esp_ble_adv_data_type::ESP_BLE_AD_TYPE_PUBLIC_TARGET

esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_int_min
 esp_ble_adv_params_t::adv_int_max
 esp_ble_adv_params_t::adv_filter_policy
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
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 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_ble_adv_params_t::adv_type
 esp_BLE_AD_FLAG_BREDR_NOT_SPT

esp_ble_adv_data_type::ESP_BLE_AD_TYPE_APP_EA

esp_ble_adv_data_type::ESP_BLE_AD_TYPE_CHAN_MAP

esp_ble_adv_data_type::ESP_BLE_AD_TYPE_DEV_CLS

esp_ble_adv_data_type::ESP_BLE_AD_TYPE_ADV_INT

esp_BLE_AD_FLAG_BREDR_NOT_SPT

esp_BLE_AD_FLAG_DMT_HOST_SPT

ESP_BLE_ADV_FLAG_GEN_DISC

ESP_BLE_ADV_FLAG_LIMIT_DISC

ESP_BLE_ADV_FLAG_NON_LIMIT_DISC

ESP_BLE_ADV_FLAG_BREDR_NOT_SPT
Index

(C++ struct), 281
esp_ble_gap_cb_param_t::ble_set_rand_cmpl
(C++ member), 281
esp_ble_gap_cb_param_t::ext_scan_stop
(C++ member), 281
esp_ble_gap_cb_param_t::ble_update_conn_params_cmpl
(C++ member), 282
esp_ble_gap_cb_param_t::ext_conn_params_set
(C++ member), 282
esp_ble_gap_cb_param_t::ext_adv_stop
(C++ member), 282
esp_ble_gap_cb_param_t::ext_adv_set_rand_addr
(C++ member), 282
esp_ble_gap_cb_param_t::ext_adv_set_params
(C++ member), 282
esp_ble_gap_cb_param_t::ext_adv_report
(C++ member), 282
esp_ble_gap_cb_param_t::ext_adv_remove
(C++ member), 282
esp_ble_gap_cb_param_t::ext_adv_data_set
(C++ member), 282
esp_ble_gap_cb_param_t::clear_bond_dev_cmpl
(C++ member), 282
esp_ble_gap_cb_param_t::channel_sel_alg
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_whitelist_cmpl_evt_param::wl_operation
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_whitelist_cmpl_evt_param::status
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param::subcode
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param::status
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param::length
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_duplicate_exceptional_list_cmpl_evt_param::device_info
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::timeout
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::status
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::min_int
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::max_int
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::latency
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::conn_int
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param::bda
(C++ member), 282
esp_ble_gap_cb_param_t::ble_update_conn_params_evt_param
(C++ member), 282
esp_ble_gap_cb_param_t::ble_set_rand_cmpl_evt_param::status
(C++ member), 282
Index
Index

ESP_BLE_GAP_PAST_MODE_NO_REPORT_EVT (C macro), 295
ESP_BLE_GAP_PAST_MODE_DUP_FILTER_DISABLED (C macro), 296
ESP_BLE_GAP_NO_PREFER_TRANSMIT_PHY (C++ member), 296
ESP_BLE_GAP_NO_PREFER_RECEIVE_PHY (C++ member), 296

esp_ble_gap_ext_adv_reprot_t::dir_addr (C++ member), 295
esp_ble_gap_ext_adv_reprot_t::dir_addr (C++ member), 295
esp_ble_gap_ext_adv_reprot_t::event_type (C++ member), 294
esp_ble_gap_ext_adv_reprot_t::per_adv_interval (C++ member), 294
esp_ble_gap_ext_adv_reprot_t::primary_phy (C++ member), 294
esp_ble_gap_ext_adv_reprot_t::rssi (C++ member), 294
esp_ble_gap_ext_adv_reprot_t::secondly_phy (C++ member), 294
esp_ble_gap_ext_adv_reprot_t::sid (C++ member), 294
esp_ble_gap_ext_adv_reprot_t::tx_power (C++ member), 294
esp_ble_gap_ext_adv_set_clear (C++ function), 260
esp_ble_gap_ext_adv_set_params (C++ function), 259
esp_ble_gap_ext_adv_set_rand_addr (C++ function), 259
esp_ble_gap_ext_adv_set_remove (C++ function), 260
esp_ble_gap_ext_adv_start (C++ function), 260
esp_ble_gap_ext_adv_stop (C++ function), 260
esp_ble_gap_ext_adv_t (C++ struct), 293
esp_ble_gap_ext_adv_t::duration (C++ member), 293
esp_ble_gap_ext_adv_t::instance (C++ member), 293
esp_ble_gap_ext_adv_t::max_events (C++ member), 293
ESP_BLE_GAP_EXT_SCAN_CFG_CODE_MASK (C macro), 304
ESP_BLE_GAP_EXT_SCAN_CFG_UNICODE_MASK (C macro), 304
espble_get_device_name (C++ function), 255
espble_get_local_used_addr (C++ function), 255
espble_get_whitelist_size (C++ function), 254
ESP_BLE_GAP_NO_PREFER_RECEIVE_PHY (C macro), 303
ESP_BLE_GAP_NO_PREFER_TRANSMIT_PHY (C macro), 303
ESP_BLE_GAP_PAST_MODE_DUP_FILTER_DISABLED (C macro), 305
ESP_BLE_GAP_PAST_MODE_DUP_FILTER_ENABLED (C macro), 305
ESP_BLE_GAP_PAST_MODE_NO_REPORT_EVT (C macro), 305
ESP_BLE_GAP_PAST_MODE_NO_SYNC_EVT (C macro), 305
esp_ble_gap_past_mode_t (C++ type), 306
display_gap_past_params_t (C++ struct), 296
esp_ble_gap_past_params_t::cte_type (C++ member), 296
esp_ble_gap_past_params_t::mode (C++ member), 296
esp_ble_gap_past_params_t::skip (C++ member), 296
esp_ble_gap_past_params_t::sync_timeout (C++ member), 296
esp_ble_gap_periodic_adv_add_dev_to_list (C++ function), 262
esp_ble_gap_periodic_adv_clear_dev (C++ function), 262
esp_ble_gap_periodic_adv_create_sync (C++ function), 261
esp_ble_gap_periodic_adv_params_t (C++ struct), 293
esp_ble_gap_periodic_adv_params_t::interval_max (C++ member), 293
esp_ble_gap_periodic_adv_params_t::interval_min (C++ member), 293
esp_ble_gap_periodic_adv_params_t::properties (C++ member), 293
esp_ble_gap_periodic_adv_recv_enable (C++ function), 263
esp_ble_gap_periodic_adv_remove_dev_from_list (C++ function), 262
esp_ble_gap_periodic_adv_report_t (C++ struct), 295
esp_ble_gap_periodic_adv_report_t::data (C++ member), 295
esp_ble_gap_periodic_adv_report_t::data_length (C++ member), 295
esp_ble_gap_periodic_adv_report_t::data_status (C++ member), 295
esp_ble_gap_periodic_adv_report_t::rssi (C++ member), 295
esp_ble_gap_periodic_adv_report_t::sync_handle (C++ member), 295
esp_ble_gap_periodic_adv_report_t::tx_power (C++ member), 295
esp_ble_gap_periodic_adv_set_info_trans (C++ function), 263
esp_ble_gap_periodic_adv_set_params (C++ function), 260
esp_ble_gap_periodic_adv_start (C++ function), 261
esp_ble_gap_periodic_adv_stop (C++ function), 261
espble_gap_periodic_adv_sync_cancel (C++ function), 262
espble_gap_periodic_adv_sync_estab_t (C++ struct), 295
ESP_BLE_GAP_EXT_SCAN_CFG_CODE_MASK (C macro), 304
ESP_BLE_GAP_EXT_SCAN_CFG_UNICODE_MASK (C macro), 304
espble_get_device_name (C++ function), 255
espble_get_local_used_addr (C++ function), 255
espble_get_whitelist_size (C++ function), 254
ESP_BLE_GAP_NO_PREFER_RECEIVE_PHY (C macro), 303
ESP_BLE_GAP_NO_PREFER_TRANSMIT_PHY (C macro), 303
ESP_BLE_GAP_PAST_MODE_DUP_FILTER_DISABLED (C macro), 305
ESP_BLE_GAP_PAST_MODE_DUP_FILTER_ENABLED (C macro), 305
ESP_BLE_GAP_PAST_MODE_NO_REPORT_EVT (C macro), 305
ESP_BLE_GAP_PAST_MODE_NO_SYNC_EVT (C macro), 305
espble_gap_periodic_adv_sync_estab_t::addr_type (C++ member), 296
Submit Document Feedback
Index

esp_ble_gap_periodic_adv_sync_estab_t::esp_ble_gap_periodic_adv_sync_estab_t (C++ function), 252
esp_ble_gap_periodic_adv_sync_estab_t::esp_ble_gap_periodic_adv_sync_estab_t (C++ member), 296
esp_ble_gap_periodic_adv_sync_estab_t::esp_ble_gap_periodic_adv_sync_estab_t (C++ struct), 293
esp_ble_gap_periodic_adv_sync_estab_t::esp_ble_gap_periodic_adv_sync_estab_t (C++ type), 262
esp_ble_gap_periodic_adv_sync_estab_t::esp_ble_gap_periodic_adv_sync_estab_t (C function), 262
ESP_BLE_GAP_PHY_1M (C macro), 303
ESP_BLE_GAP_PHY_1M_PREF_MASK (C macro), 304
ESP_BLE_GAP_PHY_2M (C macro), 304
ESP_BLE_GAP_PHY_2M_PREF_MASK (C macro), 304
ESP_BLE_GAP_PHY_CODED (C macro), 303
ESP_BLE_GAP_PHY_CODED_PREF_MASK (C macro), 304
esp_ble_gap_phy_mask_t (C++ type), 306
ESP_BLE_GAP_PHY_OPTIONS_NO_PREF (C macro), 304
ESP_BLE_GAP_PHY_OPTIONS_PREF_S2_CODING (C macro), 304
Esp_BLE_GAP_PHY_OPTIONS_PREF_S8_CODING (C macro), 304
esp_ble_gap_phy_t (C++ type), 306
esp_ble_gap_prefer_ext_connect_params_set (C++ function), 262
esp_ble_gap_prefer_phy_options_t (C++ type), 306
ESP_BLE_GAP_PRI_PHY_1M (C macro), 303
ESP_BLE_GAP_PRI_PHY_CODED (C macro), 303
esp_ble_gap_pri_phy_t (C++ type), 306
esp_ble_gap_read_phy (C++ function), 259
esp_ble_gap_read_rssi (C++ function), 255
esp_ble_gap_read_rssi (C++ function), 257
esp_ble_gap_register_callback (C++ function), 252
esp_ble_gap_register_callback (C++ member), 296
esp_ble_gap_register_duplicate_scan_exceptional_device (C++ function), 256
esp_ble_gap_security_rsp (C++ function), 257
esp_ble_gatts_add_included_service
(C++ function), 334
esp_ble_gatts_add_char_descr
(C++ function), 334
esp_ble_gatts_add_char
(C++ function), 335
esp_ble_gatts_add_char_descr
(C++ function), 335
esp_ble_gatts_app_register
(C++ function), 334
esp_ble_gatts_app_unregister
(C++ function), 334
esp_ble_gatts_cb_param_t
(C++ union), 337
esp_ble_gatts_cb_param_t::add_attr_tab
(C++ member), 338
esp_ble_gatts_cb_param_t::add_char
(C++ member), 338
esp_ble_gatts_cb_param_t::add_char_descr
(C++ member), 338
esp_ble_gatts_cb_param_t::add_incl_srvc
(C++ member), 338
esp_ble_gatts_cb_param_t::cancel_open
(C++ member), 338
esp_ble_gatts_cb_param_t::close
(C++ member), 338
esp_ble_gatts_cb_param_t::connect
(C++ member), 338
esp_ble_gatts_cb_param_t::create
(C++ member), 338
esp_ble_gatts_cb_param_t::del
(C++ member), 338
esp_ble_gatts_cb_param_t::disconnect
(C++ member), 338
esp_ble_gatts_cb_param_t::exec_write
(C++ member), 337
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ struct), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_ble_gatts_cb_param_t::gatts_add_attr_tab_evt
(C++ member), 339
esp_gatts_add_attr_tab_evt_param
(C++ struct), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
esp_gatts_add_attr_tab_evt_param
(C++ member), 338
Index

esp_ble_key_value_t::lcsrk_key (C++ member), 264
esp_ble_key_value_t::lenc_key (C++ member), 264
esp_ble_key_value_t::pcsrk_key (C++ member), 264
esp_ble_key_value_t::penc_key (C++ member), 263
esp_ble_key_value_t::pid_key (C++ member), 264
esp_ble_lcsrk_keys (C++ struct), 287
esp_ble_lcsrk_keys::counter (C++ member), 287
esp_ble_lcsrk_keys::csrk (C++ member), 288
esp_ble_lcsrk_keys::div (C++ member), 288
esp_ble_lcsrk_keys::sec_level (C++ member), 288
ESP_BLE_LEGACY_ADV_TYPE_DIRECT_IND (C macro), 305
ESP_BLE_LEGACY_ADV_TYPE_IND (C macro), 305
ESP_BLE_LEGACY_ADV_TYPE_NONCON_IND (C macro), 305
ESP_BLE_LEGACY_ADV_TYPE_SCAN_IND (C macro), 305
ESP_BLE_LEGACY_ADV_TYPE_SCAN_RSP_TO_ADV_IND (C macro), 305
ESP_BLE_LEGACY_ADV_TYPE_SCAN_RSP_TO_ADV_SCAN (C macro), 305
esp_ble_lenc_keys_t (C++ struct), 287
esp_ble_lenc_keys_t::div (C++ member), 287
esp_ble_lenc_keys_t::key_size (C++ member), 287
esp_ble_lenc_keys_t::ltk (C++ member), 287
esp_ble_lenc_keys_t::sec_level (C++ member), 287
ESP_BLE_LINK_KEY_MASK (C macro), 245
esp_ble_local_id_keys_t (C++ struct), 289
esp_ble_local_id_keys_t::dhk (C++ member), 289
esp_ble_local_id_keys_t::ir (C++ member), 289
esp_ble_local_id_keys_t::irk (C++ member), 289
esp_ble_local_oob_data_t (C++ struct), 289
esp_ble_local_oob_data_t::oob_c (C++ member), 290
esp_ble_local_oob_data_t::oob_r (C++ member), 290
ESP_BLE_MESH_ACTUATOR_BLOCKED_ERROR (C macro), 667
ESP_BLE_MESH_ACTUATOR_BLOCKED_WARNING (C macro), 667
ESP_BLE_MESH_ADDR_ALL_NODES (C macro), 574
ESP_BLE_MESH_ADDR_FRIENDS (C macro), 574
ESP_BLE_MESH_ADDR_IS_GROUP (C macro), 575
ESP_BLE_MESH_ADDR_IS_RFU (C macro), 575
ESP_BLE_MESH_ADDR_IS_UNICAST (C macro), 575
ESP_BLE_MESH_ADDR_IS_VIRTUAL (C macro), 575
ESP_BLE_MESH_ADDR_PROXIES (C macro), 574
ESP_BLE_MESH_ADDR_RELAYS (C macro), 574
ESP_BLE_MESH_ADDR_TYPE_PUBLIC (C macro), 577
ESP_BLE_MESH_ADDR_TYPE_RANDOM (C macro), 577
ESP_BLE_MESH_ADDR_TYPE_RPA_PUBLIC (C macro), 577
ESP_BLE_MESH_ADDR_TYPE_RPA_RANDOM (C macro), 577
esp_ble_mesh_addr_type_t (C++ type), 596
ESP_BLE_MESH_ADDR_UNASSIGNED (C macro), 574
ESP_BLE_MESH_BEACON_ENABLED (C macro), 578
esp_ble_mesh_bd_addr_t (C++ type), 596
ESP_BLE_MESH_BEACON_DISABLED (C macro), 575
ESP_BLE_MESH_BATTERY_LOW_ERROR (C macro), 666
ESP_BLE_MESH_BATTERY_LOW_WARNING (C macro), 666
ESPREBLE_MESH_BATTERY_ENABLED (C macro), 578
esp_ble_mesh_cb_t (C++ type), 596
esp_ble_mesh_cb_type_t::ESP_BLE_MESH_TYPE_COMPLETE (C++ enumerator), 598
esp_ble_mesh_cb_type_t::ESP_BLE_MESH_TYPE_INPUT (C++ enumerator), 598
esp_ble_mesh_cb_type_t::ESP_BLE_MESH_TYPE_LINK_CONN_RSP (C++ enumerator), 598
esp_ble_mesh_cb_type_t::ESP_BLE_MESH_TYPE_LINK_OP (C++ enumerator), 598
esp_ble_mesh_cb_type_t::ESP_BLE_MESH_TYPE_OUTPUT (C++ enumerator), 598
esp_ble_mesh_cfg_app_key_add_t::app_key (C++ member), 638
esp_ble_mesh_cfg_app_key_add_t::app_idx (C++ member), 638
esp_ble_mesh_cfg_app_key_add_t::app_key (C++ member), 638
esp_ble_mesh_cfg_app_key_delete_t (C++ struct), 643
esp_ble_mesh_cfg_app_key_delete_t::app_idx (C++ member), 643
esp_ble_mesh_cfg_client_set_state_t::net_key_delete
esp_ble_mesh_cfg_client_set_state_t::net_key_add
esp_ble_mesh_cfg_client_set_state_t::model_sub_va_overwrite
esp_ble_mesh_cfg_client_set_state_t::model_sub_va_delete
esp_ble_mesh_cfg_client_set_state_t::model_sub_va_add
esp_ble_mesh_cfg_client_set_state_t::model_sub_overwrite
esp_ble_mesh_cfg_client_set_state_t::model_sub_delete_all
esp_ble_mesh_cfg_client_set_state_t::model_sub_delete
esp_ble_mesh_cfg_client_set_state_t::model_sub_add
esp_ble_mesh_cfg_client_set_state_t::model_pub_va_set
esp_ble_mesh_cfg_client_set_state_t::model_app_unbind
esp_ble_mesh_cfg_client_set_state_t::model_app_bind
esp_ble_mesh_cfg_client_set_state_t::kr_phase_set
esp_ble_mesh_cfg_client_set_state_t::heartbeat_sub_set
esp_ble_mesh_cfg_client_set_state_t::heartbeat_pub_set
esp_ble_mesh_cfg_client_set_state_t::friend_set
esp_ble_mesh_cfg_client_set_state_t::default_ttl_set
esp_ble_mesh_cfg_client_set_state_t::beacon_set
esp_ble_mesh_cfg_client_set_state_t::app_key_update
esp_ble_mesh_cfg_client_set_state_t::app_key_add
esp_ble_mesh_cfg_client_get_state_t::vnd_model_sub_get
esp_ble_mesh_cfg_client_get_state_t::vnd_model_app_get
esp_ble_mesh_cfg_client_get_state_t::sig_model_app_get
esp_ble_mesh_cfg_client_get_state_t::node_identity_get
esp_ble_mesh_cfg_hb_pub_status_cb_t::ttl
esp_ble_mesh_cfg_hb_pub_status_cb_t::status
esp_ble_mesh_cfg_hb_pub_status_cb_t::period
esp_ble_mesh_cfg_hb_pub_status_cb_t::net_idx
esp_ble_mesh_cfg_hb_pub_status_cb_t::features
esp_ble_mesh_cfg_hb_pub_status_cb_t::dst
esp_ble_mesh_cfg_hb_pub_status_cb_t::count
esp_ble_mesh_cfg_gatt_proxy_status_cb_t::gatt_proxy
esp_ble_mesh_cfg_gatt_proxy_set_t::gatt_proxy
esp_ble_mesh_cfg_friend_status_cb_t::friend_state
esp_ble_mesh_cfg_friend_status_cb_t::friend_set
esp_ble_mesh_cfg_friend_set_t::friend_state
esp_ble_mesh_cfg_friend_set_t::friend_set
esp_ble_mesh_cfg_default_ttl_status_cb_t::default_ttl
esp_ble_mesh_cfg_default_ttl_status_cb_t::composition_data
esp_ble_mesh_cfg_default_ttl_set_t::ttl
esp_ble_mesh_cfg_default_ttl_set_t::composition_data
esp_ble_mesh_cfg_composition_data_get_t::page
esp_ble_mesh_cfg_composition_data_get_t::composition_data
esp_ble_mesh_cfg_client_set_state_t::relay_set
esp_ble_mesh_cfg_client_set_state_t::node_identity_set
esp_ble_mesh_cfg_client_set_state_t::net_key_update

<table>
<thead>
<tr>
<th>C++ struct</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>struct esp_ble_mesh_cfg_lpn_polltimeout_get_t</code></td>
<td>637</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_lpn_pollto_status_cb_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_app_unbind_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_pub_get_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_pub_set_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_app_list_cb_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_app绑定_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_app_listCb_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_appunbind_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_appunbindCb_t</code></td>
<td>635</td>
</tr>
<tr>
<td><code>struct esp_ble_mesh_cfg_model_appunbindCb_t</code></td>
<td>635</td>
</tr>
</tbody>
</table>

Submit Document Feedback

Releases

- v5.1.2

Espersif Systems

2769

Release v5.1.2
Index

(C++ struct), 647
(C++ member), 648

esp_ble_mesh_cfg_model_sub_status_cb_t (C++ member), 647
esp_ble_mesh_cfg_model_sub_status_cb_t::status (C++ member), 647

esp_ble_mesh_cfg_model_sub_status_cb_t (C++ struct), 641

esp_ble_mesh_cfg_model_sub_status_cb_t::model_id (C++ member), 650
esp_ble_mesh_cfg_model_sub_status_cb_t::element_addr (C++ member), 650
esp_ble_mesh_cfg_model_sub_status_cb_t::company_id (C++ member), 650

esp_ble_mesh_cfg_model_sub_set_t (C++ struct), 641

esp_ble_mesh_cfg_model_sub_set_t::model_id (C++ member), 644
esp_ble_mesh_cfg_model_sub_set_t::label_uuid (C++ member), 644
esp_ble_mesh_cfg_model_sub_set_t::element_addr (C++ member), 644
esp_ble_mesh_cfg_model_sub_set_t::company_id (C++ member), 644

esp_ble_mesh_cfg_node_identity_set_t (C++ struct), 641

esp_ble_mesh_cfg_node_identity_set_t::net_idx (C++ member), 651
esp_ble_mesh_cfg_node_identity_set_t::identity (C++ member), 651
esp_ble_mesh_cfg_node_identity_set_t::net_idx (C++ member), 651
esp_ble_mesh_cfg_node_identity_set_t::status (C++ member), 651

esp_ble_mesh_cfg_node_identity_get_t (C++ struct), 641

esp_ble_mesh_cfg_node_identity_get_t::net_idx (C++ member), 651
esp_ble_mesh_cfg_node_identity_get_t::status (C++ member), 651

esp_ble_mesh_cfg_node_identity_get_t::model_id (C++ member), 651
esp_ble_mesh_cfg_node_identity_get_t::net_idx (C++ member), 651
esp_ble_mesh_cfg_node_identity_get_t::status (C++ member), 651

esp_ble_mesh_cfg_node_identity_get_t::model_id (C++ member), 651
esp_ble_mesh_cfg_node_identity_get_t::net_idx (C++ member), 651
esp_ble_mesh_cfg_node_identity_get_t::status (C++ member), 651

esp_ble_mesh_cfg_net_trans_set_t (C++ struct), 641

esp_ble_mesh_cfg_net_trans_set_t::net_transmit (C++ member), 651
esp_ble_mesh_cfg_net_trans_set_t::net_transmit_step (C++ member), 651
esp_ble_mesh_cfg_net_trans_set_t::net_transmit_count (C++ member), 651

esp_ble_mesh_cfg_net_trans_set_t (C++ struct), 641

esp_ble_mesh_cfg_net_trans_set_t::net_transmit (C++ member), 651
esp_ble_mesh_cfg_net_trans_set_t::net_transmit_step (C++ member), 651
esp_ble_mesh_cfg_net_trans_set_t::net_transmit_count (C++ member), 651

esp_ble_mesh_cfg_net_key_update_t (C++ struct), 641

esp_ble_mesh_cfg_net_key_update_t::net_key (C++ member), 651
esp_ble_mesh_cfg_net_key_update_t::net_idx (C++ member), 651

esp_ble_mesh_cfg_net_key_update_t (C++ struct), 641

esp_ble_mesh_cfg_net_key_update_t::net_key (C++ member), 651
esp_ble_mesh_cfg_net_key_update_t::net_idx (C++ member), 651

esp_ble_mesh_server_set_t (C++ struct), 641

esp_ble_mesh_server_set_t::net_transmit (C++ member), 651
esp_ble_mesh_server_set_t::net_transmit_step (C++ member), 651
esp_ble_mesh_server_set_t::net_transmit_count (C++ member), 651

esp_ble_mesh_server_set_t::ctx (C++ member), 651

esp_ble_mesh_server_set_t (C++ struct), 641

esp_ble_mesh_server_set_t::net_transmit (C++ member), 651
esp_ble_mesh_server_set_t::net_transmit_step (C++ member), 651
esp_ble_mesh_server_set_t::net_transmit_count (C++ member), 651

esp_ble_mesh_server_set_t::ctx (C++ member), 651

esp_ble_mesh_server_set_t (C++ struct), 641

---

Espressif Systems

Release v5.1.2

Submit Document Feedback
Index

(C macro), 585
ESP_BLE_MESH_CFG_STATUS_INVALID_PUBLISH_PARAMETERS (C macro), 585
ESP_BLE_MESH_CFG_STATUS_KEY_INDEX_ALREADY_STORED (C macro), 585
ESP_BLE_MESH_CFG_STATUS_NOT_A_SUBSCRIBE_MODEL (C macro), 585
ESP_BLE_MESH_CFG_STATUS_STORAGE_FAILURE (C macro), 585
ESP_BLE_MESH_CFG_STATUS_SUCCESS (C macro), 585
esp_ble_mesh_client_t::internal_data (C++ member), 571
esp_ble_mesh_client_t::model (C++ member), 571
esp_ble_mesh_client_t::msg_role (C++ member), 571
esp_ble_mesh_client_t::op_pair (C++ member), 571
esp_ble_mesh_client_t::op_pair_size (C++ member), 571
esp_ble_mesh_device_delete_t::uuid (C++ member), 571
esp_ble_mesh_device_delete_t::flag (C++ member), 571
esp_ble_mesh_device_delete_t::addr_type (C++ member), 571
esp_ble_mesh_device_delete_t::addr (C++ member), 571
esp_ble_mesh_deinit_param_t::erase_flash (C++ member), 571
esp_ble_mesh_deinit (C++ function), 571
esp_ble_mesh_deinit_param_t (C++ struct), 571
esp_ble_mesh_client_common_param_t::ctx (C++ member), 571
esp_ble_mesh_client_common_param_t::model (C++ member), 571
esp_ble_mesh_client_common_param_t::msg_role (C++ member), 571
esp_ble_mesh_client_common_param_t::msg_role (C++ member), 571
esp_ble_mesh_client_common_param_t::msg_role (C++ member), 571
esp_ble_mesh_client_common_param_t::msg_role (C++ member), 571
esp_ble_mesh_client_common_param_t::msg_role (C++ member), 571
esp_ble_mesh_client_common_param_t::model (C++ member), 571
esp_ble_mesh_client_op_pair_t::status_op (C++ member), 571
esp_ble_mesh_client_op_pair_t::cli_op (C++ member), 571
esp_ble_mesh_client_op_pair_t::status_op (C++ member), 571
esp_ble_mesh_client_op_pair_t::status_op (C++ member), 571
esp_ble_mesh_client_t::internal_data (C++ member), 571
esp_ble_mesh_client_t::model (C++ member), 571
esp_ble_mesh_client_t::msg_role (C++ member), 571
esp_ble_mesh_client_t::op_pair (C++ member), 571
esp_ble_mesh_client_t::op_pair_size (C++ member), 571
esp_ble_mesh_device_delete_t::uuid (C++ member), 571
esp_ble_mesh_device_delete_t::addr (C++ member), 571
esp_ble_mesh_device_delete_t::addr_type (C++ member), 571
esp_ble_mesh_client_t::internal_data (C++ member), 571
esp_ble_mesh_client_t::model (C++ member), 571
esp_ble_mesh_client_t::msg_role (C++ member), 571
esp_ble_mesh_client_t::op_pair (C++ member), 571
esp_ble_mesh_client_t::op_pair_size (C++ member), 571
esp_ble_mesh_device_delete_t::uuid (C++ member), 571
esp_ble_mesh_device_delete_t::addr (C++ member), 571
esp_ble_mesh_device_delete_t::addr_type (C++ member), 571

Submit Document Feedback
Index

(C++ member), 687
esp_ble_mesh_gen_def_trans_time_status esp_ble_mesh_gen_level_status_cb_t::op_en
(C++ struct), 681
esp_ble_mesh_gen_def_trans_time_status esp_ble_mesh_gen_level_status_cb_t::present_level
(C++ member), 681
esp_ble_mesh_gen_delta_set_t (C++ struct), 676
esp_ble_mesh_gen_delta_set_t::delay
(C++ member), 676
esp_ble_mesh_gen_delta_set_t::level
(C++ member), 676
esp_ble_mesh_gen_delta_set_t::op_en
(C++ member), 676
esp_ble_mesh_gen_delta_set_t::tid
(C++ member), 676
esp_ble_mesh_gen_delta_set_t::trans_time
(C++ struct), 676
esp_ble_mesh_gen_def_trans_time_status esp_ble_mesh_gen_level_status_cb_t::remain_time
(C++ member), 681
esp_ble_mesh_gen_delta_set_t esp_ble_mesh_gen_level_status_cb_t::target_level
(C++ member), 681
esp_ble_mesh_gen_loc_local_status_cb_t::uncertainty
esp_ble_mesh_gen_loc_local_status_cb_t::local_north
esp_ble_mesh_gen_loc_local_status_cb_t::local_east
esp_ble_mesh_gen_loc_local_status_cb_t::local_altitude
esp_ble_mesh_gen_loc_local_status_cb_t::floor_number
esp_ble_mesh_gen_loc_local_status_cb_t::global_longitude
esp_ble_mesh_gen_loc_local_status_cb_t::global_latitude
esp_ble_mesh_gen_loc_local_status_cb_t::global_altitude
esp_ble_mesh_gen_loc_local_set_t (C++ struct), 678
esp_ble_mesh_gen_loc_local_set_t::local_north
esp_ble_mesh_gen_loc_local_set_t::local_east
esp_ble_mesh_gen_loc_local_set_t::local_altitude
esp_ble_mesh_gen_loc_global_status_cb_t::global_longitude
esp_ble_mesh_gen_loc_global_status_cb_t::global_latitude
esp_ble_mesh_gen_loc_global_status_cb_t::global_altitude
esp_ble_mesh_gen_loc_global_set_t (C++ struct), 678
esp_ble_mesh_gen_loc_global_set_t::global_longitude
esp_ble_mesh_gen_loc_global_set_t::global_latitude
esp_ble_mesh_gen_loc_global_set_t::global_altitude
esp_ble_mesh_gen_loc_global_srv_t (C++ struct), 687
esp_ble_mesh_gen_loc_global_set_t::local_latitude
esp_ble_mesh_gen_loc_global_set_t::local_altitude
esp_ble_mesh_gen_loc_global_set_t::local_east
esp_ble_mesh_gen_loc_global_set_t::floor_number
esp_ble_mesh_gen_loc_global_srv_t::last
(C++ member), 687
esp_ble_mesh_gen_loc_global_srv_t::model
(C++ member), 687
esp_ble_mesh_gen_loc_global_srv_t::rsp_ctrl
esp_ble_mesh_gen_loc_local_status_cb_t
(C++ member), 687
esp_ble_mesh_gen_loc_local_srv_t (C++ struct), 687
esp_ble_mesh_gen_loc_local_set_t::local_latitude
esp_ble_mesh_gen_loc_local_set_t::local_altitude
esp_ble_mesh_gen_loc_local_set_t::local_east
esp_ble_mesh_gen_loc_local_set_t::floor_number
esp_ble_mesh_gen_loc_local_srv_t::last
(C++ member), 687
esp_ble_mesh_gen_loc_local_srv_t::model
(C++ member), 687
esp_ble_mesh_gen_loc_local_srv_t::rsp_ctrl
esp_ble_mesh_gen_loc_local_srv_t::state
(C++ member), 687
esp_ble_mesh_gen_loc_local_srv_t::trans_time
(C++ struct), 686
esp_ble_mesh_gen_loc_local_status_cb_t esp_ble_mesh_gen_loc_local_status_cb_t::floor_number
(C++ member), 687
esp_ble_mesh_gen_loc_local_status_cb_t esp_ble_mesh_gen_loc_local_status_cb_t::local_east
(C++ member), 687
esp_ble_mesh_gen_loc_local_status_cb_t esp_ble_mesh_gen_loc_local_status_cb_t::local_altitude
(C++ member), 687
esp_ble_mesh_gen_loc_local_status_cb_t esp_ble_mesh_gen_loc_local_status_cb_t::local_north
(C++ member), 687
esp_ble_mesh_gen_loc_local_status_cb_t esp_ble_mesh_gen_loc_local_status_cb_t::local_latitude
(C++ member), 687
esp_ble_mesh_gen_location_setup_srv_t::state
esp_ble_mesh_gen_location_setup_srv_t::rsp_ctrl
(C++ member), 687
esp_ble_mesh_gen_location_setup_srv_t::floor_number
(C++ member), 687
esp_ble_mesh_gen_location_setup_srv_t::last
(C++ member), 687
esp_ble_mesh_gen_location_setup_srv_t::model
(C++ member), 687
esp_ble_mesh_gen_location_setup_srv_t::trans_time
(C++ struct), 691
esp_ble_mesh_gen_location_setup_srv_t::move_start
(C++ struct), 691
esp_ble_mesh_gen_location_setup_srv_t::target
event
esp_ble_mesh_gen_location_setup_srv_t::rsp_ctrl
(C++ struct), 692
esp_ble_mesh_gen_location_setup_srv_t::move
(C++ struct), 692
esp_ble_mesh_gen_location_setup_srv_t::move
(C++ struct), 692
esp_ble_mesh_gen_location_setup_srv_t::move
(C++ struct), 692
esp_ble_mesh_gen_location_setup_srv_t (C++

Submit Document Feedback
Index

(C++ enum), 708
(C++ member), 685

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_PROHIBIT
(C++ member), 685
(C++ function), 684

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_READ
(C++ member), 685

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_READ_WRITE
(C++ member), 685

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_WRITE
(C++ member), 685

Index

(C++ function), 684

esp_ble_mesh_gen_user_property_status_cb_t::user_access
(C++ member), 692

esp_ble_mesh_gen_user_property_status_cb_t::property_value
(C++ function), 692

esp_ble_mesh_gen_user_property_set_t::property_value
(C++ union), 684

esp_ble_mesh_gen_user_property_get_t::property_id
(C++ union), 679

esp_ble_mesh_gen_user_properties_status_cb_t::property_ids
(C++ function), 671

esp_ble_mesh_gen_user_prop_srv_t::rsp_ctrl
(C++ function), 707

esp_ble_mesh_gen_user_prop_srv_t::property_count
(C++ function), 707

esp_ble_mesh_gen_user_prop_srv_t::properties
(C++ function), 707

esp_ble_mesh_gen_user_prop_srv_t::model
(C++ function), 707

Index

(C++ member), 685

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_PROHIBIT
(C++ enumerator), 708

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_READ
(C++ enumerator), 708

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_READ_WRITE
(C++ enumerator), 708

esp_ble_mesh_gen_user_prop_access_t::ESP_BLE_MESH_GEN_USER_ACCESS_WRITE
(C++ enumerator), 708

Index

(C++ function), 707

esp_ble_mesh_generic_property_t::id
(C++ member), 679

esp_ble_mesh_generic_property_t::admin_access
(C++ member), 679

esp_ble_mesh_generic_property_t
(C++ enum), 679

esp_ble_mesh_generic_message_opcode_t
(C++ enum), 679

esp_ble_mesh_generic_client_set_state_t::user_property_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::power_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::power_range_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::power_level_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::power_default_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::move_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::manufacturer_property_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::loc_local_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::loc_global_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::level_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::delta_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::def_trans_time_set
(C++ member), 684

esp_ble_mesh_generic_client_set_state_t::admin_property_set
(C++ member), 684

Index

(C++ union), 597

esp_ble_mesh_generic_client_cb_param_t::esp_ble_mesh_generic_client_cb_event_t::ESP_BLE_MESH_GENERIC_CLIENT_SET_STATE_EVT
(C++ function), 692

esp_ble_mesh_generic_client_cb_param_t::esp_ble_mesh_generic_client_get_state_t::ESP_BLE_MESH_GENERIC_CLIENT_EVT_MAX
(C++ function), 692

esp_ble_mesh_generic_client_get_state_t::user_property_get
(C++ function), 692

esp_ble_mesh_generic_client_get_state_t::manufacturer_property_get
(C++ function), 692

esp_ble_mesh_generic_client_get_state_t::client_properties_get
(C++ function), 692

esp_ble_mesh_generic_client_get_state_t::admin_property_get
(C++ function), 692

Index

(C++ member), 707

esp_ble_mesh_generic_client_cb_t::esp_ble_mesh_generic_client_cb_param_t::status_cb
(C++ union), 707

esp_ble_mesh_generic_client_cb_event_t::ESP_BLE_MESH_GENERIC_CLIENT_TIMEOUT_EVT
(C++ function), 597

esp_ble_mesh_generic_client_cb_event_t::ESP_BLE_MESH_GENERIC_CLIENT_SET_STATE_EVT
(C++ function), 597

esp_ble_mesh_generic_client_cb_event_t::ESP_BLE_MESH_GENERIC_CLIENT_PUBLISH_EVT
(C++ function), 597

esp_ble_mesh_generic_client_cb_event_t::ESP_BLE_MESH_GENERIC_CLIENT_GET_STATE_EVT
(C++ function), 597

esp_ble_mesh_generic_client_cb_event_t::ESP_BLE_MESH_GENERIC_CLIENT_EVT_MAX
(C++ function), 597

Index

(C++ member), 692

esp_ble_mesh_generic_client_cb_param_t::esp_ble_mesh_generic_property_t::id
(C++ function), 692

Submit Document Feedback
ESP_BLE_MESH_GET_TRANSMIT_COUNT (C macro), 576
ESP_BLE_MESH_GET_TRANSMIT_INTERVAL (C macro), 576
ESP_BLE_MESH_GET_TRANSMIT_COUNT (C macro), 726
ESP_BLE_MESH_GET_TRANSMIT_INTERVAL (C macro), 727

ESP_BLE_MESH_FAULT_GET (C macro), 576

ESP_BLE_MESH_CLIENT_COMMON_CB_PARAM_T::current_status (C++ member), 660
ESP_BLE_MESH_CLIENT_COMMON_CB_PARAM_T::attention_status (C++ member), 660

esp_ble_mesh_health_client_common_cb_param_t (C++ struct), 665
esp_ble_mesh_health_client_common_cb_param_t::params (C++ member), 665
esp_ble_mesh_health_client_common_cb_param_t::error_code (C++ member), 665

esp_ble_mesh_health_client_cb_param_t (C++ struct), 663
esp_ble_mesh_health_client_set_state_t (C++ struct), 663
esp_ble_mesh_health_client_set_state_t::fault_test (C++ member), 663
esp_ble_mesh_health_client_set_state_t::fault_clear (C++ member), 663
esp_ble_mesh_health_client_set_state_t::attention_set (C++ member), 663

esp_ble_mesh_health_client_set_state (C++ function), 658

esp_ble_mesh_health_client_get_state_t (C++ struct), 663
esp_ble_mesh_health_client_get_state_t::fault_get (C++ member), 663
esp_ble_mesh_health_client_get_state_t::company_id (C++ member), 663

esp_ble_mesh_health_client_common_cb_param_t::period_status (C++ member), 663
esp_ble_mesh_health_client_common_cb_param_t::fault_status (C++ member), 663

ESP_BLE_MESH_CLIENT common_cb_param_t (C++ struct), 663
esp_ble_mesh_health_client_common_cb_param_t::company_id (C++ member), 663
esp_ble_mesh_health_client_common_cb_param_t::test_id (C++ member), 663
esp_ble_mesh_health_client_common_cb_param_t::attention_set (C++ member), 663
esp_ble_mesh_health_client_common_cb_param_t (C++ union), 660
esp_ble_mesh_health_client_common_cb_param_t::fault_status (C++ member), 660
esp_ble_mesh_health_client_common_cb_param_t::company_id (C++ member), 660

ESP_BLE_MESH_FAULT_TEST_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

esp_ble_mesh_health_fault_test_cb_t (C++ struct), 663
esp_ble_mesh_health_fault_test_cb_t::company_id (C++ member), 663

esp_ble_mesh_health_fault_status_cb_t (C++ struct), 663
esp_ble_mesh_health_fault_status_cb_t::test_id (C++ member), 663
esp_ble_mesh_health_fault_status_cb_t::company_id (C++ member), 663

esp_ble_mesh_health_fault_clear_t (C++ struct), 663
esp_ble_mesh_health_fault_clear_cb_t (C++ struct), 663
esp_ble_mesh_health_fault_clear_t::company_id (C++ member), 663

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_GET_TRANSMIT_COUNT (C macro), 726
ESP_BLE_MESH_GET_TRANSMIT_INTERVAL (C macro), 727
ESP_BLE_MESH_GET_TRANSMIT_COUNT (C macro), 727

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESP_BLE_MESH_FAULT_GET (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 576
ESP_BLE_MESH_FAULT_GET_ARRAY_SIZE (C macro), 726

ESpressif Systems 2781 Release v5.1.2
Submit Document Feedback
esp_ble_mesh_light_ctl_setup_srv_t
- state (C++ struct), 784
- rsp_ctrl (C++ member), 785
- model (C++ member), 785
- last (C++ member), 784
- tt_delta_temperature (C++ member), 783
- tt_delta_delta_uv (C++ member), 783
- transition (C++ member), 783
- state (C++ struct), 783
- target_ctl_temperature (C++ member), 783
- target_ctl_lightness (C++ member), 783
- target_ctl_temperature_status_cb_t::present_ctl_temperature (C++ member), 775
- target_ctl_lightness_status_cb_t::present_ctl_lightness (C++ member), 775
- target_ctl_temperature_status_cb_t::op_en (C++ member), 775
- target_ctl_lightness_status_cb_t::op_en (C++ member), 775
- esp_ble_mesh_light_ctl_temperature_status_cb_t::present CTL Delta UV (C++ member), 775
- esp_ble_mesh_light_ctl_temperature_status_cb_t::op_en (C++ member), 775
- esp_ble_mesh_light_ctl_temperature_set_t::temperature_range_min (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::temperature_range_max (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::temperature_default (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::target_temperature (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::target_lightness (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::target_delta_uv (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::lightness_default (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::lightness (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::delta_uv_default (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_set_t::delta_uv (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_range_status_cb_t::status_code (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_range_status_cb_t::range_min (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_range_status_cb_t::range_max (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_range_set_t::range_min (C++ member), 784
- esp_ble_mesh_light_ctl_temperature_range_set_t::range_max (C++ member), 784
- esp_ble_mesh_light_ctl_temp_srv_t::tt_delta_temperature (C++ member), 784
- esp_ble_mesh_light_ctl_temp_srv_t::tt_delta_delta_uv (C++ member), 784
- esp_ble_mesh_light_ctl_temp_srv_t::transition (C++ member), 784
- esp_ble_mesh_light_ctl_temp_srv_t::rsp_ctrl (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::model (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::last (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::state (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::temperature_range_status_cb_t::range_min (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::temperature_range_status_cb_t::range_max (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::temperature_range_set_t::range_min (C++ member), 785
- esp_ble_mesh_light_ctl_temp_srv_t::temperature_range_set_t::range_max (C++ member), 785
- esp_ble_mesh_light_ctl_status_cb_t::target_ctl_temperature (C++ member), 775
- esp_ble_mesh_light_ctl_status_cb_t::target_ctl_lightness (C++ member), 775
- esp_ble_mesh_light_ctl_status_cb_t::remain_time (C++ member), 784
- esp_ble_mesh_light_ctl_status_cb_t::target_ctl_temperature_status_cb_t::target_ctl_temperature (C++ member), 775
- esp_ble_mesh_light_ctl_status_cb_t::target_ctl_lightness_status_cb_t::target_ctl_lightness (C++ member), 775
- esp_ble_mesh_light_ctl_setup_srv_t::state (C++ member), 784
- esp_ble_mesh_light_ctl_setup_srv_t::rsp_ctrl (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::model (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::last (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::state (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::temperature_range_status_cb_t::range_min (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::temperature_range_status_cb_t::range_max (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::temperature_range_set_t::range_min (C++ member), 785
- esp_ble_mesh_light_ctl_setup_srv_t::temperature_range_set_t::range_max (C++ member), 785
- esp_ble_mesh_light_ctl_state_t::temperature_range_min (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::temperature_range_max (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::temperature_default (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::target_temperature (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::target_lightness (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::target_delta_uv (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::lightness_default (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::lightness (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::delta_uv_default (C++ member), 783
- esp_ble_mesh_light_ctl_state_t::delta_uv (C++ member), 783
- esp_ble_mesh_light_ctl_srv_t::tt_delta_temperature (C++ member), 784
- esp_ble_mesh_light_ctl_srv_t::tt_delta_delta_uv (C++ member), 784
- esp_ble_mesh_light_ctl_srv_t::transition (C++ member), 784
- esp_ble_mesh_light_ctl_srv_t::rsp_ctrl (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::model (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::last (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::state (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::temperature_range_status_cb_t::range_min (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::temperature_range_status_cb_t::range_max (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::temperature_range_set_t::range_min (C++ member), 785
- esp_ble_mesh_light_ctl_srv_t::temperature_range_set_t::range_max (C++ member), 785
Index

esp_ble_mesh_light_ctl_temperature_status_cb_t::target_ctl_temperature
 esp_ble_mesh_light_ctl_temperature_status_cb_t::target_ctl_delta_uv
 esp_ble_mesh_light_ctl_temperature_status_cb_t::remain_time
 esp_ble_mesh_light_ctl_temperature_status_cb_t::op_en

esp_ble_mesh_light_hsl_hue_set_t (C++ member), 770
 esp_ble_mesh_light_hsl_hue_set_t::tid
 esp_ble_mesh_light_hsl_hue_set_t::hue
 esp_ble_mesh_light_hsl_hue_set_t::delay
 (C++ struct), 787

esp_ble_mesh_light_hsl_saturation_status_cb_t::target_saturation
 esp_ble_mesh_light_hsl_saturation_status_cb_t::remain_time
 esp_ble_mesh_light_hsl_saturation_status_cb_t::present_saturation
 esp_ble_mesh_light_hsl_saturation_status_cb_t::op_en

esp_ble_mesh_light_hsl_saturation_set_t (C++ member), 775
 esp_ble_mesh_light_hsl_saturation_set_t::saturation
 esp_ble_mesh_light_hsl_saturation_set_t::op_en
 esp_ble_mesh_light_hsl_saturation_set_t::delay
 (C++ struct), 770

esp_ble_mesh_light_hsl_default_set_t esp_ble_mesh_light_hsl_range_set_t::saturation_range_max
 esp_ble_mesh_light_hsl_default_set_t::saturation_range_min
 esp_ble_mesh_light_hsl_range_set_t::saturation_range_min
 esp_ble_mesh_light_hsl_range_set_t::saturation_range_max
 esp_ble_mesh_light_hsl_range_set_t::hue_range_min
 esp_ble_mesh_light_hsl_range_set_t::hue_range_max
 esp_ble_mesh_light_hsl_range_set_t::model
 esp_ble_mesh_light_hsl_range_set_t::last
 (C++ struct), 770

esp_ble_mesh_light_hsl_default_status_cb_t::saturation
 esp_ble_mesh_light_hsl_default_status_cb_t::lightness
 esp_ble_mesh_light_hsl_default_status_cb_t::hue
 (C++ struct), 778

Esperrif Systems

Release v5.1.2

Submit Document Feedback
Index

esp_ble_mesh_light_hsl_set_t (C++ struct), esp_ble_mesh_light_hsl_state_t::saturation_default
(C++ member), 785
esp_ble_mesh_light_hsl_set_t::delay esp_ble_mesh_light_hsl_state_t::saturation_range_min
(C++ member), 786
esp_ble_mesh_light_hsl_set_t::hsl_hue esp_ble_mesh_light_hsl_state_t::saturation_range_max
(C++ member), 786
esp_ble_mesh_light_hsl_set_t::hsl_lightness esp_ble_mesh_light_hsl_state_t::status_code
(C++ member), 786
esp_ble_mesh_light_hsl_set_t::hsl_saturation esp_ble_mesh_light_hsl_state_t::target_hue
(C++ member), 785
esp_ble_mesh_light_hsl_set_t::op_en esp_ble_mesh_light_hsl_state_t::target_lightness
(C++ member), 785
esp_ble_mesh_light_hsl_set_t::tid esp_ble_mesh_light_hsl_state_t::target_saturation
(C++ member), 785
esp_ble_mesh_light_hsl_set_t::trans_time esp_ble_mesh_light_hsl_status_cb_t
(C++ struct), 776
esp_ble_mesh_light_hsl_setup_srv_t esp_ble_mesh_light_hsl_status_cb_t::hsl_hue
(C++ struct), 776
esp_ble_mesh_light_hsl_setup_srv_t::model esp_ble_mesh_light_hsl_status_cb_t::hsl_lightness
(C++ member), 776
esp_ble_mesh_light_hsl_setup_srv_t::rsp_ctrl esp_ble_mesh_light_hsl_status_cb_t::hsl_saturation
(C++ member), 776
esp_ble_mesh_light_hsl_setup_srv_t::state esp_ble_mesh_light_hsl_status_cb_t::op_en
(C++ member), 776
esp_ble_mesh_light_hsl_srv_t (C++ struct), esp_ble_mesh_light_hsl_status_cb_t::remain_time
(C++ member), 776
esp_ble_mesh_light_hsl_srv_t::last esp_ble_mesh_light_hsl_target_status_cb_t
(C++ struct), 776
esp_ble_mesh_light_hsl_srv_t::model esp_ble_mesh_light_hsl_target_status_cb_t::hsl_hue
(C++ member), 777
esp_ble_mesh_light_hsl_srv_t::rsp_ctrl esp_ble_mesh_light_hsl_target_status_cb_t::hsl_lightness
(C++ member), 776
esp_ble_mesh_light_hsl_srv_t::state esp_ble_mesh_light_hsl_target_status_cb_t::hsl_saturation
(C++ member), 777
esp_ble_mesh_light_hsl_srv_t::transition esp_ble_mesh_light_hsl_target_status_cb_t::op_en
(C++ member), 776
esp_ble_mesh_light_hsl_srv_t::tt_delta esp_ble_mesh_light_hsl_target_status_cb_t::remain_time
(C++ member), 777
esp_ble_mesh_light_hsl_srv_t::tt_delta esp_ble_mesh_light_lc_light_onoff_status_cb_t
(C++ struct), 772
esp_ble_mesh_light_hsl_srv_t::tt_delta esp_ble_mesh_light_lc_light_onoff_status_cb_t::delay
(C++ member), 772
esp_ble_mesh_light_hsl_state_t (C++ esp_ble_mesh_light_lc_light_onoff_status_cb_t::light_onoff
(C++ member), 786
struct), 785
esp_ble_mesh_light_hsl_state_t::hue esp_ble_mesh_light_lc_light_onoff_status_cb_t::op_en
(C++ member), 785
esp_ble_mesh_light_hsl_state_t::hue_default esp_ble_mesh_light_lc_light_onoff_status_cb_t::op_en
(C++ member), 785
esp_ble_mesh_light_hsl_state_t::hue_range_min esp_ble_mesh_light_lc_light_onoff_status_cb_t::trans_time
(C++ member), 785
esp_ble_mesh_light_hsl_state_t::hue_range_max esp_ble_mesh_light_lc_light_onoff_status_cb_t::trans_time
(C++ member), 785
esp_ble_mesh_light_hsl_state_t::lightness esp_ble_mesh_light_lc_light_onoff_status_cb_t::trans_time
(C++ member), 780
esp_ble_mesh_light_hsl_state_t::lightness_default esp_ble_mesh_light_lc_light_onoff_status_cb_t::trans_time
(C++ member), 780
esp_ble_mesh_light_hsl_state_t::saturation esp_ble_mesh_light_lc_light_onoff_status_cb_t::remain_time
(C++ member), 785

Espressif Systems  2787  Release v5.1.2
Submit Document Feedback
Index

esp_ble_mesh_light_lc_light_onoff_status (C++ member), 780
esp_ble_mesh_light_lc_light_onoff_property_state_t::time_fade
(C++ member), 791
esp_ble_mesh_light_lc_mode_set_t (C++ struct), 772
esp_ble_mesh_light_lc_mode_set_t::mode
esp_ble_mesh_light_lc_property_state_t::time_occu
(C++ member), 791
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_prol
(C++ member), 791
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_run
(C++ member), 791
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_occupan
(C++ member), 791
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_fade_stan
(C++ member), 791
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_fade_stan
(C++ member), 780
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_fade_autom
(C++ struct), 791
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_fade_autom
(C++ struct), 772
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_fade_manual
(C++ struct), 780
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_fade_manual
(C++ struct), 772
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_occupancy_del
(C++ struct), 780
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_occupancy_del
(C++ struct), 772
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_occupancy_del
(C++ struct), 780
esp_ble_mesh_light_lc_mode_status_cb_t esp_ble_mesh_light_lc_property_state_t::time_occupancy_del
(C++ struct), 772
esp_ble_mesh_light_lc_property_get_t esp_ble_mesh_light_lc_setup_srv_t
(C++ struct), 794
esp_ble_mesh_light_lc_property_get_t::property_value
esp_ble_mesh_light_lc_setup_srv_t::rspb_ctrl
(C++ member), 794
esp_ble_mesh_light_lc_property_get_t::property_id
esp_ble_mesh_light_lc_setup_srv_t::rspb_ctrl
(C++ member), 794
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_occupancy_delay
(C++ struct), 791
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 791
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 780
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 772
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 791
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 772
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 780
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 772
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 780
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 772
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_t::time_fade_on
(C++ struct), 780
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::model
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_setup_srv_t::last
(C++ member), 793
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade_on
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_ble_mesh_light_lc_state_machine_t::fade
(C++ member), 792
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_BLE_mesh_light_lc_state_machine_t::ambient_luxlevel
(C++ member), 790
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_BLE_mesh_light_lc_state_machine_t::ambient_luxlevel
(C++ member), 790
esp_ble_mesh_light_lc_state_t::ambient_luxlevel
esp_BLE_mesh_light_lc_state_machine_t::ambient_luxlevel
(C++ member), 790

<table>
<thead>
<tr>
<th>Function/Structure/Variable</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_mesh_light_lightness_set_t::trans_time</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_set_t::tid</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_set_t::op_en</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_set_t::lightness</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_set_t::delay</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_set_t::tid</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_set_t::op_en</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_set_t::lightness</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_last_status_cb_t::lightness</td>
<td>774</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_default_status_cb_t::lightness</td>
<td>774</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_default_set_t::lightness</td>
<td>766</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_state_t::target_light_onoff</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_state_t::occupancy_mode</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_state_t::occupancy</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_state_t::mode</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_linear_state_t::linear_output</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::target_lightness_linear</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::target_lightness_actual</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::status_code</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::lightness_range_min</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::lightness_range_max</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::lightness_last</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::lightness_default</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_state_t::lightness_actual</td>
<td>765</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::state</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::rsp_ctrl</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::model</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::linear_transition</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::actual_transition</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::last</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::tt_delta_lightness</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::trans_time</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::tid</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::op_en</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::lightness</td>
<td>782</td>
</tr>
<tr>
<td>esp_ble_mesh_light_lightness_srv_t::delay</td>
<td>782</td>
</tr>
</tbody>
</table>
Index

```cpp
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_set_t::trans_time (C++ struct), 773
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_set_t::xyl_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_set_t::xyl_x (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_set_t::xyl_y (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_status_cb_t::xyl_y_range_min (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_status_cb_t::xyl_y_range_max (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_status_cb_t::xyl_x_range_min (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_status_cb_t::xyl_x_range_max (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_set_t::xyl_y (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_set_t::xyl_x (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_range_set_t::xyl_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::y (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::x_range_min (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::x_range_max (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::x_default (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::x (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::tt_delta_y (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::tt_delta_x (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::tt_delta_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::transition (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::state (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::rsp_ctrl (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::model (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::last (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::state (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::rsp_ctrl (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::model (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::last (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::state (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::transition (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::tt_delta_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::tt_delta_x (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_srv_t::tt_delta_y (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::xyl_state_t (C++ struct), 788
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
esp_ble_mesh_light_lightness_status_cb::esp_ble_mesh_light_xyl_state_t::target_lightness (C++ member), 771
```

Espressif Systems 2790 Release v5.1.2

Submit Document Feedback
Index

esp_ble_mesh_lighting_server_state_change_t::ctl_default_set
(C++ member), 788

esp_ble_mesh_lighting_server_state_change_t::y_default_set
(C++ member), 789

esp_ble_mesh_lighting_server_recv_status_msg_t::sensor_status
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::xyl_range
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::xyl_default
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::xyl
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lightness_range
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lightness_linear
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lightness_default
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lightness
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lc_property
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lc_om
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lc_mode
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::lc_light_onoff
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::hsl_saturation
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::hsl_range
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::hsl_hue
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::hsl
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::ctl_temp_range
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::ctl_temp
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::ctl_default
(C++ member), 789

esp_ble_mesh_lighting_server_recv_set_msg_t::ctl
(C++ member), 789

esp_ble_mesh_lighting_server_recv_get_msg_t::lc_property
(C++ member), 789

esp_ble_mesh_lighting_server_recv_get_msg_t::ctl
(C++ member), 789

esp_ble_mesh_lighting_server_cb_value_t::status
(C++ member), 789

esp_ble_mesh_lighting_server_cb_value_t::state_change
(C++ member), 789

esp_ble_mesh_lighting_server_cb_value_t::y_default_set
(C++ member), 790

esp_ble_mesh_lighting_server_cb_value_t::range_set
(C++ member), 790

esp_ble_mesh_lighting_server_recv_get_msg_t::ctl
(C++ member), 790

esp_ble_mesh_lighting_server_cb_value_t::range
(C++ member), 790

esp_ble_mesh_lighting_server_cb_value_t::state
(C++ member), 790

esp_ble_mesh_lighting_server_cb_status_t::op
(C++ member), 790

esp_ble_mesh_lighting_server_cb_status_t::remaining
(C++ member), 790

esp_ble_mesh_lighting_server_cb_status_t::remaining
set
(C++ member), 790

esp_ble_mesh_lighting_server_cb_status_t::remaining
get
(C++ member), 790

Index
Index

esp_ble_mesh_lighting_server_state_change_t::ler (C++ member), 566
esp_ble_mesh_model::element_idx (C++ member), 762
esp_ble_mesh_lighting_server_state_change_t::mg (C++ member), 566
temp_set (C++ member), 762
esp_ble_mesh_model::flags (C++ member), 566
temp_set (C++ member), 762
esp_ble_mesh_model::groups (C++ member), 566
default_set (C++ member), 763
esp_ble_mesh_model::keys (C++ member), 566
hue_set (C++ member), 763
esp_ble_mesh_model::model_id (C++ member), 566
model_set (C++ member), 565
esp_ble_mesh_model::model_idx (C++ member), 566
esp_ble_mesh_lighting_server_state_change_t::model (C++ member), 763
esp_ble_mesh_model::op (C++ member), 566
esp_ble_mesh_model::pub (C++ member), 566
esp_ble_mesh_model::user_data (C++ member), 566
off_set (C++ member), 566
esp_ble_mesh_model::vnd (C++ member), 565
esp_ble_mesh_lighting_server_state_change_t::[anonymous] (C++ member), 565
esp_ble_mesh_model::cb_event_t (C++ member), 607
esp_ble_mesh_lighting_server_state_change_t::[anonymous] (C++ member), 607
esp_ble_mesh_model::client_model_send_timeout_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_recv_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_model::client_model_send_publish_msg_event_t::ESP_BLE_MESH_CLIENT_MODEL_SEND_PUBLISH_MSG_EVT (C++ enumerator), 607
esp_ble_mesh_lighting_server_state_change_t::client_model_send_publish_msg_event_t (C++ union), 560
esp_ble_mesh_lighting_server_state_change_t::client_model_recv_publish_msg_event_t (C++ union), 560
esp_ble_mesh_lighting_server_state_change_t::client_model_send_publish_msg_event_t (C++ union), 560
esp_ble_mesh_lpn_disable (C++ function), 611
esp_ble_mesh_lpn_enable (C++ function), 611
esp_ble_mesh_lpn_poll (C++ function), 611
ESP_BLE_MESH_MECHANISM_JAMMED_ERROR (C macro), 668
ESP_BLE_MESH_MECHANISM_JAMMED_WARNING (C macro), 668
ESP_BLE_MESH_MEMORY_ERROR (C macro), 667
ESP_BLE_MESH_MEMORY_WARNING (C macro), 667
ESP_BLE_MESH_MIC_LONG (C macro), 573
ESP_BLE_MESH_MIC_SHORT (C macro), 573
esp_ble_mesh_model (C++ struct), 565
esp_ble_mesh_model::cb (C++ member), 566
esp_ble_mesh_model::company_id (C++ member), 566
esp_ble_mesh_model::element (C++ member), 566
esp_ble_mesh_model::element_idx (C++ member), 762
esp_ble_mesh_model::flags (C++ member), 566
temp_set (C++ member), 762
esp_ble_mesh_model::groups (C++ member), 566
default_set (C++ member), 763
esp_ble_mesh_model::keys (C++ member), 566
hue_set (C++ member), 763
esp_ble_mesh_model::model_id (C++ member), 566
model_set (C++ member), 565
esp_ble_mesh_model::model_idx (C++ member), 566
esp_ble_mesh_model::op (C++ member), 566
esp_ble_mesh_model::pub (C++ member), 566
esp_ble_mesh_model::user_data (C++ member), 566
off_set (C++ member), 566
esp_ble_mesh_model::vnd (C++ member), 565
esp_ble_mesh_lighting_server_state_change_t::client_model_send_publish_msg_event_t (C++ union), 560
esp_ble_mesh_model::cb_event_t (C++ union), 560
esp_ble_mesh_model::client_model_send_timeout_param::opcode (C++ function), 611
esp_ble_mesh_model::client_model_send_timeout_param::model (C++ function), 611
esp_ble_mesh_model::client_model_send_timeout_param::model (C++ function), 611
esp_ble_mesh_model::client_model_recv_publish_msg_param::msg (C++ function), 611
esp_ble_mesh_model::client_model_recv_publish_msg_param::length (C++ function), 611
esp_ble_mesh_model::client_model_recv_publish_msg_param::ctx (C++ function), 611
esp_ble_mesh_model::vnd (C++ function), 565
esp_ble_mesh_model::op (C++ function), 565
esp_ble_mesh_model::model_idx (C++ function), 565
esp_ble_mesh_model::flags (C++ function), 565
temp_set (C++ function), 762
esp_ble_mesh_model::groups (C++ function), 565
default_set (C++ function), 763
esp_ble_mesh_model::keys (C++ function), 565
hue_set (C++ function), 763
esp_ble_mesh_model::model_id (C++ function), 565
model_set (C++ function), 565
esp_ble_mesh_model::model_idx (C++ function), 565
esp_ble_mesh_model::op (C++ function), 565
esp_ble_mesh_model::pub (C++ function), 565
esp_ble_mesh_model::user_data (C++ function), 565
off_set (C++ function), 565
esp_ble_mesh_model::vnd (C++ function), 565
esp_ble_mesh_lighting_server_state_change_t::client_model_send_publish_msg_event_t (C++ union), 560
esp_ble_mesh_model::cb_event_t (C++ union), 560
esp_ble_mesh_model::client_model_send_timeout_param::opcode (C++ function), 611
esp_ble_mesh_model::client_model_send_timeout_param::model (C++ function), 611
esp_ble_mesh_model::client_model_recv_publish_msg_param::msg (C++ function), 611
esp_ble_mesh_model::client_model_recv_publish_msg_param::length (C++ function), 611
esp_ble_mesh_model::client_model_recv_publish_msg_param::ctx (C++ function), 611
esp_ble_mesh_model::vnd (C++ function), 565
esp_ble_mesh_model::op (C++ function), 565
esp_ble_mesh_model::model_idx (C++ function), 565
esp_ble_mesh_model::flags (C++ function), 565
temp_set (C++ function), 762
esp_ble_mesh_model::groups (C++ function), 565
default_set (C++ function), 763
esp_ble_mesh_model::keys (C++ function), 565
hue_set (C++ function), 763
esp_ble_mesh_model::model_id (C++ function), 565
model_set (C++ function), 565
esp_ble_mesh_model::model_idx (C++ function), 565
esp_ble_mesh_model::op (C++ function), 565
esp_ble_mesh_model::pub (C++ function), 565
esp_ble_mesh_model::user_data (C++ function), 565
off_set (C++ function), 565
esp_ble_mesh_model::vnd (C++ function), 565
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_CLI
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_SRV
ESP_BLE_MESH_MODEL_ID_GEN_CLIENT_PROP_CLI
ESP_BLE_MESH_MODEL_ID_GEN_CLIENT_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_CLI
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_CLI
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SRV
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_CLI
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_CLI
ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_SRV
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_CLI
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_CLI
ESP_BLE_MESH_MODEL_ID_GEN_BATTERY_SRV
ESP_BLE_MESH_MODEL_ID_GEN_CLIENT_PROP_CLI
ESP_BLE_MESH_MODEL_ID_GEN_CLIENT_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_CLI
ESP_BLE_MESH_MODEL_ID_GEN_DEF_TRANS_TIME_SRV
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_CLI
ESP_BLE_MESH_MODEL_ID_GEN_LOCATION_SRV
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_CLI
ESP_BLE_MESH_MODEL_ID_GEN_MANUFACTURER_PROP_SRV
ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_CLI
ESP_BLE_MESH_MODEL_ID_GEN_ONOFF_SRV
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_CLI
ESP_BLE_MESH_MODEL_ID_GEN_USER_PROP_SRV
| ESP_BLE_MESH_MODEL_LIGHT_HSL_HUE_SRV (C macro), 810 | ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GET (C macro), 581 |
| ESP_BLE_MESH_MODEL_LIGHT_HSL_SAT_SRV (C macro), 810 | ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_STATUS (C macro), 581 |
| ESP_BLE_MESH_MODEL_LIGHT_HSL_SETUP_SRV (C macro), 810 | ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_GET (C macro), 584 |
| ESP_BLE_MESH_MODEL_LIGHT_HSL_SRV (C macro), 810 | ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SET (C macro), 582 |
| ESP_BLE_MESH_MODEL_LIGHT_LC_CLI (C macro), 808 | ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_STATUS (C macro), 584 |
| ESP_BLE_MESH_MODEL_LIGHT_LC_SETUP_SRV (C macro), 812 | ESP_BLE_MESH_MODEL_OP_END (C macro), 578 |
| ESP_BLE_MESH_MODEL_LIGHT_LC_SRV (C macro), 811 | ESP_BLE_MESH_MODEL_OP_FRIEND_GET (C macro), 581 |
| ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_CLI | ESP_BLE_MESH_MODEL_OP_FRIEND_SET (C macro), 583 |
| ESP_BLE_MESH_MODEL_LIGHT_LIGHTNESS_SRV | ESP_BLE_MESH_MODEL_OP_FRIEND_STATUS (C macro), 585 |
| ESP_BLE_MESH_MODEL_LIGHT_XYL_CLI (C macro), 808 | ESP_BLE_MESH_MODEL_OP_GATT_PROXY_GET (C macro), 581 |
| ESP_BLE_MESH_MODEL_LIGHT_XYL_SRV (C macro), 811 | ESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET (C macro), 582 |
| esp_ble_mesh_model_msg_opcode_init (C+ function), 612 | ESP_BLE_MESH_MODEL_OP_GATT_PROXY_STATUS (C macro), 584 |
| ESP_BLE_MESH_MODEL_NONE (C macro), 578 | ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_GET (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP (C macro), 577 | ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTIES_STATUS (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_1 (C macro), 577 | ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_GET (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_2 (C macro), 577 | ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_3 (C macro), 577 | ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_SET_UNACK (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD (C macro), 583 | ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_STATUS (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_APP_KEY_DELETE (C macro), 583 | ESP_BLE_MESH_MODEL_OP_GEN_BATTERY_GET (C macro), 588 |
| ESP_BLE_MESH_MODEL_OP_APP_KEY_GET (C macro), 581 | ESP_BLE_MESH_MODEL_OP_GEN_BATTERY_STATUS (C macro), 588 |
| ESP_BLE_MESH_MODEL_OP_APP_KEY_LIST (C macro), 584 | ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_GET (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_APP_KEY_STATUS (C macro), 584 | ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_STATUS (C macro), 589 |
| ESP_BLE_MESH_MODEL_OP_APP_KEY_UPDATE (C macro), 583 | ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_GET (C macro), 587 |
| ESP_BLE_MESH_MODEL_OP_ATTENTION_GET (C macro), 586 | ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_SET (C macro), 587 |
| ESP_BLE_MESH_MODEL_OP_ATTENTION_SET (C macro), 586 | ESP_BLE_MESH_MODEL_OP_GEN_DEF_TRANS_TIME_SET_UNACK (C macro), 587 |
| ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK (C macro), 586 | ESP_BLE_MESH_MODEL_OP_GEN_DELTA_GET (C macro), 587 |
| ESP_BLE_MESH_MODEL_OP_ATTENTION_STATUS (C macro), 586 | ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET (C macro), 587 |
| ESP_BLE_MESH_MODEL_OP_BEACON_GET (C macro), 581 | ESP_BLE_MESH_MODEL_OP_GEN_DELTA_SET_UNACK (C macro), 587 |
| ESP_BLE_MESH_MODEL_OP_BEACON_SET (C macro), 582 | ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_GET (C macro), 587 |
ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET (C) ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET_UNACK (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_SET_UNACK ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_STATUS (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_LEVEL_STATUS ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_GET (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_GET ESP_BLE_MESH_MODEL_OP_GEN_POWER_LAST_STATUS (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_SET ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_GET (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_LOC_GLOBAL_SET_UNACK ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_GET ESP_BLE_MESH_MODEL_OP_GEN_POWER_LEVEL_SET_UNACK (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_GET (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_SET_UNACK ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_LOC_LOCAL_STATUS ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_SET_UNACK (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_STATUS (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK ESP_BLE_MESH_MODEL_OP_GEN_POWER_RANGE_STATUS (C macro), 588
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_GET (C macro), 589
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_GET ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTIES_STATUS (C macro), 589
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET (C macro), 589
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET (C macro), 589
ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET_UNACK_ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_SET (C macro), 589
ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET (C) ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_STATUS (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_MOVE_SET_UNACK ESP_BLE_MESH_MODEL_OP_HEALTH_CURRENT_STATUS (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_GET (C) ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR (C macro), 586
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET (C) ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_CLEAR_UNACK (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_SET_UNACK ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_STATUS ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_STATUS (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_GET ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_SET_UNACK ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_GET (C macro), 587
ESP_BLE_MESH_MODEL_OP_GEN_ONPOWERUP_STATUS_ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET (C macro), 586
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_SET_ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK (C macro), 586
ESP_BLE_MESH_MODEL_OP_GEN_POWER_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_STATUS
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_SET
ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_STATUS
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_STATUS
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_RANGE_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LINEAR_RANGE_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LINEAR_RANGE_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LINEAR_RANGE_SET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LINEAR_RANGE_SET_UNACK
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LINEAR_LINEAR_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_RANGE_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_RANGE_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_RANGE_SET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_RANGE_SET_UNACK
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_LINEAR_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_LINEAR_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_LINEAR_SET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_LINEAR_SET_UNACK
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_SET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_SET_UNACK
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_LAST_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_LAST_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_DEFAULT_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_DEFAULT_SET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_DEFAULT_SET_UNACK
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LIGHTNESS_DEFAULT_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LC_PROPERTY_GET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LC_PROPERTY_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LC_PROPERTY_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_LC_OM_STATUS
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_GET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_STATUS
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_STATUS
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_SET_UNACK
(C macro), 595
ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_DEFAULT_GET
(C macro), 594
ESP_BLE_MESH_MODEL_OP_NET_KEY_STATUS  ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_GET
(C macro), 584
ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE  ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET
(C macro), 583
ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT  ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_SET_UNACK
(C macro), 582
ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT  ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_STATUS
(C macro), 584
ESP_BLE_MESH_MODEL_OP_NODE_RESET  ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET
(C macro), 585
ESP_BLE_MESH_MODEL_OP_NODE_RESET_STATUS  ESP_BLE_MESH_MODEL_OP_SENSOR_COLUMN_GET
(C macro), 582
ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_GET  ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTION_GET
(C macro), 590
ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_STATUS  ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTION_STATUS
(C macro), 590
ESP_BLE_MESH_MODEL_OP_NODE_RESET  (C ESP_BLE_MESH_MODEL_OP_SENSOR_GET
(macro), 583
ESP_BLE_MESH_MODEL_OP_NODE_RESET_STATUS  ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_GET
(C macro), 590
ESP_BLE_MESH_MODEL_OP_RELAY_GET  (C ESP_BLE_MESH_MODEL_OP_SENSOR_SERIES_STATUS
(macro), 581
ESP_BLE_MESH_MODEL_OP_RELAY_SET  (C ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_GET
(macro), 582
ESP_BLE_MESH_MODEL_OP_RELAY_STATUS  (C ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET
(macro), 584
ESP_BLE_MESH_MODEL_OP_SCENE_DELETE  (C ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_SET_UNACK
(macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_DELETE_UNACK  ESP_BLE_MESH_MODEL_OP_SENSOR_SETTING_STATUS
(C macro), 590
ESP_BLE_MESH_MODEL_OP_SCENE_GET  (C ESP_BLE_MESH_MODEL_OP_SENSOR_SETTNGS_GET
(macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL  (C ESP_BLE_MESH_MODEL_OP_SENSOR_SETTNGS_STATUS
(macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_RECALL_UNACK  ESP_BLE_MESH_MODEL_OP_SENSOR_STATUS
(C macro), 590
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_GET  ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_GET
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_GET  ESP_BLE_MESH_MODEL_OP_SIG_MODEL_APP_LIST
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_STATUS  ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_GET
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_STORE  ESP_BLE_MESH_MODEL_OP_SIG_MODEL_SUB_LIST
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK  esp_ble_mesh_model_op_t (C++ struct), 564
esp_ble_mesh_model_op_t::min_len (C++ member), 565
esp_ble_mesh_model_op_t::opcode (C++ member), 565
esp_ble_mesh_model_op_t::param_cb
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_GET
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_GET
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCHEDULER_ACT_STATUS
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCHEDULER_GET
(C macro), 591
ESP_BLE_MESH_MODEL_OP_SCHEDULER_STATUS
(C macro), 591
ESP_BLE_MESH_MODEL_OP_TIME_GET  (C

Index
sp_ble_mesh_model_pub_t::update (C++ member), 564
esp_ble_mesh_model_publish (C++ function), 613
ESP_BLE_MESH_MODEL_SCENE_CLI (C macro), 752
ESP_BLE_MESH_MODEL_SCENE_SETUP_SRV (C macro), 754
ESP_BLE_MESH_MODEL_SCENE_SRV (C macro), 753
ESP_BLE_MESH_MODEL_SCHEDULER_CLI (C macro), 752
ESP_BLE_MESH_MODEL_SCHEDULER_SETUP_SRV (C macro), 754
ESP_BLE_MESH_MODEL_SCHEDULER_SRV (C macro), 754
ESP_BLE_MESH_MODEL_SENSOR_CLI (C macro), 724
ESP_BLE_MESH_MODEL_SENSOR_SETUP_SRV (C macro), 725
ESP_BLE_MESH_MODEL_SENSOR_SRV (C macro), 725
ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MAX (C macro), 596
ESP_BLE_MESH_MODEL_STATUS_CANNOT_SET_RANGE_MIN (C macro), 596
ESP_BLE_MESH_MODEL_STATUS_SUCCESS (C macro), 596
esp_ble_mesh_model_status_t (C++ type), 598
esp_ble_mesh_model_subscribe_group_addr (C++ function), 609
esp_ble_mesh_model_t (C++ type), 596
ESP_BLE_MESH_MODEL_TIME_CLI (C macro), 752
ESP_BLE_MESH_MODEL_TIME_SETUP_SRV (C macro), 753
ESP_BLE_MESH_MODEL_TIME_SRV (C macro), 753
esp_ble_mesh_model_unsubscribe_group_addr (C++ function), 609
esp_ble_mesh_model_unsubscribe_group_addr (C++ function), 609
esp_ble_mesh_msg_ctx_t::recv_ttl (C++ member), 564
esp_ble_mesh_msg_ctx_t::recv_rssi (C++ member), 564
esp_ble_mesh_msg_ctx_t::recv_op (C++ member), 564
esp_ble_mesh_msg_ctx_t::recv_dst (C++ member), 564
esp_ble_mesh_msg_ctx_t::net_idx (C++ member), 564
esp_ble_mesh_msg_ctx_t::model (C++ member), 564
esp_ble_mesh_msg_ctx_t::app_idx (C++ member), 564
esp_ble_mesh_msg_ctx_t::addr (C++ member), 564
esp_ble_mesh_model_publish (C++ function), 613
### C++ enumerator

- `ESP_BLE_MESH_OVERLOAD_ERROR`
- `ESP_BLE_MESH_OVERLOAD_WARNING`
- `ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_WARNING`
- `ESP_BLE_MESH_POWER_SUPPLY_INTERRUPTED_ERROR`
- `ESP_BLE_MESH_OVERLOAD_ERROR`
- `ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT`
- `ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT`
- `ESP_BLE_MESH_LPN_ENABLE_COMP_EVT`
- `ESP_BLE_MESH_LPN_DISABLE_COMP_EVT`
- `ESP_BLE_MESH_PROV_GATT`
- `ESP_BLE_MESH_PROV_ADV`
- `ESP_BLE_MESH_PROV_REGISTER_COMP_EVT`
- `ESP_BLE_MESH_PROV_EVT_MAX`
- `ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT`
- `ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT`
- `ESP_BLE_MESH_NODE_PROV_LINK_OPEN_EVT`
- `ESP_BLE_MESH_NODE_PROV_LINK_CLOSE_EVT`
- `ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT`
- `ESP_BLE_MESH_NODE_PROV_RESET_EVT`
- `ESP_BLE_MESH_NODE_PROV_INPUT_STRING_EVT`
- `ESP_BLE_MESH_NODE_PROV_INPUT_NUMBER_EVT`
- `ESP_BLE_MESH_NODE_PROV_INPUT_STRING_COMP_EVT`
- `ESP_BLE_MESH_NODE_PROV_ENABLE_COMP_EVT`
- `ESP_BLE_MESH_NODE_PROV_DISABLE_COMP_EVT`
- `ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT`
- `ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT`
- `ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_LINK_OPEN_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_RESET_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_STRING_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_SET_OOB_PUB_KEY_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_RESET_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_STRING_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT`
- `ESP_BLE_MESH_PROVISIONER_PROV_SET_OOB_PUB_KEY_COMP_EVT`
Index
Index

- esp_ble_mesh_prov_cb_param_t::provisioner_update
  - (C++ member), 535
- esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_INPUT_OOB_MAX_LEN
  - (C++ enumerator), 599
- esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_INPUT_OOB_MAX_LEN
  - (C++ enumerator), 599
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_cb_param_t::proxy_client_add
  - (C++ member), 539
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_cb_param_t::proxy_client_add
  - (C++ member), 539
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_cb_param_t::proxy_client_coordinator_init
  - (C++ member), 539
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_cb_param_t::proxy_client_coordinator_init
  - (C++ member), 539
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_cb_param_t::proxy_client_handler
  - (C++ member), 539
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_cb_param_t::proxy_client_handler
  - (C++ member), 539
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_data_info_t::net_idx
  - (C++ member), 537
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_data_info_t::net_idx
  - (C++ member), 537
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_data_info_t::flags
  - (C++ member), 536
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_data_info_t::flags
  - (C++ member), 536
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_data_info_t::iv_index
  - (C++ member), 537
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_data_info_t::iv_index
  - (C++ member), 537
- ESP_BLE_MESH_PROV_INPUT_OOB_MAX_LEN (C macro), 577
- esp_ble_mesh_prov_oob_info_t (C++ enum), 599
- esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_IN_BOX
  - (C++ enumerator), 599
- esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_BAR_CODE
  - (C++ enumerator), 599
- esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_2D_CODE
  - (C++ enumerator), 599
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_URI
  - (C++ member), 538
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_OTHER
  - (C++ member), 538
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_ON_PAPER
  - (C++ member), 538
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_ON_DEV
  - (C++ member), 538
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_ON_BOX
  - (C++ member), 538
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_NUMBER
  - (C++ member), 538
- esp_ble_mesh_prov_oob_info_t::esp_ble_mesh_prov_oob_info_t::ESP_BLE_MESH_PROV_OOB_NFC
  - (C++ member), 538

---

Espressif Systems

Submit Document Feedback
Index

- esp_ble_mesh_provisioner_get_node_table
  - (C++ function), 615 (C++ function), 615
- esp_ble_mesh_proxy_client_remove_filter_addr
  - (C++ function), 626
- esp_ble_mesh_provisioner_get_node_with_addr
  - (C++ function), 614 (C++ function), 614
- esp_ble_mesh_provisioner_get_node_with_filter_type
  - (C++ enum), 600 (C++ enum), 600
- esp_ble_mesh_proxy_client_connect
  - (C++ function), 626
- esp_ble_mesh_proxy_client_disconnect
  - (C++ function), 626
- esp_ble_mesh_provisioner_update_local_net_key
  - (C++ function), 616
- esp_ble_mesh_provisioner_update_local_app_key
  - (C++ function), 625
- esp_ble_mesh_provisioner_store_node_comp_data
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_static_oob_value
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_prov_data_info
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_primary_elem_addr
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_node_name
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_heartbeat_filter_type
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_heartbeat_filter_info
  - (C++ function), 625
- esp_ble_mesh_provisioner_set_dev_uuid_match
  - (C++ function), 625
- esp_ble_mesh_provisioner_recv_heartbeat
  - (C++ function), 625
- esp_ble_mesh_provisioner_read_oob_pub_key
  - (C++ function), 625
- esp_ble_mesh_provisioner_prov_enable
  - (C++ function), 625
- esp_ble_mesh_provisioner_prov_disable
  - (C++ function), 625
- esp_ble_mesh_provisioner_prov_device_with_addr
  - (C++ function), 625
- esp_ble_mesh_provisioner_open_settings_with_uid
  - (C++ function), 625
- esp_ble_mesh_provisioner_open_settings_with_index
  - (C++ function), 625
- esp_ble_mesh_provisioner_input_string
  - (C++ function), 625
- esp_ble_mesh_provisioner_input_number
  - (C++ function), 625
- esp_ble_mesh_provisioner_get_settings_uid
  - (C++ function), 625
- esp_ble_mesh_provisioner_get_prov_node_count
  - (C++ function), 625
- esp_ble_mesh_provisioner_get_node_with_uuid
  - (C++ function), 625
- esp_ble_mesh_provisioner_get_node_with_name
  - (C++ function), 625
- esp_ble_mesh_provisioner_get_node_with_addr
  - (C++ function), 625
- esp_ble_mesh_provisioner_get_node_table_entry
  - (C++ function), 625
- ESP_BLE_MESH_SCENE_NUMBER_LEN
  - (C++ macro), 626
- ESP_BLE_MESH_SCENE_NOT_FOUND
  - (C++ macro), 626
- esp_ble_mesh_scene_delete_t::scene_number
  - (C++ struct), 626
- esp_ble_mesh_register_time_scene_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_time_scene_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_prov_callback
  - (C++ function), 626
- esp_ble_mesh_register_lighting_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_light_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_custom_model_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_client_callback
  - (C++ function), 626
- esp_ble_mesh_proxy_identity_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_gatt_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_WHITELIST
  - (C++ enumerator), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_BLACKLIST
  - (C++ enumerator), 626
- esp_ble_mesh_proxy_client_set_filter_type
  - (C++ function), 626
- esp_ble_mesh_proxy_client_remove_filter_addr
  - (C++ function), 626
- ESP_BLE_MESH_PUBLISH_TRANSMIT
  - (C macro), 576
- esp_ble_mesh_proxy_client_disconnect
  - (C++ function), 626
- esp_ble_mesh_proxy_client_connect
  - (C++ function), 626
- esp_ble_mesh_proxy_client_disconnect
  - (C++ function), 626
- esp_ble_mesh_proxy_client_connect
  - (C++ function), 626
- esp_ble_mesh_proxy_client_disconnect
  - (C++ function), 626
- ESP_BLE_MESH_PUBLISH_TRANSMIT
  - (C macro), 576
- esp_ble_mesh_register_time_scene_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_time_scene_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_prov_callback
  - (C++ function), 626
- esp_ble_mesh_register_lighting_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_light_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_custom_model_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_client_callback
  - (C++ function), 626
- esp_ble_mesh_proxy_identity_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_gatt_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_WHITELIST
  - (C++ enumerator), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_BLACKLIST
  - (C++ enumerator), 626
- esp_ble_mesh_proxy_client_set_filter_type
  - (C++ function), 626
- esp_ble_mesh_proxy_client_remove_filter_addr
  - (C++ function), 626
- ESP_BLE_MESH_PUBLISH_TRANSMIT
  - (C macro), 576
- esp_ble_mesh_register_time_scene_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_time_scene_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_prov_callback
  - (C++ function), 626
- esp_ble_mesh_register_lighting_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_light_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_custom_model_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_client_callback
  - (C++ function), 626
- esp_ble_mesh_proxy_identity_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_gatt_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_WHITELIST
  - (C++ enumerator), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_BLACKLIST
  - (C++ enumerator), 626
- esp_ble_mesh_proxy_client_set_filter_type
  - (C++ function), 626
- esp_ble_mesh_proxy_client_remove_filter_addr
  - (C++ function), 626
- ESP_BLE_MESH_PUBLISH_TRANSMIT
  - (C macro), 576
- esp_ble_mesh_register_time_scene_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_time_scene_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_sensor_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_prov_callback
  - (C++ function), 626
- esp_ble_mesh_register_lighting_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_light_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_health_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_generic_client_callback
  - (C++ function), 626
- esp_ble_mesh_register_custom_model_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_server_callback
  - (C++ function), 626
- esp_ble_mesh_register_config_client_callback
  - (C++ function), 626
- esp_ble_mesh_proxy_identity_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_gatt_enable
  - (C++ function), 626
- esp_ble_mesh_proxy_filter_type_t::PROXY_FILTER_WHITELIST
  - (C++ enumerator), 626
- espBLE_MESH_RELAY_DISABLED
  - (C macro), 626
- ESP_BLE_MESH_RELAY_ENABLED
  - (C macro), 576
- ESP_BLE_MESH_RELAY_NOT_SUPPORTED
  - (C macro), 576
Index

755
esp_ble_mesh_scene_recall_t (C++ struct), 735
esp_ble_mesh_scene_recall_t::delay (C++ member), 735
esp_ble_mesh_scene_recall_t::op_en (C++ member), 735
esp_ble_mesh_scene_recall_t::scene_number (C++ member), 735
esp_ble_mesh_scene_recall_t::tid (C++ member), 735
esp_ble_mesh_scene_recall_t::trans_time (C++ member), 735
ESP_BLE_MESH_SCENE_REG_FULL (C macro), 756
esp_ble_mesh_scene_register_status_cb_t::esp_ble_mesh_scenes_state_t::current_scene (C++ member), 742
esp_ble_mesh_scene_register_status_cb_t::esp_ble_mesh_scenes_state_t::in_progress (C++ member), 742
esp_ble_mesh_scene_register_status_cb_t::esp_ble_mesh_scenes_state_t::scene_count (C++ member), 742
esp_ble_mesh_scene_register_status_cb_t::esp_ble_mesh_scenes_state_t::scenes (C++ member), 742
esp_ble_mesh_scene_register_status_cb_t::esp_ble_mesh_scenes_state_t::status_code (C++ member), 743
esp_ble_mesh_scene_register_status_cb_t (C++ struct), 739
esp_ble_mesh_scenes_state_t (C++ struct), 735
esp_ble_mesh_scenes_state_t::current_scene (C++ member), 738
esp_ble_mesh_scenes_state_t::status_code (C++ member), 738
esp_ble_mesh_scenes_state_t::target_scene (C++ member), 738
esp_ble_scenes_state_t (C++ struct), 742
esp_ble_scenes_state_t::current_scene (C++ member), 742
esp_ble_scenes_state_t::status_code (C++ member), 743
esp_ble_scenes_state_t::in_progress (C++ member), 743
esp_ble_scenes_state_t (C++ struct), 739
esp_ble_scenes_state_t::status_code (C++ member), 739
esp_ble_scenes_state_t::target_scene (C++ member), 739
esp_ble_scenes_state_t (C++ struct), 741
esp_ble_scenes_state_t::status_code (C++ member), 741
esp_ble_scenes_state_t::target_scene (C++ member), 741
esp_ble_schedule_register_t (C++ struct), 744
esp_ble_schedule_register_t::scene_number (C++ member), 744
esp_ble_schedule_register_t::minute (C++ member), 744
esp_ble_schedule_register_t::in_use (C++ member), 744
esp_ble_schedule_register_t::day (C++ member), 744
esp_ble_schedule_register_t::day_of_week (C++ member), 744
esp_ble_schedule_register_t::delay (C++ member), 744
esp_ble_schedule_register_t::second (C++ member), 744
esp_ble_schedule_register_t::action (C++ member), 744
esp_ble_schedule_register_t::day (C++ member), 744
esp_ble_schedule_register_t::day_of_week (C++ member), 744
esp_ble_schedule_register_t::delay (C++ member), 744
esp_ble_schedule_register_t::second (C++ member), 744
esp_ble_schedule_register_t (C++ struct), 744
esp_ble_schedule_register_t::action (C++ member), 744
esp_ble_schedule_register_t::day_of_week (C++ member), 744
ESP_BLE_MESH_SCENE_SUCCESS (C macro), 756
esp_ble_mesh_scenes_state_t (C++ struct), 755
esp_ble_mesh_scenes_state_t::status_code (C++ member), 755
esp_ble_mesh_scenes_state_t::target_scene (C++ member), 755
esp_ble_mesh_scenes_state_t (C++ struct), 755
esp_ble_mesh_scenes_state_t::status_code (C++ member), 755
esp_ble_mesh_scenes_state_t::target_scene (C++ member), 755
esp_ble_mesh_scenes_state_t (C++ struct), 756
esp_ble_mesh_scenes_state_t::status_code (C++ member), 756
Index

```
ESP_BLE_MESH_SENSOR_DATA_FORMAT_A_MPID_LEN (C macro), 726
ESP_BLE_MESH_SENSOR_DATA_FORMAT_B (C macro), 726
ESP_BLE_MESH_SENSOR_DATA_FORMAT_B_MPID (C macro), 727
ESP_BLE_MESH_SENSOR_DATA_FORMAT_B_MPID_LEN (C macro), 726
esp_ble_mesh_sensor_data_t (C++ struct), 719
esp_ble_mesh_sensor_data_t::format (C++ member), 719
esp_ble_mesh_sensor_data_t::length (C++ member), 719
ESP_BLE_MESH_SENSOR_DATA_ZERO_LEN (C macro), 726
esp_ble_mesh_sensor_descriptor_get_t (C++ struct), 713
esp_ble_mesh_sensor_descriptor_get_t::op_en (C++ member), 719
esp_ble_mesh_sensor_descriptor_get_t::property_id (C++ member), 713
ESP_BLE_MESH_SENSOR_DESCRIPTOR_LEN (C macro), 725
esp_ble_mesh_sensor_descriptor_status_cb_t (C++ struct), 716
esp_ble_mesh_sensor_descriptor_status_cb_t::data (C++ member), 716
esp_ble_mesh_sensor_descriptor_t (C++ struct), 718
esp_ble_mesh_sensor_descriptor_t::measure_period (C++ member), 718
esp_ble_mesh_sensor_descriptor_t::negative_tolerance (C++ member), 718
esp_ble_mesh_sensor_descriptor_t::positive_tolerance (C++ member), 718
esp_ble_mesh_sensor_descriptor_t::sampling_function (C++ struct), 717
esp_ble_mesh_sensor_descriptor_t::update_interval (C++ member), 718
ESP_BLE_MESH_SENSOR_DIVISOR_TRIGGER_TYPE_LEN (C++ member), 717
(ESP) BLE_MESH_SENSOR-server CB event_t (C++ enum), 729
esp_ble_mesh_sensor_server_cb_event_t::ESP_BLE_MESH_SENSOR_SERVER_EVT_MAX (C++ enumerator), 728
esp_ble_mesh_sensor_server_cb_event_t::ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT (C++ enumerator), 729
esp_ble_mesh_sensor_server_cb_event_t::ESP_BLE_MESH_SENSOR_SERVER_RECV_GET_MSG_EVT (C++ enumerator), 729
esp_ble_mesh_sensor_server_cb_event_t::ESP_BLE_MESH_SENSOR_SERVER_RECV_SET_MSG_EVT (C++ enumerator), 729
esp_ble_mesh_sensor_server_cb_event_t::ESP_BLE_MESH_SENSOR_SERVER_EVT_MAX (C++ enumerator), 729
esp_ble_mesh_sensor_server_cb_event_t::model (C++ struct), 724
esp_ble_mesh_sensor_server_cb_event_t::ctx (C++ member), 724
ESP_BLE_MESH_SENSOR_PROPERTY_ID_LEN (C macro), 726
esp_ble_mesh_sensor_sample_func (C++ enum), 728
esp_ble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_UNSPECIFIED (C++ enumerator), 729
esp_ble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_RMS (C++ enumerator), 729
espble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_MINIMUM (C++ enumerator), 729
espble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_MAXIMUM (C++ enumerator), 729
espble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_COUNT (C++ enumerator), 729
espble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_ACCUMULATED (C++ enumerator), 729
espble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_AVG (C++ enumerator), 729
espble_mesh_sensor_sample_func::ESP_BLE_MESH_SAMPLE_FUNC_ACCUMULATED (C++ enumerator), 729
espble_mesh_sensor_series_column_t::raw_value_x (C++ member), 719
espble_mesh_sensor_series_column_t::raw_value_x1 (C++ member), 719
espble_mesh_sensor_series_column_t::raw_value_x2 (C++ member), 719
espble_mesh_sensor_series_column_t::raw_value_y (C++ member), 719
espble_mesh_sensor_series_column_t::column_width (C++ member), 720
espble_mesh_sensor_series_series_column_t::raw_value_x (C++ member), 719
espble_mesh_sensor_series_series_column_t::raw_value_y (C++ member), 719
espble_mesh_sensor_series_status_cb_t::sensor_series_value (C++ member), 715
espble_mesh_sensor_series_status_cb_t::property_id (C++ member), 715
espble_mesh_sensor_series_status_status_cb_t::property_id (C++ member), 717
espble_mesh_sensor_series_status_status_cb_t::sensor_series_value (C++ member), 717
```

Espressif Systems 2814 Release v5.1.2
Submit Document Feedback
<table>
<thead>
<tr>
<th>Member/Field</th>
<th>Line Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_mesh_sensor_server_cb_param_t::value</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_setting_set_t::sensor_setting</td>
<td>715</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_t::sensor_type</td>
<td>728</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_status_cb_t::state</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_status_cb_t::model</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_status_set_get_t::sensor_property_ids</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_status_set_get_t::sensor_property_id</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_status_set_get_t::sensor_setting_property_id</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_set_msg_t::sensor_setting</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_setting</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_series</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_descriptor</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_data</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_column</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_cadence</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_state_change_t::sensor_setting_set</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_state_change_t::sensor_cadence_set</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_setting</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_cadence</td>
<td>721</td>
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<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_series</td>
<td>721</td>
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<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_descriptor</td>
<td>721</td>
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<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_column</td>
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<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_cadence</td>
<td>721</td>
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<tr>
<td>esp_ble_mesh_sensor_server_state_change_t::sensor_setting_set</td>
<td>720</td>
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<td>esp_ble_mesh_sensor_server_state_change_t::sensor_cadence_set</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_series</td>
<td>721</td>
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<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_descriptor</td>
<td>721</td>
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<td>721</td>
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<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_column</td>
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<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_cadence</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_state_change_t::sensor_setting_set</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_state_change_t::sensor_cadence_set</td>
<td>720</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_series</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_descriptor</td>
<td>721</td>
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<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_data</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_column</td>
<td>721</td>
</tr>
<tr>
<td>esp_ble_mesh_sensor_server_recv_get_msg_t::sensor_cadence</td>
<td>721</td>
</tr>
</tbody>
</table>
Index

esp_ble_mesh_sensor_status_cb_t::marshalled_sensor_data
(C++ member), 717

esp_ble_mesh_server_recv_gen_move_set_t::op_en
(C++ member), 698

esp_ble_mesh_server_recv_gen_move_set_t::delta_level
(C++ member), 698

esp_ble_mesh_server_recv_gen_move_set_t::delay
(C++ member), 698

esp_ble_mesh_server_recv_gen_loc_local_set_t::uncertainty
(C++ member), 720

esp_ble_mesh_server_recv_gen_loc_local_set_t::local_north
(C++ member), 720

esp_ble_mesh_server_recv_gen_loc_local_set_t::local_east
(C++ member), 720

esp_ble_mesh_server_recv_gen_loc_local_set_t::local_altitude
(C++ member), 720

esp_ble_mesh_server_recv_gen_level_set_t::trans_time
(C++ member), 699

esp_ble_mesh_server_recv_gen_level_set_t::tid
(C++ member), 699

esp_ble_mesh_server_recv_gen_level_set_t::op_en
(C++ member), 699

esp_ble_mesh_server_recv_gen_level_set_t::level
(C++ member), 699

ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERRVAL_LENGTH
(C macro), 726

ESP_BLE_MESH_SENSOR_STATUS_MIN_INTERRVAL_LENGTH
(C macro), 726

ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_UINT16
table
(C macro), 700

ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_UINT16
table
(C macro), 700

ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_CHAR
table
(C macro), 701

ESP_BLE_MESH_SENSOR_STATUS_TRIGGER_TYPE_CHAR
table
(C macro), 701

ESP_BLE_MESH_SENSOR_UNSPECIFIED_POS_TOLERANCE
(C macro), 701

ESP_BLE_MESH_SENSOR_UNSPECIFIED_POS_TOLERANCE
(C macro), 701

ESP_BLE_MESH_SERVER_AUTO_RSP (C macro), 701

esp_ble_mesh_server_model_send_msg
(C++ function), 612

esp_ble_mesh_server_model_update_state (C++ function), 613

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 697

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 697

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 701

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 701

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 701

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 701

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

esp_ble_mesh_server_recv_gen_admin_properties_set
table (C++ struct), 702

Espessif Systems 2816 Release v5.1.2
Submit Document Feedback
Index

esp_ble_mesh_server_recv_light_ctl_temperature_set_t::trans_time
(C++ member), 699
esp_ble_mesh_server_recv_light_ctl_temperature_set_t
(C++ struct), 802
esp_ble_mesh_server_recv_light_ctl_temperature_range_set_t::range_min
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_temperature_range_set_t::range_max
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_set_t::tid
(C++ member), 801
esp_ble_mesh_server_recv_light_ctl_set_t::temperature
(C++ member), 801
esp_ble_mesh_server_recv_light_ctl_set_t::op_en
(C++ member), 801
esp_ble_mesh_server_recv_light_ctl_set_t::lightness
(C++ member), 801
esp_ble_mesh_server_recv_light_ctl_set_t::delta_uv
(C++ member), 801
esp_ble_mesh_server_recv_light_ctl_set_t::delay
(C++ member), 801
esp_ble_mesh_server_recv_light_ctl_default_set_t::temperature
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_default_set_t::op_en
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_default_set_t::lightness
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_default_set_t::delta_uv
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_default_set_t::delay
(C++ member), 802
esp_ble_mesh_server_recv_light_ctl_default_set_t::trans_time
(C++ member), 802
esp_ble_mesh_server_recv_gen_power_range_set_t::range_min
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_range_set_t::range_max
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_level_set_t::trans_time
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_level_set_t::power
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_level_set_t::op_en
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_level_set_t::delay
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_default_set_t::power
(C++ member), 700
esp_ble_mesh_server_recv_gen_power_default_set_t
(C++ struct), 700
esp_ble_mesh_server_recv_gen_onpowerup_set_t::onpowerup
(C++ member), 701
esp_ble_mesh_server_recv_gen_onpowerup_set_t
(C++ struct), 701
esp_ble_mesh_server_recv_gen_onoff_set_t::trans_time
(C++ member), 700
esp_ble_mesh_server_recv_gen_onoff_set_t::tid
(C++ member), 700
esp_ble_mesh_server_recv_gen_onoff_set_t::op_en
(C++ member), 700
esp_ble_mesh_server_recv_gen_onoff_set_t::onoff
(C++ member), 700
esp_ble_mesh_server_recv_gen_onoff_set_t::delay
(C++ member), 700
esp_ble_mesh_server_recv_gen_onoff_set_t
(C++ struct), 700
esp_ble_mesh_server_recv_gen_move_set_t::trans_time
(C++ member), 700
esp_ble_mesh_server_recv_gen_move_set_t::tid
(C++ member), 700
esp_ble_mesh_server_recv_gen_move_set_t::op_en
(C++ member), 700
esp_ble_mesh_server_recv_gen_move_set_t::onoff
(C++ member), 700
esp_ble_mesh_server_recv_gen_move_set_t::delay
(C++ member), 700
esp_ble_mesh_server_recv_gen_move_set_t
(C++ struct), 700
esp_ble_mesh_server_recv_light_hsl_hue_set_t::trans_time
(C++ member), 699
esp_ble_mesh_server_recv_light_hsl_hue_set_t
(C++ struct), 803
esp_ble_mesh_server_recv_light_hsl_hue_set_t::op_en
(C++ member), 804
esp_ble_mesh_server_recv_light_hsl_hue_set_t::hue
(C++ member), 804
esp_ble_mesh_server_recv_light_hsl_hue_set_t::delay
(C++ member), 804
esp_ble_mesh_server_recv_light_hsl_hue_set_t
(C++ struct), 803
esp_ble_mesh_server_recv_light_hsl_default_set_t::saturation
(C++ member), 803
esp_ble_mesh_server_recv_light_hsl_default_set_t::lightness
(C++ member), 803
esp_ble_mesh_server_recv_light_hsl_default_set_t::hue
(C++ member), 803
esp_ble_mesh_server_recv_light_hsl_default_set_t
(C++ struct), 804
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::trans_time
(C++ member), 699
esp_ble_mesh_server_recv_light_ctl_temperature_set_t
(C++ struct), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::op_en
(C++ member), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::delta_uv
(C++ member), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::tid
(C++ member), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::temperature
(C++ member), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::lightness
(C++ member), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t::delay
(C++ member), 803
esp_ble_mesh_server_recv_light_ctl_temperature_set_t
(C++ struct), 804
802
803
804
801
Esp`ble`mesh`server`recv_scheduler_act_set_t::mon
(C++ member), 806

Esp`ble`mesh`server`recv_scheduler_act_set_t::sec
(C++ member), 751

Esp`ble`mesh`server`recv_light_xyl_range_set_t::y_range_min
(C++ member), 804

Esp`ble`mesh`server`recv_light_xyl_range_set_t::y_range_max
(C++ member), 805

Esp`ble`mesh`server`recv_light_xyl_set::lightness
(C++ member), 804

Esp`ble`mesh`server`recv_light_xyl_set::delay
(C++ member), 805
Index

esp_ble_mesh_server_state_value_t::light_ctl_t (C++ member),  655
esp_ble_mesh_server_state_value_t::light_ctl (C++ member),  655
esp_ble_mesh_server_state_value_t::light_hsl (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_update_t::net_idx (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_update_t::app_idx (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_update_t (C++ struct),  656
esp_ble_mesh_server_state_change_cfg_appkey_delete_t::net_idx (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_delete_t::app_idx (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_delete_t (C++ struct),  656
esp_ble_mesh_server_state_change_cfg_appkey_add_t::net_idx (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_add_t::app_key (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_add_t::app_idx (C++ member),  655
esp_ble_mesh_server_state_change_cfg_appkey_add_t (C++ struct),  656

ESP_BLE_MESH_SETTINGS_UID_SIZE (C macro),  574
ESP_BLE_MESH_SIG_MODEL (C macro),  577
esp_ble_mesh_state_change_cfg_appkey_add_t::model_id (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_add_t::element_addr (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_add_t::company_id (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_add_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_model_sub_add_t::element_addr (C++ member),  655
esp_ble_mesh_state_change_cfg_model_sub_add_t::company_id (C++ member),  655
esp_ble_mesh_state_change_cfg_model_sub_add_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_model_sub_add_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_model_app_unbind_t::element_addr (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_unbind_t::company_id (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_unbind_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_unbind_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_model_app_bind_t::model_id (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_bind_t::element_addr (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_bind_t::company_id (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_bind_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_model_app_bind_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_mod_pub_set_t::pub_ttl (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t::pub_retransmit (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t::pub_period (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t::element_addr (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t::cred_flag (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t::company_id (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_mod_pub_set_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_kr_phase_set_t::kr_phase (C++ member),  655
esp_ble_mesh_state_change_cfg_kr_phase_set_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_appkey_update_t::net_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_update_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_update_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_appkey_delete_t::net_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_delete_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_delete_t (C++ struct),  656
esp_ble_mesh_state_change_cfg_appkey_add_t::net_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_add_t::app_key (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_add_t::app_idx (C++ member),  655
esp_ble_mesh_state_change_cfg_appkey_add_t (C++ struct),  656
esp_ble_mesh_set_unprovisioned_device_name (C function),  621
esp_ble_mesh_set_fast_prov_info (C function),  625
esp_ble_mesh_set_fast_prov_action (C function),  625

Esys queryString 2021
Release v5.1.2
Submit Document Feedback
<table>
<thead>
<tr>
<th>C++ member</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_ble_mesh_state_change_light_ctl_set_t::delta_uv</td>
<td>696</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_ctl_default_set_t::lightness</td>
<td>696</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_ctl_default_set_t::temperature</td>
<td>696</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_light_ctl_default_set_t::delta_uv</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::power</td>
<td>695</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>696</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>695</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>695</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_default_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_max</td>
<td>694</td>
</tr>
<tr>
<td>esp_ble_mesh_state_change_gen_power_range_set_t::range_min</td>
<td>694</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Index

esp_ble_penc_keys_t::rand (C++ member), 286
esp_ble_penc_keys_t::sec_level (C++ member), 286
esp_ble_pid_keys_t (C++ struct), 287
esp_ble_pid_keys_t::addr_type (C++ member), 287
esp_ble_pid_keys_t::irk (C++ member), 287
esp_ble_pid_keys_t::static_addr (C++ member), 287
esp_pkt_data_length_params_t (C++ struct), 286
esp_pkt_data_length_params_t::tx_len (C++ member), 286
esp_pkt_data_length_params_t::rx_len (C++ member), 286
esp_power_type_t (C++ enum), 529
esp_power_type_t::ESP_BLE_PWR_TYPE_ADV (C++ enumerator), 530
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL3 (C++ member), 284
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL4 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL5 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL6 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL7 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL8 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_ADV (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_NUM (C++ enumerator), 529
esp_power_type_t::ESP_BLE_PWR_TYPE_DEFAULT (C++ member), 284
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL3 (C++ enum), 315
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL4 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL5 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL6 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_DEFAULT (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL7 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL8 (C++ enum), 314
esp_sec::oob_data (C++ struct), 288
esp_sec::key_notif (C++ member), 288
esp_power_type_t (C++ struct), 288
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL3 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL4 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL5 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL6 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL7 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL8 (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_ADV (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_NUM (C++ enumerator), 529
esp_power_type_t::ESP_BLE_PWR_TYPE_DEFAULT (C++ member), 284
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL3 (C++ enum), 315
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL4 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL5 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL6 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_DEFAULT (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL7 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL8 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_ADV (C++ member), 285
esp_power_type_t::ESP_BLE_PWR_TYPE_NUM (C++ enumerator), 529
esp_power_type_t::ESP_BLE_PWR_TYPE_DEFAULT (C++ member), 284
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL3 (C++ enum), 315
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL4 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL5 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL6 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_DEFAULT (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL7 (C++ enum), 314
esp_power_type_t::ESP_BLE_PWR_TYPE_CONN_HDL8 (C++ enum), 314

Espresif Systems 2828 Release v5.1.2
Submit Document Feedback
Index

esp_ble_sm_param_t::ESP_BLE_APP_ENC_KEY entry key
  bluetooth_sdp_mns_record_t (C++ type), 520
  (C++ enumerator), 315
esp_ble_sm_param_t::ESP_BLE_SM_AUTHENTICATION (C++ type), 520
  (C++ enumerator), 314
esp_ble_sm_param_t::ESP_BLE_SM_CLEAR_OOB_ADMIN (C++ type), 520
  (C++ enumerator), 314
esp_ble_sm_param_t::ESP_BLE_SM_IOCAP_MODE (C++ type), 520
  (C++ enumerator), 314
esp_ble_sm_param_t::ESP_BLE_SM_MAX_KEY (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_MAX_PARAM (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_MIN_KEY (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_OOB_SUPPORTED (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_PASSKEY (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_SET_INITIALIZED (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_SET_RX_SM (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_SET_RX_TX (C++ type), 520
  (C++ union), 114
esp_ble_sm_param_t::ESP_BLE_SM_SET_RX_TX_RX (C++ type), 520
  (C++ union), 114

C++ member

C++ type

C++ union

C++ enum

C++ struct
esp_blufi_cb_event_t (C++ enum), 377
esp_blufi_cb_event_t::ESP BLUFI EVENT BLE CONNECT (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT BLE DISCONNECT (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT DEAUTHENTICATE_STA (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT GET WIFI OPMODE (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT REQ DISCONNECT_FROM_AP (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT REQ CONNECT TO AP (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT REPORT ERROR (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_STA SSID (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_STA PASSWD (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SOFTAP SSID (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SOFTAP PASSWD (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SOFTAP MAX_CONN NUM (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SOFTAP CHANNEL (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SOFTAP AUTH MODE (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SLAVE_DISCONNECT_BLE (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SERVER_PRIV_KEY (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_SERVER_CERT (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_CUSTOM DATA (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_CLIENT_PRIV_KEY (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_CLIENT_CERT (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_RECV_CA_CERT (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_GET_WIFI_STATUS (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_GET_WIFI_LIST (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_DEINIT_FINISH (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_DEAUTHENTICATE_STA (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_BLE_DISCONNECT (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_BLE_CONNECT (C++ member), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_BLE_CONNECT_EVT_PARAM (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_BLE_DISCONNECT_EVT_PARAM (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_BLE_CONNECT_EVT_PARAM (C++ struct), 370
esp_blufi_cb_event_t::ESP BLUFI EVENT_BLE_DISCONNECT_EVT_PARAM (C++ struct), 370

Index
Index

esp_blufi_error_state_t::ESP_BLUFI_INIT (C++ function), 368
(\texttt{C++ enumerator}), 379
eesp_blufi_init_state_t (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_MAKE_STATE_ERROR (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_MSG_ERROR (C++ enum), 379
eesp_blufi_init_state_t::ESP_BLUFI_INIT_FAILED (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_READ_PARAM_ERROR (C++ enum), 379
eesp_blufi_init_state_t::ESP_BLUFI заказ data_handler_t (C++ type), 377
esp_blufi_error_state_t::ESP_BLUFI_SEQUENCE_ERROR (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_WIFI_PROFILE_DEFINE (C++ function), 368
eesp_blufi_init_state_t (C++ enum), 379
esp_blufi_event_cb_t (C++ type), 377
esp_blufi_send_custom_data (C++ function), 368
eesp_blufi_send_custom_data (\texttt{C++ function}), 368
eesp_blufi_send_error_info (C++ function), 368
esp_blufi_send_wifi_conn_report (C++ function), 368
eesp_blufi_send_wifi_list (C++ function), 368
esp_blufi_sta_conn_state_t (C++ enum), 379
esp_blufi_sta_conn_state_t (C++ enum), 379
esp_bredr_sco_datapath_set (C++ function), 523
esp_bredr_tx_power_get (C++ function), 523
esp_bredr_tx_power_set (C++ function), 522
ESP_BT_COD_FORMAT_TYPE_1 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_2 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_MASK (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET (C macro), 395
ESP_BT_COD_MAJOR_DEV_BIT_MASK (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
esp_blufi_error_state_t::ESP_BLUFI_STA_CONN_FAIL (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_CONN_SUCCESS (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_NO_IP (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_CONNECTING (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTING (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED_ERROR (C++ enum), 379
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
esp_bredr_sco_datapath_set (C++ function), 523
esp_bredr_tx_power_get (C++ function), 523
esp_bredr_tx_power_set (C++ function), 522
ESP_BT_COD_FORMAT_TYPE_1 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_2 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_MASK (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET (C macro), 395
ESP_BT_COD_MAJOR_DEV_BIT_MASK (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
esp_blufi_error_state_t::ESP_BLUFI_STA_CONN_FAIL (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_CONN_SUCCESS (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTING (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED_ERROR (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED_ERROR (C++ enum), 379
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
esp_bredr_sco_datapath_set (C++ function), 523
esp_bredr_tx_power_get (C++ function), 523
esp_bredr_tx_power_set (C++ function), 522
ESP_BT_COD_FORMAT_TYPE_1 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_2 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_MASK (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET (C macro), 395
ESP_BT_COD_MAJOR_DEV_BIT_MASK (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
esp_blufi_error_state_t::ESP_BLUFI_STA_CONN_FAIL (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_CONN_SUCCESS (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTING (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED_ERROR (C++ enum), 379
esp_blufi_error_state_t::ESP_BLUFI_STA_DISCONNECTED_ERROR (C++ enum), 379
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394
esp_bredr_sco_datapath_set (C++ function), 523
esp_bredr_tx_power_get (C++ function), 523
esp_bredr_tx_power_set (C++ function), 522
ESP_BT_COD_FORMAT_TYPE_1 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_2 (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_MASK (C macro), 395
ESP_BT_COD_FORMAT_TYPE_BIT_OFFSET (C macro), 395
ESP_BT_COD_MAJOR_DEV_BIT_MASK (C macro), 394
ESP_BT_COD_MAJOR_DEV_BIT_OFFSET (C macro), 394

Index

esp_bt_controller_get_status (C++ function), 523
esp_bt_controller_init (C++ function), 523
esp_bt_controller_mem_release (C++ function), 524
esp_bt_controller_status_t (C++ enum), 529
esp_bt_controller_status_t::ESP_BT_CONTROLLER_STATUS_NUM (C++ enumeration), 392
esp_bt_controller_status_t::ESP_BT_CONTROLLER_STATUS_INITED (C++ enumeration), 392
esp_bt_controller_status_t::ESP_BT_CONTROLLER_STATUS_IDLE (C++ enumeration), 392
esp_bt_controller_status_t::ESP_BT_CONTROLLER_STATUS_ENABLED (C++ enumeration), 392
esp_bt_controller_mem_release (C++ function), 529
esp_bt_controller_mem_release (C++ macro), 392
esp_bt_controller_status_t::ESP_BT_CONTROLLER_STATUS_ENABLED (C++ macro), 392
esp_bt_controller_mem_release (C++ macro), 392
esp_bt_discovery_mode_t (C++ macro), 393
esp_bt_discovery_mode_t::ESP_BT_NON_DISCOVERABLE (C++ macro), 393
esp_bt_discovery_mode_t::ESP_BT_GENERAL_DISCOVERABLE (C++ macro), 393
esp_bt_dev_type_t (C++ enum), 317
esp_bt_dev_type_t::ESP_BT_DEVICE_TYPE_DUMO (C++ macro), 393
esp_bt_dev_type_t::ESP_BT_DEVICE_TYPE_BREDR (C++ macro), 393
esp_bt_dev_type_t::ESP_BTDEVICE_TYPE_BLE (C++ macro), 393
esp_bt_duplicate_exceptional_subcode_type_t (C++ macro), 393
esp_bt_duplicate_exceptional_subcode_type_t::ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_REMOVE (C++ macro), 393
esp_bt_duplicate_exceptional_subcode_type_t::ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_CLEAN (C++ macro), 393
esp_bt_duplicate_exceptional_subcode_type_t::ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_ADD (C++ macro), 393
esp_bt_eir_data_t (C++ struct), 392
esp_bt_eir_data_t::fsc_required (C++ member), 392
esp_bt_eir_data_t::flag (C++ member), 392
esp_bt_eir_data_t::include_name (C++ member), 392
esp_bt_eir_data_t::include_txpower (C++ member), 392
esp_bt_eir_data_t::include_uuid (C++ member), 392
esp_bt_eir_data_t::manufacturer_len (C++ member), 392
esp_bt_eir_data_t::p_manufacturer_data (C++ member), 392
esp_bt_eir_data_t::p_url (C++ member), 392
esp_bt_eir_data_t::url_len (C++ member), 392

Espresif Systems

2834

Release v5.1.2

Submit Document Feedback
Index

(C++ enumerator), 399

esp_bt_gap_cb_event_t::ESP_BT_GAP_MODE_CHG_EVT (C++ struct), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_PIN_REQ_EVT (C++ struct), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_QOS_CMP_EVT (C++ struct), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ struct), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ struct), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ struct), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_REMOTE_NAME_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_READ_RSSI_DELTA_EVT (C++ member), 387

esp_bt_gap_cb_event_t::ESP_BT_GAP_REMOVE_BOND_EVT (C++ member), 387
Index
Index

esp_bt_gap_remove_bond_device (C++ function), 383
esp_bt_gap_resolve_eir_data (C++ function), 382
ESP_BT_GAP_RSSI_HIGH_THRLD (C macro), 392
ESP_BT_GAP_RSSI_LOW_THRLD (C macro), 392
esp_bt_gap_set_adv_channels (C++ function), 384
esp_bt_gap_set_ccid (C++ function), 382
esp_bt_gap_set_pin (C++ function), 383
esp_bt_gap_set_qos (C++ function), 384
esp_bt_gap_set_scan_mode (C++ function), 381
esp_bt_gap_set_security_param (C++ function), 384
esp_bt_gap_ssp_confirm_reply (C++ function), 384
esp_bt_gap_ssp_passkey_reply (C++ function), 384
esp_bt_gap_start_discovery (C++ function), 381
ESP_BT_GAP_TFOLL_DFT (C macro), 395
ESP_BT_GAP_TFOLL_MAX (C macro), 395
ESP_BT_GAP_TFOLL_MIN (C macro), 395
ESP_BT_HF_AT_SEND_XAPL_LEN (C macro), 463
ESP_BT_HF_CLIENT_OPERATOR_NAME_LEN (C macro), 463
ESP_BT_HF_CLIENT_NUMBER_LEN (C macro), 463
esp_bt_hid_host_init (C++ function), 494
esp_bt_hid_host_init (C++ function), 494
esp_bt_hid_host_register_callback (C++ function), 494
esp_bt_hid_host_send_data (C++ function), 496
esp_bt_hid_host_set_idle (C++ function), 495
esp_bt_hid_host_set_info (C++ function), 495
esp_bt_hid_host_set_protocol (C++ function), 495
esp_bt_hid_host_set_report (C++ function), 496
esp_bt_hid_host_virtual_cable_unplug (C++ function), 494
esp_bt_inq_mode_t (C++ enum), 400
esp_bt_inq_mode_t::ESP_BT_INQ_MODE_GENERAL_INQUIRY (C++ enumerator), 400
esp_bt_inq_mode_t::ESP_BT_INQ_MODE_LIMITED_INQUIRY (C++ enumerator), 400
ESP_BT_IO_CAP_IN (C macro), 394
ESP_BT_IO_CAP_IN (C macro), 394
ESP_BT_IO_CAP_IN (C macro), 394
ESP_BT_IO_CAP_OUT (C macro), 394
esp_bt_io_cap_t (C++ type), 395
esp_bt_12cap_cb_event_t (C++ enum), 513
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_CL_INIT_EVT (C++ enumerator), 514
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_CL_INIT_EVT (C++ enum), 513
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_CLOSE_EVT (C++ enumerator), 514
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_CLOSE_EVT (C++ enum), 513
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_INIT_EVT (C++ enumerator), 514
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_INIT_EVT (C++ enum), 513
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_OPEN_EVT (C++ enumerator), 514
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_OPEN_EVT (C++ enum), 513
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_SRV_STOP_EVT (C++ enumerator), 514
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_SRV_STOP_EVT (C++ enum), 513
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_UNINIT_EVT (C++ enum), 514
esp_bt_12cap_cb_event_t::ESP_BT_L2CAP_UNINIT_EVT (C++ enum), 513
esp_bt_12cap_cb_param_t (C++ union), 510
esp_bt_12cap_cb_param_t::cl_init (C++ member), 510
esp_bt_12cap_cb_param_t::close (C++ member), 510
esp_bt_12cap_cb_param_t::init (C++ member), 510
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ struct), 510
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ member), 511
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ member), 511
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ member), 511
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ member), 511
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ struct), 511
esp_bt_12cap_cb_param_t::ESP_BT_L2CAP_CL_INIT_EVT_PARAM (C++ struct), 511

Index

(C++ member), 511

ESP_BT_L2CAP_SEC_NONE (C macro), 512

esp_bt_l2cap_cb_param_t::l2cap_close_evt_param (C++ function), 509

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_BUSY (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_FAILURE (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_NEED_DEINIT (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_NEED_INIT (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_NO_CONNECTION (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_NO_RESOURCE (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_NO_SERVER (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_SUCCESS (C++ enum), 513

esp_bt_l2cap_client_t::esp_bt_l2cap_client_status_t::ESP_BT_L2CAP_TICK (C++ function), 509

esp_bt_l2cap_stop_srv (C++ function), 509

esp_bt_l2cap_vfs_register (C++ function), 509

esp_bt_l2cap_vfs_unregister (C++ function), 509

esp_bt_mem_release (C++ function), 524

esp_bt_mode_t (C++ enum), 528

esp_bt_mode_t::ESP_BT_MODE_BLE (C++ function), 528

esp_bt_mode_t::ESP_BT_MODE_BTDM (C++ function), 528

esp_bt_mode_t::ESP_BT_MODE_CLASSIC_BT (C++ function), 528

esp_bt_mode_t::ESP_BT_MODE_IDLE (C++ function), 528

ESP_BT_OCTET16_LEN (C macro), 244

ESP_BT_OCTET8_LEN (C macro), 244

esp_octet8_t (C++ type), 245

ESP_BT_PIN_CODE_LEN (C macro), 394

esp_bluetooth_pin_code_t (C++ type), 395

esp_bluetooth_pin_code_t::ESP_BT_PIN_TYPE_FIXED (C++ enum), 398

esp_bluetooth_pin_code_t::ESP_BT_PIN_TYPE_VARIABLE (C++ enum), 398

ESP_BT_PM_MD_ACTIVE (C macro), 394

ESP_BT_PM_MD_HOLD (C macro), 394

ESP_BT_PM_MD_PARK (C macro), 394

ESP_BT_PM_MD_SNIFF (C macro), 394

esp_bt_mode_t (C++ type), 395

esp_sleeep_disable (C++ function), 525

esp_socket_enable (C++ function), 525

esp_socket_param_t (C++ enum), 398

esp_socket_param_t::ESP_BTSCRIPTION_MODE (C++ function), 398

ESP_BT_STATUS_BASE_FOR_HCI_ERR (C macro), 513

ESP_BT_L2CAP_SEC_AUTHORIZE (C macro), 512

ESP_BT_L2CAP_SEC_ENCRYPT (C macro), 513

ESP_BT_L2CAP_SEC_AUTHENTICATE (C macro), 512

ESP_BT_L2CAP_SEC_DEAUTHENTICATE (C macro), 512

ESP_BT_PM_MD_CONNECT (C macro), 394
Index

esp_eap_fast_config::fast_max_pac_list_t esp_efuse_coding_scheme_t::EFUSE_CODING_SCHEME_3_4 (C++ member), 942
esp_eap_fast_config::fast_pac_format_binary esp_efuse_coding_scheme_t::EFUSE_CODING_SCHEME_NO_REPEAT (C++ member), 942
esp_eap_fast_config::fast_provisioning esp_efuse_coding_scheme_t::EFUSE_CODING_SCHEME_REPEAT (C++ member), 942
esp_eap_ttls_phase2_types::ESP_EAP_TTLS_PHASE2_MSCHAPV2 esp_efuse_check_secure_version (C++ function), 1925
esp_eap_ttls_phase2_types::ESP_EAP_TTLS_PHASE2_EAP esp_efuse_check_errors (C++ function), 1925
esp_eap_ttls_phase2_types::ESP_EAP_TTLS_PHASE2_CHAP esp_efuse_block_t::EFUSE_BLK_SECURE_BOOT (C++ function), 1925
(esp_efuse_block_t::EFUSE_BLK_MAX) esp_efuse_block_t::EFUSE_BLK_KEY_MAX (C++ function), 1925
(esp_efuse_block_t::EFUSE_BLK_KEY2) esp_efuse_block_t::EFUSE_BLK_MAX (C++ function), 1925
(esp_efuse_block_t::EFUSE_BLK_KEY1) esp_eap_eap_config::fast_provisioning (C++ function), 1925
(esp_efuse_block_t::EFUSE_BLK_KEY0) esp_eap_eap_config::fast_pac_format_binary (C++ function), 1925
(esp_efuse_block_t::EFUSE_BLK_ENCRYPT_FLASH) esp_eap_eap_config::fast_max_pac_list_t (C++ function), 1925
(esp_efuse_block_t::EFUSE_BLK0) esp_eap_eap_config::fast_max_pac_list_t (C++ function), 1925
esp_eap_fast_config::fast_provisioning esp_eap_ttls_phase2_types::ESP_EAP_TTLS_PHASE2_CHAP (C++ member), 942
esp_efuse_batch_write_begin (C++ function), 1929
esp_efuse_batch_write_cancel (C++ function), 1930
esp_efuse_batch_write_commit (C++ function), 1931
esp_efuse_block_is_empty (C++ function), 1932
esp_efuse_block_t (C++ enum), 942
esp_efuse_block_t::EFUSE_BLK0 (C++ enumerator), 2161
esp_efuse_block_t::EFUSE_BLK1 (C++ enumerator), 2161
esp_efuse_block_t::EFUSE_BLK2 (C++ enumerator), 2161
esp_efuse_block_t::EFUSE_BLK3 (C++ enumerator), 2161
esp_efuse_block_t::EFUSE_BLK0 (C++ function), 1924
esp_efuse_block_t::EFUSE_BLK1 (C++ function), 1924
esp_efuse_block_t::EFUSE_BLK2 (C++ function), 1924
esp_efuse_block_t::EFUSE_BLK3 (C++ function), 1925
esp_efuse_block_t::EFUSE_BLK0 (C++ member), 942
esp_efuse_block_t::EFUSE_BLK1 (C++ member), 942
esp_efuse_block_t::EFUSE_BLK2 (C++ member), 942
esp_efuse_block_t::EFUSE_BLK3 (C++ member), 942
esp_efuse_block_t::EFUSE_BLK_SECURE_BOOT (C++ member), 942
esp_efuse_check_errors (C++ function), 1934
esp_efuse_check_secure_version (C++ function), 1930
esp_efuse_coding_scheme_t (C++ enum), 1925
esp_efuse_coding_scheme_t::EFUSE_CODING_SCHEME_3_4 (C++ function), 1925
esp_efuse_coding_scheme_t::EFUSE_CODING_SCHEME_NO_REPEAT (C++ function), 1925
esp_efuse_check_secure_version (C++ function), 1925
esp_efuse_read_secure_version (C++ function), 1925
esp_efuse_read_reg (C++ function), 1928
esp_efuse_read_secure_version (C++ function), 1930

Espressif Systems 2843 Release v5.1.2
Submit Document Feedback
Index

esp_efuse_reset (C++ function), 1929
macro), 1022
esp_efuse_rom_log_scheme_t (C++ enum), ESP_ERR_ESP_NETIF_INIT_FAILED (C macro),
1935
1022
esp_efuse_rom_log_scheme_t::ESP_EFUSE_ROM_LOG_ALWAYS_OFF
ESP_ERR_ESP_NETIF_INVALID_PARAMS
(C
(C++ enumerator), 1935
macro), 1021
esp_efuse_rom_log_scheme_t::ESP_EFUSE_ROM_LOG_ALWAYS_ON
ESP_ERR_ESP_NETIF_IP6_ADDR_FAILED (C
(C++ enumerator), 1935
macro), 1022
esp_efuse_rom_log_scheme_t::ESP_EFUSE_ROM_LOG_ON_GPIO_HIGH
ESP_ERR_ESP_NETIF_MLD6_FAILED (C macro),
(C++ enumerator), 1935
1022
esp_efuse_rom_log_scheme_t::ESP_EFUSE_ROM_LOG_ON_GPIO_LOW
ESP_ERR_ESP_NETIF_NO_MEM (C macro), 1022
ESP_ERR_ESP_TLS_BASE (C macro), 157
(C++ enumerator), 1935
esp_efuse_set_key_dis_read (C++ function), ESP_ERR_ESP_TLS_CANNOT_CREATE_SOCKET
(C macro), 157
1932
esp_efuse_set_key_dis_write (C++ func- ESP_ERR_ESP_TLS_CANNOT_RESOLVE_HOSTNAME
tion), 1932
(C macro), 157
esp_efuse_set_read_protect (C++ function), ESP_ERR_ESP_TLS_CONNECTION_TIMEOUT (C
1928
macro), 158
esp_efuse_set_rom_log_scheme (C++ func- ESP_ERR_ESP_TLS_FAILED_CONNECT_TO_HOST
tion), 1930
(C macro), 157
esp_efuse_set_write_protect (C++ func- ESP_ERR_ESP_TLS_SE_FAILED (C macro), 158
tion), 1927
ESP_ERR_ESP_TLS_SOCKET_SETOPT_FAILED
esp_efuse_update_secure_version (C++
(C macro), 158
function), 1930
ESP_ERR_ESP_TLS_TCP_CLOSED_FIN
(C
esp_efuse_write_block (C++ function), 1929
macro), 158
esp_efuse_write_field_bit (C++ function), ESP_ERR_ESP_TLS_UNSUPPORTED_PROTOCOL_FAMILY
(C macro), 157
1927
esp_efuse_write_field_blob (C++ function), ESP_ERR_ESPNOW_ARG (C macro), 829
1927
ESP_ERR_ESPNOW_BASE (C macro), 829
esp_efuse_write_field_cnt (C++ function), ESP_ERR_ESPNOW_EXIST (C macro), 829
1927
ESP_ERR_ESPNOW_FULL (C macro), 829
esp_efuse_write_key (C++ function), 1933
ESP_ERR_ESPNOW_IF (C macro), 829
esp_efuse_write_keys (C++ function), 1933
ESP_ERR_ESPNOW_INTERNAL (C macro), 829
esp_efuse_write_reg (C++ function), 1928
ESP_ERR_ESPNOW_NO_MEM (C macro), 829
ESP_ERR_CODING (C macro), 1934
ESP_ERR_ESPNOW_NOT_FOUND (C macro), 829
ESP_ERR_DAMAGED_READING (C macro), 1935
ESP_ERR_ESPNOW_NOT_INIT (C macro), 829
ESP_ERR_DPP_FAILURE (C macro), 951
ESP_ERR_FLASH_BASE (C macro), 1937
ESP_ERR_DPP_INVALID_ATTR (C macro), 951
ESP_ERR_FLASH_NOT_INITIALISED (C macro),
ESP_ERR_DPP_TX_FAILURE (C macro), 951
1350
ESP_ERR_EFUSE (C macro), 1934
ESP_ERR_FLASH_OP_FAIL (C macro), 1344
ESP_ERR_EFUSE_CNT_IS_FULL (C macro), 1934 ESP_ERR_FLASH_OP_TIMEOUT (C macro), 1344
ESP_ERR_EFUSE_REPEATED_PROG (C macro), ESP_ERR_FLASH_PROTECTED (C macro), 1350
1934
ESP_ERR_FLASH_UNSUPPORTED_CHIP
(C
ESP_ERR_ESP_NETIF_BASE (C macro), 1021
macro), 1350
ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED ESP_ERR_FLASH_UNSUPPORTED_HOST
(C
(C macro), 1022
macro), 1350
ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED ESP_ERR_HTTP_BASE (C macro), 173
(C macro), 1022
ESP_ERR_HTTP_CONNECT (C macro), 173
ESP_ERR_ESP_NETIF_DHCP_NOT_STOPPED (C ESP_ERR_HTTP_CONNECTING (C macro), 173
macro), 1022
ESP_ERR_HTTP_CONNECTION_CLOSED
(C
ESP_ERR_ESP_NETIF_DHCPC_START_FAILED
macro), 173
(C macro), 1022
ESP_ERR_HTTP_EAGAIN (C macro), 173
ESP_ERR_ESP_NETIF_DHCPS_START_FAILED
ESP_ERR_HTTP_FETCH_HEADER (C macro), 173
ESP_ERR_HTTP_INVALID_TRANSPORT
(C
(C macro), 1022
ESP_ERR_ESP_NETIF_DNS_NOT_CONFIGURED
macro), 173
ESP_ERR_HTTP_MAX_REDIRECT (C macro), 173
(C macro), 1022
ESP_ERR_ESP_NETIF_DRIVER_ATTACH_FAILED ESP_ERR_HTTP_WRITE_DATA (C macro), 173
ESP_ERR_HTTPD_ALLOC_MEM (C macro), 228
(C macro), 1022
ESP_ERR_ESP_NETIF_IF_NOT_READY
(C ESP_ERR_HTTPD_BASE (C macro), 228

Espressif Systems

2844
Submit Document Feedback

Release v5.1.2


ESP_ERR_HTTPD_HANDLER_EXISTS (C macro), 228
ESP_ERR_HTTPD_HANDLERS_FULL (C macro), 228
ESP_ERR_HTTPD_INVALID_REQ (C macro), 228
ESP_ERR_HTTPD_RESP_HDR (C macro), 228
ESP_ERR_HTTPD_RESP_SEND (C macro), 228
ESP_ERR_HTTPD_RESULT_TRUNC (C macro), 228
ESP_ERR_HTTPD_TASK (C macro), 228
ESP_ERR_HTTPSOTA_BASE (C macro), 1944
ESP_ERR_HTTPSOTA_IN_PROGRESS (C macro), 1944
ESP_ERR_HW_CRYPTO_BASE (C macro), 1937
ESP_ERR_INVALID_ARG (C macro), 1937
ESP_ERR_INVALID_CRC (C macro), 1937
ESP_ERR_INVALID_RESPONSE (C macro), 1937
ESP_ERR_INVALID_SIZE (C macro), 1937
ESP_ERR_INVALID_STATE (C macro), 1937
ESP_ERR_INVALID_VERSION (C macro), 1937
ESP_ERR_MBEDTLS_CERT_PARTLY_OK (C macro), 158
ESP_ERR_MBEDTLS_CTR_DRBG_SEED_FAILED (C macro), 158
ESP_ERR_MBEDTLS_PK_PARSE_KEY_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_CONF_ALPN_PROTOCOLS (C macro), 158
ESP_ERR_MBEDTLS_SSL_CONF_OWN_CERT_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_CONF_PSK_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_CONFIG_DEFAULTS_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_HANDSHAKE_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_SET_HOSTNAME_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_SETUP_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_TICKET_SETUP_FAILED (C macro), 158
ESP_ERR_MBEDTLS_SSL_WRITE_FAILED (C macro), 158
ESP_ERR_MBEDTLS_X509_CRT_PARSE_FAILED (C macro), 158
ESP_ERR_MEMPROT_BASE (C macro), 1938
ESP_ERR_MESH_ARGUMENT (C macro), 862
ESP_ERR_MESH_BASE (C macro), 1937
ESP_ERR_MESH_DISCARD (C macro), 863
ESP_ERR_MESH_DISCARD_DUPLICATE (C macro), 863
ESP_ERR_MESH_DISCONNECTED (C macro), 863
ESP_ERR_MESH_EXCEED_MTU (C macro), 863
ESP_ERR_MESH_INTERFACE (C macro), 863
ESP_ERR_MESH_NO_MEMORY (C macro), 862
ESP_ERR_MESH_NO_PARENT_FOUND (C macro), 863
ESP_ERR_MESH_NO_ROUTE_FOUND (C macro), 863
ESP_ERR_MESH_NOT_ALLOWED (C macro), 862
ESP_ERR_MESH_NOT_CONFIG (C macro), 862
ESP_ERR_MESH_NOT_INIT (C macro), 862
ESP_ERR_MESH_NOT_START (C macro), 862
ESP_ERR_MESH_NOT_SUPPORT (C macro), 862
ESP_ERR_MESH_OPTION_NULL (C macro), 863
ESP_ERR_MESH_OPTION_UNKNOWN (C macro), 863
ESP_ERR_MESH_PSS (C macro), 864
ESP_ERR_MESH_QUEUE_FAIL (C macro), 863
ESP_ERR_MESH_QUEUE_FULL (C macro), 863
ESP_ERR_MESH_QUEUE_READ (C macro), 863
ESP_ERR_MESH_RECV_RELEASE (C macro), 864
ESP_ERR_MESH_TIMEOUT (C macro), 863
ESP_ERR_MESH_VOTING (C macro), 863
ESP_ERR_MESH_WIFI_NOT_START (C macro), 862
ESP_ERR_MESH_XMIT (C macro), 863
ESP_ERR_MESH_XON_NO_WINDOW (C macro), 863
ESP_ERR_NO_MEM (C macro), 1937
ESP_ERR_NOT_ENOUGH_UNUSED_KEY_BLOCKS (C macro), 1935
ESP_ERR_NOT_FINISHED (C macro), 1937
ESP_ERR_NOT_FOUND (C macro), 1937
ESP_ERR_NOT_SUPPORTED (C macro), 1937
ESP_ERR_NVS_BASE (C macro), 1835
ESP_ERR_NVSCONTENTDIFFERS (C macro), 1837
ESP_ERR_NVS_CORRUPTKEYPART (C macro), 1836
ESP_ERR_NVS_ENCRYPTION_NOT_SUPPORTED (C macro), 1836
ESP_ERR_NVS_INVALIDHANDLE (C macro), 1835
ESP_ERR_NVS_INVALIDLENGTH (C macro), 1836
ESP_ERR_NVS_INVALIDNAME (C macro), 1835
ESP_ERR_NVS_INVALIDSTATE (C macro), 1836
ESP_ERR_NVSKEYSTOOLONG (C macro), 1836
ESP_ERR_NVSKEYSNOTINITIALIZED (C macro), 1836
ESP_ERR_NVS_NEWVERSION_FOUND (C macro), 1836
ESP_ERR_NVS_NO_FREE_PAGES (C macro), 1836
ESP_ERR_NVS_NOT_ENOUGH_PAGES (C macro), 1835
ESP_ERR_NVS_NOT_FOUND (C macro), 1835
ESP_ERR_NVS_NOT_INITIALIZED (C macro), 1835
ESP_ERR_NVS_PAGE_FULL (C macro), 1836
ESP_ERR_NVS_PART_NOT_FOUND (C macro), 1836
ESP_ERR_NVS_READONLY (C macro), 1835
ESP_ERR_NVS_REMOVE_FAILED (C macro), 1835
ESP_ERR_NVS_TYPE_MISMATCH (C macro), 1835
ESP_ERR_NVS_VALUE_TOO_LONG (C macro), 1836
ESP_ERR_NVS_WRONG_ENCRYPTION (C macro), 1836
ESP_ERR_NVS_XTS_CFG_FAILED (C macro), 1836
ESP_ERR_NVS_XTS_CFG_FAILED (C macro), 1836
esp_eth_io_cmd_t::ETH_CMD_G_DUPLEX_MODE (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_G_MAC_ADDR (C++ enumerator), 970
esp_eth_io_cmd_t::ETH_CMD_G_PHY_ADDR (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_G_SPEED (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_S_AUTONEGO (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_S_DUPLEX_MODE (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_S_FLOW_CTRL (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_S_MAC_ADDR (C++ enumerator), 971
esp_eth_io_cmd_t::ETH_CMD_S_PHY_ADDR (C++ enumerator), 971
esp_eth_ioctl (C++ function), 967
esp_eth_mac_new_tstp (C++ function), 973
esp_eth_mac_s (C++ struct), 974
esp_eth_mac_s::custom_ioctl (C++ member), 978
esp_eth_mac_s::deinit (C++ member), 974
esp_eth_mac_s::del (C++ member), 978
esp_eth_mac_s::enable_flow_ctrl (C++ member), 977
esp_eth_mac_s::get_addr (C++ member), 977
esp_eth_mac_s::init (C++ member), 974
esp_eth_mac_s::read_phy_reg (C++ member), 976
esp_eth_mac_s::receive (C++ member), 976
esp_eth_mac_s::set_addr (C++ member), 976
esp_eth_mac_s::set_duplex (C++ member), 977
esp_eth_mac_s::set_link (C++ member), 977
esp_eth_mac_s::set_mediator (C++ member), 974
esp_eth_mac_s::set_peer_pause_ability (C++ member), 978
esp_eth_mac_s::set_promiscuous (C++ member), 977
esp_eth_mac_s::set_speed (C++ member), 977
esp_eth_mac_s::start (C++ member), 975
esp_eth_mac_s::stop (C++ member), 975
esp_eth_mac_s::transmit (C++ member), 975
esp_eth_mac_s::transmit_vargs (C++ member), 975
esp_eth_mac_s::write_phy_reg (C++ member), 976
esp_eth_mac_t (C++ type), 979
Index

esp_eth_phy_t (C++ type), 985
esp_eth_start (C++ function), 966
esp_eth_state_t (C++ enum), 973
esp_eth_state_t::ETH_STATE_DEINIT
(C++ enum), 973
esp_eth_state_t::ETH_STATE_DUPLEX
(C++ enum), 973
esp_eth_state_t::ETH_STATE_LINK
(C++ enum), 973
esp_eth_state_t::ETH_STATE_LLINIT
(C++ enum), 973
esp_eth_state_t::ETH_STATE_PAUSE
(C++ enum), 973
esp_eth_state_t::ETH_STATE_SPEED
(C++ enum), 973
esp_eth_stop (C++ function), 966
esp_eth_transmit (C++ function), 967
esp_eth_transmit_vargs (C++ function), 967
esp_eth_update_input_path (C++ function),
967
ESP_EVENT_ANY_BASE (C macro), 1949
ESP_EVENT_ANY_ID (C macro), 1950
ESP_EVENT_DECLARE_BASE (C macro), 1951
ESP_EVENT_DEFINE_BASE (C macro), 1952
esp_event_handler_instance_register
(C++ function), 1953
esp_event_handler_instance_register_with
(C++ function), 1954
esp_event_handler_instance_t (C++ type),
1955
esp_event_handler_unregister
(C++ function), 1956
esp_event_handler_unregister_instance_with
(C++ function), 1957
esp_event_isr_post (C++ function), 1958
esp_event_isr_post_to (C++ function), 1959
esp_event_loop_args_t (C++ struct), 1960
esp_event_loop_args_t::queue_size
(C++ member), 1961
esp_event_loop_args_t::task_core_id
(C++ member), 1962
esp_event_loop_args_t::task_name (C++
member), 1963
esp_event_loop_args_t::task_priority
(C++ member), 1964
esp_event_loop_args_t::task_stack_size
(C++ member), 1965
esp_event_loop_create (C++ function), 1966
esp_event_loop_create_default (C++ func-
ton), 1967
esp_event_loop_delete (C++ function), 1968
esp_event_loop_delete_default (C++ func-
ton), 1969
esp_event_loop_handle_t (C++ type), 1970
esp_event_loop_run (C++ function), 1971
esp_event_post (C++ function), 1972
esp_event_post_to (C++ function), 1973
ESP_EXECUTE_EXPRESSION_WITH_STACK
(C macro), 1974
esp_execute_shared_stack_function
(C++ function), 1975
ESP_FAIL (C macro), 1976
esp_fill_random (C++ function), 1977
esp_flash_chip_driver_initialized
(C++ function), 1978
esp_flash_enc_mode_t (C++ enum), 1979
esp_flash_enc_mode_t::ESP_FLASH_ENC_MODE
DEVELOPMENT (C++ enum), 1980
esp_flash_enc_mode_t::ESP_FLASH_ENC_MODE
DISABLED (C++ enum), 1981
esp_flash_enc_mode_t::ESP_FLASH_ENC_MODE
RELEASE (C++ enum), 1982
esp_flash_encrypt_check_and_update
(C++ function), 1983
esp_flash_encrypt_contents (C++ function),
1984
esp_flash_encrypt_enable (C++ function),
1985
esp_flash_encrypt_init (C++ function), 1986
esp_flash_encrypt_initialized_once
(C++ function), 1987
esp_flash_encrypt_is_write_protected
(C++ function), 1988
esp_flash_encrypt_region (C++ function),
1989
esp_flash_encrypt_state (C++ function),
1990
esp_flash_encryptionCfg_verify_release
mode (C++ function), 1991
esp_flash_encryption_enable_secure_features
(C++ function), 1992
esp_flash_encryption_enabled (C++ func-
ton), 1993
esp_flash_encryption_init_checks (C++ func-
ton), 1994
esp_flash_encryption_set_release_mode
(C++ function), 1995
esp_flash_erase_chip (C++ function), 1996
esp_flash_erase_region (C++ function), 1997
esp_flash_get_chip_write_protect (C++ func-
ton), 1998
esp_flash_get_physical_size (C++ func-
ton), 1999
esp_flash_get_protected_region (C++ func-
ton), 2000
esp_flash_get_protectable_regions
(C++ function), 2001
esp_flash_get_shared_region
(C++ function), 2002
esp_flash_get_storage_region
(C++ function), 2003
esp_flash_init (C++ function), 2004
esp_flash_page_config (C++ function),
2005
esp_flash_page_desc (C++ function), 2006
esp_flash_page_get (C++ function), 2007
esp_flash_page_get_data (C++ function),
2008
esp_flash_page_get_size (C++ function),
2009
esp_flash_page_init (C++ function), 2010
esp_flash_page_set (C++ function), 2011
esp_flash_page_set_data (C++ function),
2012
esp_flash_page_set_size (C++ function),
2013
esp_flash_page_t (C++ type), 2014
esp_flash_page_t::is_configured
(C++ function), 2015
esp_flash_page_t::is_data_enabled
(C++ function), 2016
esp_flash_page_t::is_page_enabled
(C++ function), 2017
esp_flash_page_t::is_protected
(C++ function), 2018
esp_flash_read (C++ function), 2019
esp_flash_read_page (C++ function), 2020
esp_flash_read_region (C++ function),
2021
esp_flash_read_sequence (C++ function),
2022
esp_flash_release (C++ function), 2023
esp_flash_release_page (C++ function),
2024
esp_flash_release_region (C++ function),
2025
esp_flash_release_sequence (C++ function),
2026
esp_flash_remap_page (C++ function), 2027
esp_flash_remap_region (C++ function),
2028
esp_flash_remap_sequence (C++ function),
2029
esp.flash refill_random (C++ function),
2030
esp_flash_secure_partition (C++ function),
2031
esp_flash_sector_config (C++ function),
2032
esp_flash_sector_get (C++ function), 2033
espressif Systems 2848 Release v5.1.2
Submit Document Feedback
Index

function), 1337
espf lash_get_size (C++ function), 1335
espf lash_Init (C++ function), 1334
espf lash_io_mode_t (C++ enum), 1349
espf lash_io_mode_t::SPI_FLASH_DIO (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_DOUT (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_FASTRD (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_OPI_DTR (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_OPI_STR (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_QIO (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_QOUT (C++ enum), 1350
espf lash_io_mode_t::SPI_FLASH_READ_MODE_MAX (C++ type), 1349
espflash_set_chip_write_protect (C++ function), 1338
espflash_set_size (C++ enum), 1349
espflash_set_size::ESP_FLASH_10MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_120MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_20MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_26MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_40MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_5MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_6MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_80MHZ (C++ enumerator), 1349
espflash_set_size::ESP_FLASH_SPEED_MAX (C++ enumerator), 1349
espflash_spi_device_config_t (C++ struct), 1334
espflash_spi_device_config_t::cs_id (C++ member), 1334
espflash_spi_device_config_t::cs_io_num (C++ member), 1334
espflash_spi_device_config_t::freq_mhz (C++ member), 1334
espflash_spi_device_config_t::host_id (C++ member), 1334
espflash_spi_device_config_t::input_delay_ns (C++ member), 1334
espflash_spi_device_config_t::io_mode (C++ member), 1334
espflash_spi_device_config_t::speed (C++ member), 1334
espflash_t (C++ struct), 1341
espflash_t::busy (C++ member), 1341
espflash_t::chip_drv (C++ member), 1341
espflash_t::chip_id (C++ member), 1341
espflash_t::host (C++ member), 1341
espflash_t::hpm_dummy_ena (C++ member), 1341
espflash_t::os_func (C++ member), 1341
espflash_t::os_func_data (C++ member), 1341
espflash_t::read_mode (C++ member), 1341
espflash_t::reserved_flags (C++ member), 1341
espflash_t::size (C++ member), 1341
espflash_write (C++ function), 1338
espflash_write_encrypted (C++ function), 1339
espflash_write_protect (C++ function), 1337
espflash_write_protect_crypt_cnt (C++ function), 1352
espfreertos_idle_cb_t (C++ type), 2100
espfreertos_tick_cb_t (C++ type), 2100
ESP_GAP_BLE_ADD_WHITELIST_COMPLETE_EVT (C macro), 302
esp_gap_ble_cb_event_t (C++ enum) 306
    (C++ enumerator) 307
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        (C++ enumerator) 309
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        esp_gap_ble_cb_event_t::ESP_GAP_BLE_PERIODIC_ADV_CREATE_COMPLETE_EVT
            (C++ enumerator) 309
esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        esp_gap_ble_cb_event_t::ESP_GAP_BLE_PERIODIC_ADV_CREATE_COMPLETE_EVT
            (C++ enumerator) 309
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
            esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                (C++ enumerator) 309
esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
            esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                (C++ enumerator) 309
esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
            esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                    (C++ enumerator) 309
esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
        esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
            esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                    esp_gap_ble_cb_event_t::ESP_GAP_BLE_ADV_DATA_PARAM_SET_COMPLETE_EVT
                        (C++ enumerator) 309
ESP_GATT_RSP_BY_APP

esp_gatt_prep_write_type::ESP_GATT_PREP_WRITE_EXEC

esp_gatt_prep_write_type

ESP_GATT_PREP_WRITE_CANCEL

ESP_GATT_PERM_WRITE_SIGNED_MITM

ESP_GATT_PERM_WRITE_SIGNED

ESP_GATT_PERM_WRITE_ENCRYPTED

ESP_GATT_PERM_WRITE_AUTHORIZATION

ESP_GATT_PERM_WRITE

esp_gatt_perm_t

ESP_GATT_PERM_READ_ENCRYPTED

ESP_GATT_PERM_READ_ENCRYPTED_MITM

ESP_GATT_PERM_READ_MULTI_HANDLES

ESP_GATT_PERM_READ

ESP_GATT_PERM_READ_AUTHORIZATION

ESP_GATT_PERM_READ_ENC_MITM

C

esp_gatt_status_t

esp_gatt_rsp_t

ESP_GATT_HEART_RATE_CNTL_POINT

ESP_GATT_HEART_RATE_MEAS

C

esp_gatt_id_t

ESP_GATT_ILLEGAL_HANDLE

ESP_GATT_ILLEGAL_UUID

ESP_GATT_MAX_ATTR_LEN

ESP_GATT_MAX_READ_MULTI_HANDLES

C

ESP_GATT_PERM_ENCRYPT_KEY_SIZE

ESP_GATT_PERM_READ

ESP_GATT_PERM_READ_AUTHORIZATION

C

ESP_GATT_PERM_READ_ENC_MITM

C

esp_gatt_perm_t

ESP_GATT_PERM_WRITE

ESP_GATT_PERM_WRITE_AUTHORIZATION

C

ESP_GATT_PERM_WRITE_ENC_MITM

C

ESP_GATT_PERM_WRITE_ENCRYPTED

ESP_GATT_PERM_WRITE_SIGNED

ESP_GATT_PERM_WRITE_SIGNED_MITM

C

ESP_GATT_PREP_WRITE_CANCEL

ESP_GATT_PREP_WRITE_EXEC

ESP_gatt_write_type

C++ union

ESP_GATT_RSP_BY_APP

C++ member

esp_gatt_rsp_t

attr_value

C++ member

handle

C++ member

ESP_GATT_CONN_REASON_T

ESP_GATT_CONN_TIMEOUT

C++ member

ESP_GATT_ILLEGAL_PARAMETER

C++ member

ESP_GATT_ERR_UNLIKELY

C++ member

ESP_GATT_ILLEGAL_UUID

C++ member

ESP_GATT_ILLEGAL_HANDLE

C++ member

esp_gatt_if_t

ESP_GATT_IF_NONE

esp_gatt_id_t

uuid

inst_id

esp_gatt_db_attr_type_t

ESP_GATT_DB_PRIMARY_SERVICE

ESP_GATT_DB_INCLUDED_SERVICE

ESP_GATT_DB_DESCRIPTOR

ESP_GATT_DB_CHARACTERISTIC

esp_gatt_rsp_t

handle

attr_value

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

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ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP

ESP_GATT_RSP_BY_APP
Index

(C++ enumerator), 330

esp_gatt_status_t::ESP_GATT_INVALID_PDU ESP_GATT_UUID_CHAR_DECLARE (C macro), 325
(C++ enumerator), 330

esp_gatt_status_t::ESP_GATT_MORE (C++ enumerator), 331

esp_gatt_status_t::ESP_GATT_NO_RESOURCES (C++ enumerator), 330

ESP_GATT_UUID_CHAR_EXT_PROP (C macro), 325

esp_gatt_status_t::ESP_GATT_NOT_ENCRYPTED (C++ enumerator), 331

esp_gatt_status_t::ESP_GATT_NOT_FOUND (C++ enumerator), 330

esp_gatt_status_t::ESP_GATT_NOT_LONG (C++ enumerator), 330

esp_gatt_status_t::ESP_GATT_OK (C++ enumerator), 329

ESP_GATT_UUID_CONT_GLUCOSE_MONITOR_SVC (C macro), 325

esp_gatt_status_t::ESP_GATT_OUT_OF_RANGE (C++ enumerator), 331

ESP_GATT_UUID_CSC_MEASUREMENT (C macro), 327

esp_gatt_status_t::ESP_GATT_PENDINQ (C++ enumerator), 331

ESP_GATT_UUID_CURRENT_TIME (C macro), 326

esp_gatt_status_t::ESP_GATT_PRC.IN_PROGRESS (C++ enumerator), 331

ESP_GATT_UUID_CURRENT_TIME_SVC (C macro), 324

esp_gatt_status_t::ESP_GATT_PREPARE_Q_FULL (C++ enumerator), 330

ESP_GATT_UUID_CYCLING_POWER_SVC (C macro), 324

esp_gatt_status_t::ESP_GATT_READ NOT PERMIT (C macro), 324

ESP_GATT_UUID_CYCLING_SPEED_CADENCE_SVC (C macro), 325

esp_gatt_status_t::ESP_GATT_REQ NOT_SUPPORTED (C++ enumerator), 330

ESP_GATT_UUID_ENVIRONMENTAL_SENSING_SVC (C macro), 325

esp_gatt_status_t::ESP_GATT_SERVICE_STARTED (C++ enumerator), 331

ESP_GATT_UUID_ENV_SENSING_TRIGGER_DESCR (C macro), 325

esp_gatt_status_t::ESP_GATT_STACK_RSP (C++ enumerator), 331

ESP_GATT_UUID_ENV_SENSING_MEASUREMENT_DESCR (C macro), 325

esp_gatt_status_t::ESP_GATT_UNKNOWN_ERROR (C++ enumerator), 331

ESP_GATT_UUID_ENV_SENSING_CONFIG_DESCR (C macro), 325

esp_gatt_status_t::ESP_GATT_UNSUPPORT_GRP_TYPE (C++ enumerator), 330

ESP_GATT_UUID_EXT_RPT_REF_DESCR (C macro), 325

esp_gatt_status_t::ESP_GATT_WRITE_NOT_PERMIT (C++ enumerator), 330

ESP_GATT_UUID_FW_VERSION_STR (C macro), 326

esp_gatt_status_t::ESP_GATT_XRONG STATE (C++ enumerator), 330

ESP_GATT_UUID_GAP_CURRENT_TIME (C macro), 326

ESP_GATT_UUID_GAP_CENTRAL_ADDR_RESOL (C macro), 326

ESP_GATT_UUID_GAP_ICON (C macro), 326

ESP_GATT_UUID_GAP_NOTIFICATION (C macro), 326

ESP_GATT_UUID_GAP_NOTIFICATION (C macro), 326
Index

ESP_GATT_UUID_HID_BT_KB_INPUT (C macro), 327
ESP_GATT_UUID_HID_BT_KB_OUTPUT (C macro), 327
ESP_GATT_UUID_HID_BT_MOUSE_INPUT (C macro), 327
ESP_GATT_UUID_HID_CONTROL_POINT (C macro), 327
ESP_GATT_UUID_HID_INFORMATION (C macro), 327
ESP_GATT_UUID_HID_PROTO_MODE (C macro), 327
ESP_GATT_UUID_HID_REPORT (C macro), 327
ESP_GATT_UUID_HID_REPORT_MAP (C macro), 327
ESP_GATT_UUID_HW_VERSION_STR (C macro), 324
ESP_GATT_UUID_IMMEDIATE_ALERT_SVC (C macro), 324
ESP_GATT_UUID_INCLUDE_SERVICE (C macro), 325
ESP_GATT_UUID_LINK_LOSS_SVC (C macro), 324
ESP_GATT_UUID_LOCAL_TIME_INFO (C macro), 326
ESP_GATT_UUID_LOCATION_AND_NAVIGATION_SVC (C macro), 324
ESP_GATT_UUID_MANU_NAME (C macro), 327
ESP_GATT_UUID_MODEL_NUMBER_STR (C macro), 326
ESP_GATT_UUID_NEXT_DST_CHANGE_SVC (C macro), 325
ESP_GATT_UUID_NUM_DIGITALS_DESCR (C macro), 325
ESP_GATT_UUID_NW_STATUS (C macro), 326
ESP_GATT_UUID_NW_TRIGGER (C macro), 326
ESP_GATT_UUID_PHONE_ALERT_STATUS_SVC (C macro), 324
ESP_GATT_UUID_PNP_ID (C macro), 327
ESP_GATT_UUID_PRI_SERVICE (C macro), 325
ESP_GATT_UUID_REF_TIME_INFO (C macro), 326
ESP_GATT_UUID_REF_TIME_UPDATE_SVC (C macro), 326
ESP_GATT_UUID_RINGER_CP (C macro), 326
ESP_GATT_UUID_RINGER_SETTING (C macro), 325
ESP_GATT_UUID_RPT_REF_DESCR (C macro), 325
ESP_GATT_UUID_RSC_FEATURE (C macro), 327
ESP_GATT_UUID_RSC_MEASUREMENT (C macro), 327
ESP_GATT_UUID_RUNNING_SPEED_CADENCE_SVC (C macro), 324
ESP_GATT_UUID_SC_CONTROL_POINT (C macro), 327
ESP_GATT_UUID_SCAN_INT_WINDOW (C macro), 328
ESP_GATT_UUID_SCAN_PARAMETERS_SVC (C macro), 324
ESP_GATT_UUID_SCAN_REFRESH (C macro), 328
ESP_GATT_UUID_SEC_SERVICE (C macro), 325
ESP_GATT_UUID_SENSOR_LOCATION (C macro), 327
ESP_GATT_UUID_SERIAL_NUMBER_STR (C macro), 326
ESP_GATT_UUID_SW_VERSION_STR (C macro), 327
ESP_GATT_UUID_SYSTEM_ID (C macro), 326
ESP_GATT_UUID_TIME_TRIGGER_DESCR (C macro), 325
ESP_GATT_UUID_TX_POWER_LEVEL (C macro), 326
ESP_GATT_UUID_TX_POWER_SVC (C macro), 324
ESP_GATT_UUID_USER_DATA_SVC (C macro), 325
ESP_GATT_UUID_VALUE_TRIGGER_DESCR (C macro), 325
ESP_GATT_UUID_WEIGHT_SCALE_SVC (C macro), 325
gatt_value_t (C++ struct), 321
gatt_value_t::auth_req (C++ member), 321

gatt_value_t::handle (C++ member), 321
gatt_value_t::len (C++ member), 321
gatt_value_t::offset (C++ member), 321
gatt_value_t::value (C++ member), 321

gatt_write_type_t (C++ enum), 333
gatt_write_type_t::ESP_GATT_WRITE_TYPE_NO_RSP (C++ enum), 333
gatt_write_type_t::ESP_GATT_WRITE_TYPE_RSP (C++ enum), 333
gattc_cb_event_t (C++ enum), 364
gattc_cb_event_t::ESP_GATTC_ACL_EVT (C++ enum), 365
gattc_cb_event_t::ESP_GATTC_ADV_DATA_EVT (C++ enum), 365
gattc_cb_event_t::ESP_GATTC_ADV_VSC_EVT (C++ enum), 366
gattc_cb_event_t::ESP_GATTC_BTH_SCAN_CFG_EVT (C++ enum), 366
gattc_cb_event_t::ESP_GATTC_BTH_SCAN_DIS_EVT (C++ enum), 366
gattc_cb_event_t::ESP_GATTC_BTH_SCAN_ENB_EVT (C++ enum), 366
gattc_cb_event_t::ESP_GATTC_BTH_SCAN_PARAM_EVT (C++ enum), 366
gattc_cb_event_t::ESP_GATTC_BTH_SCAN_RD_EVT (C++ enum), 366
gattc_cb_event_t::ESP_GATTC_BTH_SCAN_THR_EVT (C++ enum), 366

gattc_cb_event_t::ESP_GATTC_CANCEL_OPEN_EVT

Espressif Systems 2854 Release v5.1.2

Submit Document Feedback
Index

esp_gattc_service_elem_t::uuid (C++ member), 322
esp_gattsvcs_attr_db_t (C++ struct), 320
esp_gatts_attr_db_t::att_desc (C++ member), 320
esp_gatts_attr_db_t::attr_control (C++ struct), 320
esp_gatts_attr_db_t (C++ struct), 320
esp_gatts_attr_db_t::att_desc (C++ member), 320
esp_gatts_attr_db_t::attr_control (C++ member), 320
esp_gatts_attr_db_t::ESP_GATTS_WRITE_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_UNREG_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_STOP_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_START_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_SET_ATTR_VAL_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_SEND_SERVICE_CHANGE_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_REG_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_READ_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_OPEN_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_EXEC_WRITE_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_DISCONNECT_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_DELETE_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_CREATE_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_CONNECT_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_CONGEST_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_CONF_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_CLOSE_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_CANCEL_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_ADD_INCL_SRVC_EVT (C++ function), 346
esp_gatts_attr_db_t::ESP_GATTS_ADD_CHAR_EVT (C++ function), 346

Release v5.1.2
Submit Document Feedback
Espresif Systems

2857

Release v5.1.2

Submit Document Feedback
Index

(C++ enumerator), 480

esp_hf_cb_event_t::ESP_HF_VTS_RESPONSE_EVT (C++ struct), 475

esp_hf_cb_event_t::ESP_HF_WBS_RESPONSE_EVT (C++ member), 476

esp_hf_cb_param_t::hf_bcs_rep_param (C++ struct), 476

esp_hf_cb_param_t::hf_bcs_rep_param::remote_addr (C++ member), 476

esp_hf_cb_param_t::hf_cind_rep_param (C++ struct), 476

esp_hf_cb_param_t::hf_cind_rep_param::remote_addr (C++ member), 476

esp_hf_cb_param_t::hf_clcc_rep_param (C++ struct), 476

esp_hf_cb_param_t::hf_clcc_rep_param::remote_addr (C++ member), 476

esp_hf_cb_param_t::hf_conn_stat_param (C++ struct), 476

esp_hf_cb_param_t::hf_conn_stat_param::remote_addr (C++ member), 476

esp_hf_cb_param_t::hf_conn_stat_param::remote_bda (C++ member), 476

esp_hf_cb_param_t::hf_conn_stat_param::peer_feat (C++ member), 476

esp_hf_cb_param_t::hf_conn_stat_param::chld_feat (C++ member), 476

esp_hf_cb_param_t::hf_conn_stat_param::state (C++ member), 476

esp_hf_cb_param_t::hf_cops_rep_param (C++ struct), 476

esp_hf_cb_param_t::hf_cops_rep_param::remote_addr (C++ member), 476

esp_hf_cb_param_t::hf_clcc_rep_param (C++ struct), 476

esp_hf_cb_param_t::hf_clcc_rep_param::remote_addr (C++ member), 476

esp_hf_cb_param_t::hf_nrec_param (C++ struct), 477

esp_hf_cb_param_t::hf_nrec_param::remote_addr (C++ member), 477

esp_hf_cb_param_t::hf_nrec_param::state (C++ member), 477

esp_hf_cb_param_t::hf_out_call_param (C++ struct), 477

esp_hf_cb_param_t::hf_out_call_param::num_or_loc (C++ member), 477

esp_hf_cb_param_t::hf_out_call_param::remote_addr (C++ member), 477

esp_hf_cb_param_t::hf_audio_stat_param (C++ struct), 477

esp_hf_cb_param_t::hf_unat_rep_param (C++ struct), 478

esp_hf_cb_param_t::hf_unat_rep_param::remote_addr (C++ member), 478

esp_hf_cb_param_t::hf_volume_control_param (C++ struct), 478

esp_hf_cb_param_t::hf_volume_control_param::remote_addr (C++ member), 478
Index

esp_hf_cb_param_t::hf_volume_control_param::type (C++ enumerator), 449
esp_hf_chld_type_t::ESP_HF_CHLD_TYPE_REL_ACC
(C++ enumerator), 449
esp_hf_chld_type_t::ESP_HF_CHLD_TYPE_REL_X
(C++ enumerator), 449
esp_hf_chld_type_t::ESP_HF_CHLD_TYPE_MERGE_DETACH
(C++ enumerator), 449
esp_hf_chld_type_t::ESP_HF_CHLD_TYPE_HOLD_ACC
(C++ enumerator), 449
esp_hf_client_cb_event_t::ESP_HF_CLIENT_CIND_SERVICE_AVAILABILITY_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_CIND_ROAMING_STATUS_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_CIND_CALL_SETUP_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_CIND_CALL_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_CIND_BATTERY_LEVEL_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_CCWA_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_BVRA_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_BTRH_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_BSIR_EVT
esp_hf_client_cb_event_t::ESP_HF_CLIENT_BINP_EVT
esp_hf_client_audio_state_t (C++ enum), 454
esp_hf_client_answer_call (C++ function), 454
esp_hf_client_audio_state_t (C++ enum), 465
esp_hf_client_audio_state_t::ESP_HF_CLIENT_AUDIO_REL (C++ enum), 465
esp_hf_client_audio_state_t::ESP_HF_CLIENT_AUDIO_REL_X (C++ enum), 465
esp_hf_client_audio_state_t::ESP_HF_CLIENT_AUDIO_MERGE_DETACH (C++ enum), 465
esp_hf_client_audio_state_t::ESP_HF_CLIENT_AUDIO_HOLD (C++ enum), 465
esp_hf_client_audio_state_t::ESP_HF_CLIENT_AUDIO_HLD (C++ enum), 465
esp_hf_client_answer_call (C++ function), 454
Index
Index

esp_hf_client_cb_param_t::hf_client_roaming
  (C++ member), 457
esp_hf_client_cb_param_t::hf_client_service_availability
  (C++ member), 457
esp_hf_client_cb_param_t::hf_client_signal_strength
  (C++ member), 457
esp_hf_client_cb_param_t::hf_client_volume_control
  (C++ member), 458
esp_hf_client_cb_param_t::hf_client_outgoing_data_cb_t
  (C++ type), 464
ESP_HF_CLIENT_CHLD_FEAT_HOLD_ACC  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_MERGE  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_MERGE_DETACH
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_PRIV_X
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_REL
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_REL_ACC
  (C macro), 461
ESP_HF_CLIENT_CONNECTION_STATE
  (C+ enumeration), 465
ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTED
  (C+ enumeration), 465
ESP_HF_CLIENT_CONNECTION_STATE_DISCONNECTING
  (C+ enumeration), 465
ESP_HF_CLIENT_CONNECTION_STATE_CONNECTED
  (C+ enumeration), 465
ESP_HF_CLIENT_CONNECTION_STATE_CONNECTING
  (C+ enumeration), 465
ESP_HF_CLIENT_CHLD_FEAT_HOLD_ACC
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_MERGE
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_MERGE_DETACH
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_PRIV_X
  (C macro), 461
ESP_HF_CLIENT_CHLD_FEAT_REL
  (C macro), 461
esp_hf_client_outgoing_data_cb_t
  (C++ type), 464
esp_hf_client_outgoing_data_ready
  (C++ member), 458

Submit Document Feedback

Espressif Systems  Release v5.1.2
Index

esp_hf_client_pcm_resample (C++ function), 456
esp_hf_client_pcm_resample_deinit (C++ function), 456
esp_hf_client_pcm_resample_init (C++ function), 456
ESP_HF_CLIENT_PEER_FEAT_3WAY (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_CODEC (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_ECC (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_ECNR (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_ECS (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_ESCO_S4 (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_EXTErr (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_HF_IND (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_INBAND (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_REJECT (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_VREC (C macro), 463
ESP_HF_CLIENT_PEER_FEAT_VTAG (C macro), 463
esp_hf_client_pkt_stat_nums_get (C++ function), 456
esp_hf_client_query_current_calls (C++ function), 454
esp_hf_client_query_current_operator_name (C++ function), 455
esp_hf_client_register_callback (C++ function), 452
esp_hf_client_register_data_callback (C++ function), 456
esp_hf_client_reject_call (C++ function), 454
esp_hf_client_request_last_voice_tag_number (C++ function), 455
esp_hf_client_retrieve_subscriber_info (C++ function), 454
esp_hf_client_send_bthr_cmd (C++ function), 454
esp_hf_client_send_chld_cmd (C++ function), 454
esp_hf_client_send_dtmf (C++ function), 455
esp_hf_client_send_iPhoneacccev (C++ function), 455
esp_hf_client_send_nrec (C++ function), 456
esp_hf_client_send_xapl (C++ function), 455
esp_hf_client_stop_voice_recognition (C++ function), 453
esp_hf_client_volume_update (C++ function), 453
ESP_HF_CLIENT_XAPL_FEAT_BATTERY_REPORT (C macro), 464
ESP_HF_CLIENT_XAPL_FEAT_DOCKED (C macro), 464
ESP_HF_CLIENT_XAPL_FEAT_RESERVED (C macro), 464
ESP_HF_CLIENT_XAPL_FEAT_SIRI_STATUS_REPORT (C macro), 464
ESP_HF_CLIENT_XAPL_NR_STATUS_REPORT (C macro), 464
esp_hf_cme_err_t (C++ enum), 450
esp_hf_cme_err_t::ESP_HF_CME_AG_FAILURE (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_DIAL_STRING_TOO_LONG (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_INcorrect_PASSWORD (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_INValid_CHARACTERS_IN_DIAL_STRING (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_INValid_CHARACTERS_IN_TEXT_STRING (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_memory_FULL (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_MEMORY_FAILURE (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_MEMORY_FULL (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_NETWORK_NOT_ALLOWED (C++ enumerator), 452
esp_hf_cme_err_t::ESP_HF_CME_NETWORK_TIMEOUT (C++ enumerator), 452
esp_hf_cme_err_t::ESP_HF_CME_NO_CONNECTION_TO_PHONE (C++ enumerator), 450
esp_hf_cme_err_t::ESP_HF_CME_NO_NETWORK_SERVICE (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_OPERATION_NOT_ALLOWED (C++ enumerator), 450
esp_hf_cme_err_t::ESP_HF_CME_OPERATION_NOT_SUPPORTED (C++ enumerator), 450
esp_hf_cme_err_t::ESP_HF_CME_PH_SIM_PIN_REQUIRED (C++ enumerator), 450
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK2_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PIN_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PIN2_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_NOT_INSERTED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_FAILURE (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_BUSY (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK2_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK_REQUIRED (C++ enumerator), 451
esp_hf_cme_err_t::ESP_HF_CME_SIM_PUK_REQUIRED (C++ enumerator), 451
Index

(C++ enumerator), 451

esp_hf_cme_err_t::ESP_HF_CME_TEXT_STRING_TOO_LONG (C++ enumerator), 447

esp_hf_connection_state_t (C++ enum), 448 esp_hf_in_band_ring_state_t::ESP_HF_IN_BAND_RINGTONE (C++ enumerator), 449

esp_hf_connection_state_t::ESP_HF_CONNECTION_STATE_DISCONNECTING (C++ enumerator), 449

esp_hf_connection_state_t::ESP_HF_CONNECTION_STATE_DISCONNECTED (C++ enumerator), 449

esp_hf_connection_state_t::ESP_HF_CONNECTION_STATE_CONNECTING (C++ enumerator), 449

esp_hf_connection_state_t::ESP_HF_CONNECTION_STATE_CONNECTED (C++ enumerator), 449

esp_hf_cme_err_t::ESP_HF_CME_TEXT_STRING_TOO_LONG (C++ enum), 447

esp_hf_cme_err_t::ESP_HF_CME_TEXT_STRING_TOO_LONG (C++ enum), 447

esp_hf_current_call_direction_t (C++ enum), 446

esp_hf_current_call_direction_t::ESP_HF_CURRENT_CALL_DIRECTION_INCOMING (C++ macro), 479

esp_hf_current_call_direction_t::ESP_HF_CURRENT_CALL_DIRECTION_OUTGOING (C++ macro), 479

esp_hf_current_call_mode_t (C++ enum), 447

esp_hf_current_call_mode_t::ESP_HF_CURRENT_CALL_MODE_DATA (C++ macro), 479

esp_hf_current_call_mode_t::ESP_HF_CURRENT_CALL_MODE_FAX (C++ macro), 479

esp_hf_current_call_mpty_type_t::ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE (C++ enum), 446

esp_hf_current_call_mpty_type_t::ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE (C++ enum), 446

esp_hf_current_call_mpty_type_t::ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE (C++ enum), 447

esp_hf_current_call_mpty_type_t::ESP_HF_CURRENT_CALL_MPTY_TYPE_SINGLE (C++ enum), 447

esp_hf_current_call_status_t (C++ enum), 446

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_WAITING (C++ enum), 447

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_INCOMING (C++ enum), 447

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_HELD_BY_RESP_HOLD (C++ enum), 447

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_HELD (C++ enum), 448

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_DIALING (C++ enum), 448

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_ALERTING (C++ enum), 448

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_ACTIVE (C++ enum), 448

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_WAITING (C++ enum), 448

esp_hf_current_call_status_t::ESP_HF_CURRENT_CALL_STATUS_INCOMING (C++ enum), 448

esp_hf_current_call_nrec_t (C++ enum), 448

esp_hf_current_call_nrec_t::ESP_HF_NREC_START (C++ enum), 448

esp_hf_current_call_nrec_t::ESP_HF_NREC_STOP (C++ enum), 448

esp_hf_current_call_nrec_t (C++ enum), 447

esp_hf_current_call_nrec_t::ESP_HF_NREC_START (C++ macro), 479

esp_hf_current_call_nrec_t::ESP_HF_NREC_STOP (C++ macro), 479

esp_hf_current_call_nrec_t::ESP_HF_NREC_STOP (C++ macro), 479

esp_hf_current_call_nrec_t::ESP_HF_NREC_STOP (C++ macro), 479

esp_hf_dial_type_t (C++ enum), 481

esp_hf_dial_type_t::ESP_HF_DIAL_MEM (C++ enum), 481

esp_hf_dial_type_t::ESP_HF_DIAL_NUM (C++ enum), 481

esp_hf_dial_type_t::ESP_HF_DIAL_VOIP (C++ enum), 481

esp_hf_in_band_ring_state_t (C++ enum), 481

esp_hf_network_state_t::ESP_HF_NETWORK_STATE_NOT_AVAILABLE (C++ enum), 449

esp_hf_network_state_t::ESP_HF_NETWORK_STATE_AVAILABLE (C++ enum), 449

esp_hf_nrec_t::ESP_HF_NREC_ITEM (C++ enum), 449

esp_hf_nrec_t (C++ enum), 449

esp_hf_nrec_t::ESP_HF_NREC_ITEM (C++ enum), 449

esp_hf_nrec_t (C++ enum), 449

esp_hf_volume_type_t::ESP_HF_VOLUME_TYPE_SPK (C++ enum), 446

esp_hf_volume_type_t::ESP_HF_VOLUME_TYPE_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_subscriber_service_type_t (C++ enum), 446

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_HOME (C++ enum), 445

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_ROAMING (C++ enum), 445

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 445

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 445

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 445

esp_hf_roaming_status_t::ESP_HF_ROAMING_STATUS_ACTIVE (C++ enum), 445

esp_hf_roaming_status_t (C++ enum), 445

esp_hf_roaming_status_t::ESP_HF_ROAMING_STATUS_INACTIVE (C++ enum), 445

esp_hf_roaming_status_t (C++ enum), 445

esp_hf_roaming_status_t::ESP_HF_ROAMING_STATUS_INACTIVE (C++ enum), 445

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_HOME (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_HOME (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_HOME (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_HOME (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_HOME (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_service_type_t::ESP_HF_SERVICE_TYPE_INBAND (C++ enum), 447

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_SPK (C++ enum), 446

esp_hf_volume_control_target_t::ESP_HF_VOLUME_CONTROL_TARGET_MIC (C++ enum), 446
esp_hidd_cb_event_t::ESP_HIDD_REGISTER_APP_EVT
(esp_hidd_cb_event_t)
esp_hidd_cb_event_t::ESP_HIDD_INTR_DATA_EVT
(esp_hidd_cb_event_t)
esp_hidd_cb_event_t::ESP_HIDD_INIT_EVT
(esp_hidd_cb_event_t)
esp_hidd_cb_event_t::ESP_HIDD_DEINIT_EVT
(esp_hidd_cb_event_t)
esp_hidd_cb_event_t::ESP_HIDD_CLOSE_EVT
(esp_hidd_cb_event_t)
esp_hidd_cb_event_t::ESP_HIDD_API_ERR_EVT
(esp_hidd_cb_event_t)

esp_hidd_boot_report_id_t::ESP_HIDD_BOOT_REPORT_ID_MOUSE
(esp_hidd_boot_report_id_t)
esp_hidd_app_param_t::subclass
(esp_hidd_app_param_t)

esp_hidd_app_param_t::provider
(esp_hidd_app_param_t)
esp_hidd_app_param_t::name
(esp_hidd_app_param_t)

esp_hidd_boot_report_id_t::ESP_HIDD_BOOT_REPORT_ID_KEYBOARD
(esp_hidd_boot_report_id_t)

esp_hidd_boot_report_id_t::ESP_HIDD_BOOT_REPORT_ID_MIDI
(esp_hidd_boot_report_id_t)

esp_hidd_boot_report_id_t::ESP_HIDD_BOOT_REPORT_IDключен
(esp_hidd_boot_report_id_t)

esp_hidd_app_param_t::deinit
(esp_hidd_app_param_t)
esp_hidd_app_param_t::close
(esp_hidd_app_param_t)

esp_hidd_boot_report_id_t::ESP_HIDD_BOOT_REPORT_ID_MOUSE
(esp_hidd_boot_report_id_t)

esp_hidd_app_param_t::report_id
(esp_hidd_app_param_t)
esp_hidd_app_param_t::report_type
(esp_hidd_app_param_t)
esp_hidd_app_param_t::buffer_size
(esp_hidd_app_param_t)

esp_hidd_app_param_t::status
(esp_hidd_app_param_t)
esp_hidd_app_param_t::status
(esp_hidd_app_param_t)
esp_hidd_app_param_t::status
(esp_hidd_app_param_t)

esp_hidd_app_param_t::report_id
(esp_hidd_app_param_t)
esp_hidd_app_param_t::report_id
(esp_hidd_app_param_t)
esp_hidd_app_param_t::report_id
(esp_hidd_app_param_t)

esp_hidd_app_param_t::status
(esp_hidd_app_param_t)
esp_hidd_app_param_t::status
(esp_hidd_app_param_t)
esp_hidd_app_param_t::status
(esp_hidd_app_param_t)
Index

esp_hidh_report_type_t::ESP_HIDH_REPORT_TYPE_OUTPUT, 493
esp_hidh_report_type_t::ESP_HIDH_REPORT_TYPE_OTHER, 493
esp_hidh_report_type_t::ESP_HIDH_REPORT_TYPE_INTRDATA, 493
esp_hidh_report_type_t::ESP_HIDH_REPORT_TYPE_INPUT, 493
esp_hidh_report_type_t::ESP_HIDH_REPORT_TYPE_FEATURE, 493

esp_hidh_cb_event_t::ESP_HIDH_VC_UNPLUG_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_SET_IDLE_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_RMV_DEV_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_OPEN_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_INIT_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_GET_RPT_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_GET_PROTO_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_GET_IDLE_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_GET_DSCP_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_DEINIT_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_DATA_EVT, 507
esp_hidh_cb_event_t::ESP_HIDH_CLOSE_EVT, 507

esp_hidh_status_t::ESP_HIDD_SUCCESS, 497
esp_hidh_status_t::ESP_HIDD_NO_RES, 497
esp_hidh_status_t::ESP_HIDD_NO_DATA, 497
esp_hidh_status_t::ESP_HIDD_NEED_REG, 497
esp_hidh_status_t::ESP_HIDD_NEED_INIT, 497
esp_hidh_status_t::ESP_HIDD_NEED_DEREG, 497
esp_hidh_status_t::ESP_HIDD_NEED_DEINIT, 497
esp_hidh_status_t::ESP_HIDD_ERROR, 497
esp_hidh_status_t::ESP_HIDD_BUSY, 497

esp_hidh_report_type_t::ESP_HIDD_REPORT_TYPE_OUTPUT, 491
esp_hidh_report_type_t::ESP_HIDD_REPORT_TYPE_OTHER, 491
esp_hidh_report_type_t::ESP_HIDD_REPORT_TYPE_INTRDATA, 491
esp_hidh_report_type_t::ESP_HIDD_REPORT_TYPE_INPUT, 491
esp_hidh_report_type_t::ESP_HIDD_REPORT_TYPE_FEATURE, 491

esp_hidh_get_dscp_evt_param::added, 507
esp_hidh_data_ind_evt_param::status, 507
esp_hidh_data_ind_evt_param::proto_mode, 507
esp_hidh_data_ind_evt_param::len, 507
esp_hidh_data_ind_evt_param::handle, 507
esp_hidh_data_ind_evt_param::data, 507
esp_hidh_close_evt_param::reason, 507
esp_hidh_close_evt_param::handle, 507
esp_hidh_close_evt_param::conn_status, 507
esp_hidh_close_evt_param::status, 507
esp_hidh_add_dev_evt_param::status, 507
esp_hidh_add_dev_evt_param::bd_addr, 507
esp_hidh_get_proto::proto, 506
esp_hidh_get_idle::status, 506
esp_hidh_get_rpt::status, 506
esp_hidh_get_dscp::status, 506
esp_hidh_get_dscp::len, 506
esp_hidh_get_dscp::proto, 506
esp_hidh_get_dscp::state, 506
esp_hidh_get_dscp::add, 506

C++ struct, 498
C++ member, 498
C++ union, 498
C++ enum, 498
C++ enumerator, 498
C++ member, 498
C++ member, 498
C++ member, 498
C++ member, 498
C++ member, 498
C++ member, 498
C++ member, 498

Index

(C++ member), 499
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::status
(C++ member), 501
esp_hidh_cb_param_t::hidh_open_evt_param::is_orig
(C++ member), 499
esp_hidh_cb_param_t::hidh_open_evt_param::handle
(C++ member), 500
esp_hidh_cb_param_t::hidh_open_evt_param::status
(C++ member), 500
esp_hidh_cb_param_t::hidh_open_evt_param::bd_addr
(C++ member), 499
esp_hidh_cb_param_t::hidh_get_rpt_evt_param::status
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_rpt_evt_param::handle
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_rpt_evt_param::len
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_proto_evt_param::status
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_proto_evt_param::proto_mode
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_proto_evt_param::handle
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_idle_evt_param::status
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_idle_evt_param::idle_rate
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_idle_evt_param::handle
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::status
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::ssr_min_tout
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::ssr_max_latency
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::product_id
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::handle
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::dsc_list
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::dl_len
(C++ member), 501
esp_hidh_cb_param_t::hidh_get_dscp_evt_param::ctry_code
(C++ member), 501
Index
<table>
<thead>
<tr>
<th>Function/Member</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_http_client_config_t::client_key_password</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::client_key_password_len</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::client_key_pem</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::common_name</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::crt_bundle_attach</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::event_handler</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::host</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::is_async</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_count</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_enable</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_idle</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_interval</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::max_authorization_retries</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::max_redirection_count</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::method</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::password</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::path</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::port</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::query</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::skip_cert_common_name</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::timeout_common_name</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::timeout_common_name_c</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::transport_ms</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::url</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::use_global_ca_store</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::user_agent</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::user_data</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::username</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::use_global_ca_store</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::crt_bundle_attach</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::event_handler</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::host</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::is_async</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_count</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_enable</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_idle</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::keep_alive_interval</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::max_authorization_retries</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::max_redirection_count</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::method</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::password</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::path</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::port</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::query</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::skip_cert_common_name</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::timeout_common_name</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::timeout_common_name_c</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::transport_ms</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::url</td>
<td>170</td>
</tr>
<tr>
<td>esp_http_client_config_t::use_global_ca_store</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::user_agent</td>
<td>171</td>
</tr>
<tr>
<td>esp_http_client_config_t::user_data</td>
<td>172</td>
</tr>
<tr>
<td>esp_http_client_config_t::username</td>
<td>170</td>
</tr>
</tbody>
</table>
Index

esp_http_client_delete_header (C++ function), 166
esp_http_client_event (C++ struct), 169
esp_http_client_event::client member), 169
esp_http_client_event::data (C++ member), 169
esp_http_client_event::data_len (C++ member), 169
esp_http_client_event::event_id (C++ member), 169
esp_http_client_event::header_key (C++ member), 170
esp_http_client_event::header_value (C++ member), 170
esp_http_client_event::user_data (C++ member), 169
esp_http_client_event_handle_t (C++ type), 173
esp_http_client_event_id_t (C++ enum), 174
esp_http_client_event_id_t::HTTP_EVENT_DISCONNECT (C++ enumerator), 175
esp_http_client_event_id_t::HTTP_EVENT_ERROR (C++ enumerator), 175
esp_http_client_event_id_t::HTTP_EVENT_HEADER_RECEIVED (C++ enumerator), 176
esp_http_client_event_id_t::HTTP_EVENT_MAX (C++ enumerator), 176
esp_http_client_event_id_t::HTTP_EVENT_METHOD_GET (C++ enumerator), 175
esp_http_client_event_id_t::HTTP_EVENT_METHOD_HEAD (C++ enumerator), 175
esp_http_client_event_id_t::HTTP_EVENT_METHOD_MAX (C++ enumerator), 176
esp_http_client_event_id_t::HTTP_EVENT_METHOD_POST (C++ enumerator), 175
esp_http_client_event_id_t::HTTP_EVENT_REDIRECT (C++ enumerator), 175
esp_http_client_event_id_t (C++ type), 173
esp_http_client_fetch_headers (C++ function), 167
esp_http_client_flush_response (C++ function), 169
esp_http_client_get_chunk_length (C++ function), 169
esp_http_client_get_content_length (C++ function), 167
esp_http_client_get_errno (C++ function), 166
esp_http_client_get_header (C++ function), 164
esp_http_client_get_password (C++ function), 165
esp_http_client_get_post_field (C++ function), 164
esp_http_client_get_status_code (C++ function), 167
esp_http_client_get_transport_type (C++ function), 168
esp_http_client_get_url (C++ function), 169
esp_http_client_get_user_data (C++ function), 165
esp_http_client_get_username (C++ function), 164
esp_http_client_handle_t (C++ type), 173
esp_http_client_init (C++ function), 163
esp_http_client_is_chunked_response (C++ function), 167
esp_http_client_is_complete_data_received (C++ function), 168
esp_http_client_method_t (C++ enum), 175
esp_http_client_method_t::HTTP_METHOD_COPY (C++ enumerator), 175
esp_http_client_method_t::HTTP_METHOD_DELETE (C++ enumerator), 175
esp_http_client_method_t::HTTP_METHOD_GET (C++ enumerator), 175
esp_http_client_method_t::HTTP_METHOD_HEAD (C++ enumerator), 175
esp_http_client_method_t::HTTP_METHOD_MAX (C++ enumerator), 176
esp_http_client_method_t::HTTP_METHOD_MKCOL (C++ function), 169
esp_http_client_method_t::HTTP_METHOD_MOVE (C++ function), 169
esp_http_client_method_t::HTTP_METHOD_OPTIONS (C++ function), 169
esp_http_client_method_t::HTTP_METHOD_POST (C++ function), 169
esp_http_client_method_t::HTTP_METHOD_PROPPATCH (C++ function), 168
esp_http_client_method_t::HTTP_METHOD_PATCH (C++ function), 168
esp_http_client_method_t::HTTP_METHOD_PROPFIND (C++ function), 168
esp_http_client_method_t::HTTP_METHOD_UNLOCK (C++ function), 168
esp_http_client_method_t::HTTP_METHOD_SUBSCRIBE (C++ function), 168
esp_http_client_method_t::HTTP_METHOD_UNSUBSCRIBE (C++ function), 167
esp_http_client_on_data (C++ struct), 170
esp_http_client_on_data::client (C++ member), 170
esp_http_client_open (C++ function), 166
esp_http_client_perform (C++ function), 163

Espressif Systems 2870
Submit Document Feedback
index
ESP_IPADDR_TYPE_ANY (C macro), 1027
ESP_IPADDR_TYPE_V4 (C macro), 1027
ESP_IPADDR_TYPE_V6 (C macro), 1027
esp_ipc_call (C++ function), 2147
esp_ipc_call_blocking (C++ function), 2148
esp_ipc_func_t (C++ type), 2148
esp_ipc_isr_asm_call (C++ function), 2148
esp_ipc_isr_asm_call_blocking (C++ function), 2148
esp_ipc_isr_func_t (C++ type), 2150
esp_ipc_isr_release_other_cpu (C++ function), 2149
esp_ipc_isr_stall_abort (C++ function), 2149
esp_ipc_isr_stall_other_cpu (C++ function), 2149
esp_ipc_isr_stall_resume (C++ function), 2149
esp_lcd_del_i80_bus (C++ function), 1176
esp_lcd_i2c_bus_handle_t (C++ type), 1181
esp_lcd_i80_bus_config_t (C++ struct), 1179
esp_lcd_i80_bus_config_t::bus_width (C++ member), 1179
esp_lcd_i80_bus_config_t::clk_src (C++ member), 1179
esp_lcd_i80_bus_config_t::data_gpio_nums (C++ member), 1179
esp_lcd_i80_bus_config_t::dc_gpio_num (C++ member), 1179
esp_lcd_i80_bus_config_t::max_transfer_bytes (C++ member), 1179
esp_lcd_i80_bus_config_t::psram_trans_align (C++ member), 1179
esp_lcd_i80_bus_config_t::sram_trans_align (C++ member), 1179
esp_lcd_i80_bus_config_t::wr_gpio_num (C++ member), 1179
esp_lcd_i80_bus_config_t::wr_gpio_num (C++ member), 1179
esp_lcd_i80_bus_config_t::wr_gpio_num (C++ member), 1179
esp_lcd_new_i80_bus (C++ function), 1176
esp_lcd_new_panel_io_i2c (C++ function), 1176
esp_lcd_fence (C++ function), 1176
esp_lcd_new_panel_i2c_dev (C++ function), 1176
esp_lcd_new_panel_io_i80 (C++ function), 1176
esp_lcd_new_panel_nt35510 (C++ function), 1176
esp_lcd_new_panel_nt35510_i80 (C++ function), 1176
esp_lcd_new_panel_ssd1306 (C++ function), 1176
esp_lcd_new_panel_st7789 (C++ function), 1176
esp_lcd_new_panel_st7789_i80 (C++ function), 1176
esp_lcd_panel_dev_config_t::bits_per_pixel (C++ member), 1185
esp_lcd_panel_dev_config_t::color_space
esp_lcd_panel_io_spi_config_t::octal_mode (C++ member), 1175
esp_lcd_panel_io_spi_config_t::on_color_transparent (C++ member), 1177
esp_lcd_panel_io_spi_config_t::pclk_hz (C++ member), 1177
esp_lcd_panel_io_spi_config_t::quad_mode (C++ member), 1178
esp_lcd_panel_io_spi_config_t::sio_mode (C++ member), 1178
esp_lcd_panel_io_spi_config_t::transport (C++ member), 1177
esp_lcd_panel_io_spi_config_t::trans_queue_depth (C++ member), 1177
esp_lcd_panel_swap_xy (C++ function), 297
esp_lcd_panel_set_gap (C++ function), 297
esp_lcd_panel_reset (C++ function), 297
ESP_LE_AUTH_BOND (C macro), 297
ESP_LE_AUTH_NO_BOND (C macro), 297
ESP_LE_AUTH_REQ_BOND_MTM (C macro), 297
ESP_LE_AUTH_REQ_MTM (C macro), 297
ESP_LE_AUTH_REQ_SC_BOND (C macro), 298
ESP_LE_AUTH_REQ_SC_MTM (C macro), 298
ESP_LE_AUTH_REQ_SC_MTM_BOND (C macro), 298
ESP_LE_AUTH_REQ_SC_ONLY (C macro), 297
ESP_LE_KEY_LCSRK (C macro), 297
ESP_LE_KEY_LENC (C macro), 297
ESP_LE_KEY_LID (C macro), 297
ESP_LE_KEY_LLK (C macro), 297
ESP_LE_KEY_NONE (C macro), 297
ESP_LE_KEY_PCSRK (C macro), 297
ESP_LE_KEY_PENC (C macro), 297
ESP_LE_KEY_PENC (C macro), 297
ESP_LE_KEY_PID (C macro), 297
ESP_LE_KEY_PCLK (C macro), 297
eesp_light_sleep_start (C++ function), 2216
eesp_link_key (C++ type), 245
eesp_local_ctrl_add_property (C++ function), 181
eesp_local_ctrl_config (C++ struct), 184
eesp_local_ctrl_config::handlers (C++ member), 185
eesp_local_ctrl_config::max_properties (C++ member), 185
eesp_local_ctrl_config::proto_sec (C++ member), 185
eesp_local_ctrl_config::transport (C++ member), 184
eesp_local_ctrl_config::transport_config (C++ member), 184

Index

C++ member, 1177
C++ function, 181
C++ function, 180
C++ member, 1177
C++ member, 184
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ member, 1177
C++ function, 184
C++ function, 182
C++ member, 182
C++ member, 182
C++ function, 182
C++ function, 182
C++ member, 182
C++ member, 182
C++ function, 182
C++ function, 182
C++ function, 182
C++ function, 182
C++ member, 182
C++ member, 182
C++ member, 182
C++ member, 182
C++ member, 182
C++ member, 182
C++ function, 184
C++ function, 184
C++ member, 184
C++ member, 184
C++ member, 184
C++ member, 184
esp_mesh_get_ieCryptoKey (C++ function), 838
esp_mesh_get_layer (C++ function), 843
esp_mesh_getMaxLayer (C++ function), 842
esp_mesh_getNetworkDutyCycle (C++ function), 853
esp_mesh_getNonMeshConnections (C++ function), 843
esp_mesh_getParentBssid (C++ function), 843
esp_mesh_getRootHealingDelay (C++ function), 848
esp_mesh_getRouter (C++ function), 841
esp_mesh_getRouterBssid (C++ function), 851
esp_mesh_getRoutingTable (C++ function), 845
esp_mesh_getRoutingTableSize (C++ function), 845
esp_mesh_getRunningActiveDutyCycle (C++ function), 853
esp_mesh_getRxPending (C++ function), 846
esp_mesh_getSelfOrganized (C++ function), 844
esp_mesh_getSubnetNodesList (C++ function), 850
esp_mesh_getSubnetNodesNum (C++ function), 850
esp_mesh_getTopology (C++ function), 851
esp_mesh_getTotalNodeNum (C++ function), 845
esp_mesh_getTsfTime (C++ function), 851
esp_mesh_getTxPending (C++ function), 846
esp_mesh_getType (C++ function), 841
esp_mesh_getVotePercentage (C++ function), 845
esp_mesh_getXonQsize (C++ function), 846
esp_mesh_init (C++ function), 836
esp_mesh_isDeviceActive (C++ function), 852
esp_mesh_isMyGroup (C++ function), 847
esp_mesh_isPsEnabled (C++ function), 852
esp_mesh_isRoot (C++ function), 843
esp_mesh_isRootConflictsAllowed (C++ function), 846
esp_mesh_isRootFixed (C++ function), 848
esp_mesh_Post_toDS_state (C++ function), 845
esp_mesh_psDutySignaling (C++ function), 854
esp_mesh_recv (C++ function), 839
esp_mesh_recvToDS (C++ function), 839
esp_mesh_scanGetApIeLen (C++ function), 849
esp_mesh_scanGetApRecord (C++ function), 849
esp_mesh_send (C++ function), 837
esp_mesh_sendBlockTime (C++ function), 841
esp_mesh_setActiveDutyCycle (C++ function), 852
esp_mesh_setAp_assoc_expire (C++ function), 845
esp_mesh_setAp_authmode (C++ function), 842
esp_mesh_setApConnections (C++ function), 843
esp_mesh_setApPassword (C++ function), 842
esp_mesh_setCapacityNum (C++ function), 847
esp_mesh_setConfig (C++ function), 840
esp_mesh_setGroupID (C++ function), 847
esp_mesh_setId (C++ function), 841
esp_mesh_setIeCryptoFuncs (C++ function), 847
esp_mesh_setIeCryptoKey (C++ function), 848
esp_mesh_setMaxLayer (C++ function), 842
esp_mesh_setNetworkDutyCycle (C++ function), 852
esp_mesh_setParent (C++ function), 849
esp_mesh_setRootHealingDelay (C++ function), 848
esp_mesh_setRouter (C++ function), 841
esp_mesh_setSelfOrganized (C++ function), 843
esp_mesh_setTopology (C++ function), 851
esp_mesh_setType (C++ function), 841
esp_mesh_setVotePercentage (C++ function), 844
esp_mesh_setXonQsize (C++ function), 846
esp_mesh_start (C++ function), 837
esp_mesh_stop (C++ function), 837
esp_mesh_switchChannel (C++ function), 850
esp_topology_t::MESH_TOPO_CHAIN (C++ function), 869
esp_topology_t::MESH_TOPO_TREE (C++ function), 869
esp_mesh_waiveRoot (C++ function), 844
esp_mmu_map (C++ function), 2121
esp_mmu_map_dumpMappedBlocks (C++ function), 2122
esp_mmu_map_getMaxConsecutiveFreeBlockSize (C++ function), 2122
ESP_MMU_MMAP_FLAG_PADDD_SHARED (C macro), 2123
esp_mmu_paddrFindCaps (C++ function), 2123
esp_mmu_paddrToVaddr (C++ function), 2122
esp_mmu_unmap (C++ function), 2121
esp_mqtt_client_config_t::broker (C++ function), 142
esp_mqtt_client_config_t::broker (C++ function), 142
Index

esp_netif_dhcp_option_mode_t (C++ enum),
1023
esp_netif_dhcp_option_mode_t::ESP_NETIF_DHCP_OPTION_MODE_GET
1023
(C++ enumerator), 1024
esp_netif_dhcp_option_mode_t::ESP_NETIF_DHCP_OPTION_MODE_MODIFY
1024
(C++ enumerator), 1024
esp_netif_dhcp_option_mode_t::ESP_NETIF_DHCP_OPTION_MODE_OVERWRITE
1024
(C++ enumerator), 1024
esp_netif_dhcp_option_mode_t::ESP_NETIF_DHCP_OPTION_MODE_DELETE
1024
(C++ enumerator), 1024
esp_netif_dhcp_status_t (C++ enum),
1023
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_STOPPED
1023
(C++ enumerator), 1023
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_STARTED
1023
(C++ enumerator), 1023
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_INIT
1023
(C++ enumerator), 1023
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_MAX
1023
(C++ enumerator), 1023
esp_netif_dhcp_option_mode_t (C++ type),
1022
esp_netif_driver_ifconfig_t (C++ type),
1022
esp_netif_flags::ESP_NETIF_DHCP_OPTION_MODE_GET
1022
(C++ enum), 1022
esp_netif_flags::ESP_NETIF_DHCP_OPTION_MODE_MODIFY
1022
(C++ enum), 1022
esp_netif_flags::ESP_NETIF_DHCP_OPTION_MODE_OVERWRITE
1022
(C++ enum), 1022
esp_netif_flags::ESP_NETIF_DHCP_OPTION_MODE_DELETE
1022
(C++ enum), 1022
esp_netif_flags::ESP_NETIF_DHCP_OPTION_MODE_MAX
1022
(C++ enum), 1022
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_STOPPED
1022
(C++ enumerator), 1022
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_STARTED
1022
(C++ enumerator), 1022
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_INIT
1022
(C++ enumerator), 1022
esp_netif_dhcp_status_t::ESP_NETIF_DHCP_STATUS_MAX
1022
(C++ enumerator), 1022
esp_netif_dhcp_option_mode_t::ESP_NETIF_DHCP_MAX
1022
(C++ enumerator), 1022

Release v5.1.2
Submit Document Feedback
Index

1020 esp_netif_inherent_config::bridge_info (C++ member), 1020 esp_netif_inherent_config::flags (C++ member), 1020 esp_netif_inherent_config::get_ip_event (C++ member), 1020 esp_netif_inherent_config::if_desc (C++ member), 1020 esp_netif_inherent_config::if_key (C++ member), 1020 esp_netif_inherent_config::ip_info (C++ member), 1020 esp_netif_inherent_config::lost_ip_event (C++ member), 1020 esp_netif_inherent_config::mac (C++ member), 1020 esp_netif_inherent_config::route_prio (C++ member), 1020 esp_netif_inherent_config_t (C++ type), 1022

ESP_NETIF_INHERENT_DEFAULT_OPENTHREAD (C macro), 996 esp_netif_init (C++ function), 1004 esp_netif_ioctl_driver_handle (C++ type), 1023 esp_netif_ip4_makeu32 (C macro), 1027 esp_netif_ip6_get_addr_type (C++ function), 1026 esp_netif_ip6_info_t (C++ struct), 1018 esp_netif_ip6_info_t::ip (C++ member), 1018 esp_netif_ip_addr_copy (C++ function), 1026 esp_netif_ip_event_type (C++ enum), 1025 esp_netif_ip_event_type::ESP_NETIF_IP_EVENT_TYPE (C++ enumerator), 1025 esp_netif_ip_event_type::ESP_NETIF_IP_EVENT_TYPE (C++ enumerator), 1025 esp_netif_ip_event_type_t (C++ type), 1022 esp_netif_ip_info_t (C++ struct), 1018 esp_netif_ip_info_t::gw (C++ member), 1018 esp_netif_ip_info_t::ip (C++ member), 1018 esp_netif_ip_info_t::netmask (C++ member), 1018 esp_netif_is_netif_up (C++ function), 1008 esp_netif_join_ip6_multicast_group (C++ function), 1007 esp_netif_leave_ip6_multicast_group (C++ function), 1007 esp_netif_napt_disable (C++ function), 1010 esp_netif_napt_enable (C++ function), 1010 esp_netif_netstack_buf_free (C++ function), 1015 esp_netif_netstack_buf_ref (C++ function), 1015 esp_netif_netstack_config_t (C++ type), 1023 esp_netif_new (C++ function), 1004 esp_netif_next (C++ function), 1015 esp_netif_pair_mac_ip_t (C++ struct), 1021 esp_netif_pair_mac_ip_t::ip (C++ member), 1021 esp_netif_receive (C++ function), 1004 esp_netif_receive_t (C++ type), 1023 esp_netif_set_default_netif (C++ function), 1007 esp_netif_set_dns_info (C++ function), 1012 esp_netif_set_driver_config (C++ function), 1004 esp_netif_set_hostname (C++ function), 1009 esp_netif_set_ip4_addr (C++ function), 1014 esp_netif_set_ip_info (C++ function), 1009 esp_netif_set_link_speed (C++ function), 1033 esp_netif_set_mac (C++ function), 1007 esp_netif_set_old_ip_info (C++ function), 1009 ESP_NETIF_SNTP_DEFAULT_CONFIG (C macro), 1017 ESP_NETIF_SNTP_DEFAULT_CONFIG_MULTIPLE (C macro), 1017 esp_netif_snntp_deinit (C++ function), 1016 esp_netif_snntp_init (C++ function), 1016 esp_netif_snntp_start (C++ function), 1016 esp_netif_snntp_sync_wait (C++ function), 1016 esp_netif_str_to_ip4 (C++ function), 1014 esp_netif_str_to_ip6 (C++ function), 1014 esp_netif_unregister (C++ function), 1008 esp_netif_unregister_transmit (C++ function), 1033 esp_netif_transmit_wrap (C++ function), 1034

esp_nimble_hci_deinit (C++ function), 815 esp_nimble_hci_init (C++ function), 814 esp_now_add_peer (C++ function), 825 esp_now_deinit (C++ function), 824 esp_now_del_peer (C++ function), 825 esp_now_eth_alen (C macro), 829 esp_now_fetch_peer (C++ function), 826 esp_now_get_peer (C++ function), 826 esp_now_get_peer_num (C++ function), 827 esp_now_get_version (C++ function), 824 esp_now_init (C++ function), 824 esp_now_is_peer_exist (C++ function), 827 ESP_NOW_KEY_LEN (C macro), 829 ESP_NOW_MAX_DATA_LEN (C macro), 830 ESP_NOW_MAX_ENCRYPT_PEER_NUM (C macro), 829 ESP_NOW_MAX_TOTAL_PEER_NUM (C macro), 829 esp_now_mod_peer (C++ function), 825 esp_now_peer_info (C++ struct), 827
esp_now_peer_info::channel (C++ member), 828
esp_now_peer_info::encrypt (C++ member), 828
esp_now_peer_info::ifidx (C++ member), 828
esp_now_peer_info::lmk (C++ member), 828
esp_now_peer_info::peer_addr (C++ member), 828
esp_now_peer_num (C++ struct), 828
esp_now_peer_num::encrypt_num (C++ member), 828
esp_now_peer_num::total_num (C++ member), 828
esp_now_peer_num_t (C++ type), 830
esp_now_rate_config (C++ struct), 828
esp_now_rate_config::ersu (C++ member), 829
esp_now_rate_config::phymode (C++ member), 829
esp_now_rate_config::rate (C++ member), 829
esp_now_rate_config_t (C++ type), 830
esp_now_recv_info (C++ struct), 828
esp_now_recv_info::des_addr (C++ member), 828
esp_now_recv_info::rx_ctrl (C++ member), 828
esp_now_recv_info::src_addr (C++ member), 828
esp_now_recv_info_t (C++ type), 830
esp_now_register_recv_cb (C++ function), 824
esp_now_register_send_cb (C++ function), 824
esp_now_send (C++ function), 825
esp_now_send_cb_t (C++ type), 830
esp_now_send_status_t (C++ enum), 830
esp_now_send_status_t::ESP_NOW_SEND_FAIL (C++ function), 830
(esp_now_send_status_t::ESP_NOW_SEND_FUNCTION, 830
(esp_now_send_status_t::ESP_NOW_SEND_SUCCESS (C++ function), 825
ESP_OK (C macro), 1936
ESP_OK_EFUSE_CNT (C macro), 1934
esp_openthread_auto_start (C++ function), 989
esp_openthread_border_router_deinit (C++ function), 996
esp_openthread_border_router_init (C++ function), 996
esp_openthread_deinit (C++ function), 989
esp_openthread_event_t (C++ enum), 993
esp_openthread_event_t::OPENTHREAD_EVENT_ATTACHED (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_DETACHED (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_GOT_IP6 (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_IF_DOWN (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_IF_UP (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_LOST_IP6 (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_MULTICAST (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_MULTICAST_ADD (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_ROLE_CHANGED (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_SET_DNS_SERVER (C++ enumerator), 994
esp_openthread_event_t::OPENTHREAD_EVENT_STOP (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_TREL_ADD (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_TREL_MUL (C++ enumerator), 993
esp_openthread_event_t::OPENTHREAD_EVENT_TREL_RM (C++ enumerator), 993
esp_openthread_get_backbone_netif (C++ function), 996
esp_openthread_get_instance (C++ function), 989
esp_openthread_get_netif (C++ function), 996
esp_openthread_host_connection_config_t::host_connection_mode (C++ struct), 991
esp_openthread_host_connection_config_t::host_connection_mode (C++ member), 992
esp_openthread_host_connection_config_t::host_usb (C++ member), 992
esp_openthread_host_connection_config_t::spi_slave_config (C++ member), 994
esp_openthread_host_connection_mode_t (C++ function), 994
esp_openthread_host_connection_mode_t::HOST_CONNE
Index

esp_openthread_uart_config_t::uart_config
(C++ member), 990
esp_ota_abort (C++ function), 2187
esp_ota_begin (C++ function), 2185
esp_ota_check.Rollback_is_possible (C++ function), 2189
esp_ota_end (C++ function), 2187
esp_ota_erase_last_boot_app_partition (C++ function), 2189
esp_ota_get_app_description (C++ function), 2185
esp_ota_get_app ELF_sha256 (C++ function), 2185
esp_ota_get_app_partition_count (C++ function), 2187
esp_ota_get_boot_partition (C++ function), 2187
esp_ota_get_last_invalid_partition (C++ function), 2189
esp_ota_get_next_update_partition (C++ function), 2188
esp_ota_get_partition_description (C++ function), 2188
esp_ota_get_running_partition (C++ function), 2188
esp_ota_get_state_partition (C++ function), 2189
esp_ota_handle_t (C++ type), 2190
esp_ota_mark_app_invalid_rollback_and_cancel_rollback (C++ function), 2188
esp_ota_mark_app_valid_cancel_rollback (C++ function), 2188
esp_ota_set_boot_partition (C++ function), 2187
esp_ota_write (C++ function), 2186
esp_ota_write_with_offset (C++ function), 2186
esp_paddr_t (C++ type), 2123
esp_partition_check_identity (C++ function), 1862
esp_partition_deregister_external (C++ function), 1862
esp_partition_erase_range (C++ function), 1861
esp_partition_find (C++ function), 1858
esp_partition_find_first (C++ function), 1858
esp_partition_get (C++ function), 1859
esp_partition_get_sha256 (C++ function), 1861
esp_partition_iterator_release (C++ function), 1859
esp_partition_iterator_t (C++ type), 1864
esp_partition_mmap (C++ function), 1861
esp_partition_mmap_handle_t (C++ type), 1864
esp_partition_mmap_memory_t (C++ enum), 1864
Index

Espressif Systems 2887 Release v5.1.2

Submit Document Feedback
Index

esp_pm_config.esp32_t (C++ type), 2199
esp_pm_config.esp32c2_t (C++ type), 2199
esp_pm_config.esp32c3_t (C++ type), 2199
esp_pm_config.esp32c6_t (C++ type), 2199
esp_pm_config.esp32s2_t (C++ type), 2199
esp_pm_config.esp32s3_t (C++ type), 2199
esp_pm_config (C++ struct), 2199
esp_pm_config_t::light_sleep_enable (C++ member), 2199
esp_pm_config_t::max_freq_mhz (C++ member), 2199
esp_pm_config_t::min_freq_mhz (C++ member), 2199
esp_pm_configure (C++ function), 2197
esp_pm_dump_locks (C++ function), 2199
esp_pm_get_configuration (C++ function), 2197
esp_pm_lock_acquire (C++ function), 2198
esp_pm_lock_create (C++ function), 2197
esp_pm_lock_delete (C++ function), 2198
esp_pm_lock_handle_t (C++ type), 2199
esp_pm_lock_release (C++ function), 2198
esp_pm_lock_type_t (C++ enum), 2200
esp_pm_lock_type_t::ESP_PM_APB_FREQ_MAX (C++ enumerator), 2200
esp_pm_lock_type_t::ESP_PM_CPU_FREQ_MAX (C++ enumerator), 2200
esp_pm_lock_type_t::ESP_PM_NO_LIGHT_SLEEP (C++ enumerator), 2200
esp_power_level_t (C++ enum), 530
esp_power_level_t::ESP_PWR_LVL_P7 (C++ enumerator), 531
esp_power_level_t::ESP_PWR_LVL_P9 (C++ enumerator), 530
esp pthread_cfg_t (C++ struct), 2204
esp pthread_cfg_t::inherited_cfg (C++ member), 2204
esp pthread_cfg_t::pin_to_core (C++ member), 2204
esp pthread_cfg_t::prio (C++ member), 2204
esp pthread_cfg_t::stack_size (C++ member), 2204
esp pthread_cfg_t::thread_name (C++ member), 2204
esp pthread_get_cfg (C++ function), 2204
esp pthread_get_default_cfg (C++ function), 2203
esp pthread_init (C++ function), 2204
esp pthread_set_cfg (C++ function), 2203
esp random (C++ function), 2205
esp_read_mac (C++ function), 2170
esp_register_freertos_idle_hook (C++ function), 2099
esp_register_freertos_idle_hook_for_cpu (C++ function), 2099
esp_register_freertos_tick_hook (C++ function), 2100
esp_register_shutdown_handler (C++ function), 2166
esp_reset_reason (C++ function), 2167
esp_reset_reason_t (C++ enum), 2167
esp_reset_reason_t::ESP_RST_BROWNOUT (C++ enumerator), 2168
esp_reset_reason_t::ESP_RST_DEEPSLEEP (C++ enumerator), 2168
esp_reset_reason_t::ESP_RST_EXT (C++ enumerator), 2168
esp_reset_reason_t::ESP_RST_INT_WDT (C++ enumerator), 2168
esp_reset_reason_t::ESP_RST_PANIC (C++ enumerator), 2168
esp_reset_reason_t::ESP_RST_POWERON (C++ enumerator), 2168
esp.reset_reason_t::ESP_RST_SDIO (C++ enumerator), 2168
esp.reset_reason_t::ESP_RST_SW (C++ enumerator), 2168
esp.reset_reason_t::ESP_RST_TASK_WDT (C++ enumerator), 2168
esp.reset_reason_t::ESP_RST_UNKNOW (C++ enumerator), 2167
esp.reset_reason_t::ESP_RST_WDT (C++ enumerator), 2168
esp_restart (C++ function), 2167
ESP_RETURN_ON_ERROR (C macro), 1935
esp_sleep_pd_domain_t::ESP_PD_DOMAIN_RTC_FAST_MEM
(C++ enumerator), 2219
esp_sleep_pd_domain_t::ESP_PD_DOMAIN_RTC_PERIPH_MEM
(C++ enumerator), 2219
esp_sleep_pd_domain_t::ESP_PD_DOMAIN_RTC_SLOW_MEM
(C++ enumerator), 2219
esp_sleep_pd_domain_t::ESP_PD_DOMAIN_VDDSDIO
(C++ enumerator), 2219
esp_sleep_pd_domain_t::ESP_PD_DOMAIN_XTAL
(C++ enumerator), 2219
esp_sleep_pd_domain_t::ESP_PD_DOMAIN_MAX
(C++ enumerator), 2219
esp_sleep_pd_config
(esp_sleep_mode_t::ESP_SLEEP_MODE_LIGHT_SLEEP)
(esp_sleep_mode_t::ESP_SLEEP_MODE_DEEP_SLEEP)
(esp_sleep_is_valid_wakeup_gpio)
(esp_sleep_get_wakeup_cause)
(esp_sleep_get_touchpad_wakeup_status)
(esp_sleep_get_ext1_wakeup_status)
(esp_sleep_ext1_wakeup_mode_t::ESP_EXT1_WAKEUP_ANY_HIGH)
(esp_sleep_ext1_wakeup_mode_t::ESP_EXT1_WAKEUP_ALL_LOW)
(esp_sleep_enable_wifi_wakeup)
(esp_sleep_enable_ulp_wakeup)
(esp_sleep_enable_uart_wakeup)
(esp_sleep_enable_touchpad_wakeup)
(esp_sleep_enable_timer_wakeup)
(esp_sleep_enable_gpio_wakeup)
(esp_sleep_enable_gpio_switch)
(esp_sleep_enable_ext1_wakeup)
(esp_sleep_enable_ext0_wakeup)
(esp_sleep_enable_bt_wakeup)
(esp_sleep_disable_wifi_wakeup)
(esp_sleep_disable_wifi_beacon_wakeup)
(esp_sleep_disable_wakeup_source)
(esp_sleep_disable_bt_wakeup)
(esp_sntp_config::index_of_first_server)
(esp_smartconfig_stop)
(esp_smartconfig_set_type)
(esp_smartconfig_get_version)
(esp_smartconfig_get_rvd_data)
(esp_smartconfig_fast_mode)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_GPIO)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_EXT1)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_BT)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_COCPU)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_COCPU_TRAP)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_EXT0)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_EXT1)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_UNDEFINED)
(esp_sleep_wakeup_cause_t::ESP_SLEEP_WAKEUP_WIFI)
(esp_smartconfig_get_rvd_data)
(esp_smartconfig_get_version)
(esp_smartconfig_set_type)
(esp_smartconfig_stop)
(sntp_config::index_of_first_server)
(C++ function), 2218
C++ enum

esp_sntp_config::ip_event_to_renew (C++ member), 1017
esp_sntp_config::num_of_servers (C++ member), 1017
esp_sntp_config::renew_servers_after_name (C++ member), 1017
esp_sntp_config::server_from_dhcp (C++ member), 1016
esp_sntp_config::servers (C++ member), 1017
esp_sntp_config::smooth_sync (C++ member), 1016
esp_sntp_config::start (C++ member), 1017
esp_sntp_config::sync_cb (C++ member), 1017
esp_sntp_config::wait_for_sync (C++ member), 1017
esp_sntp_enabled (C++ function), 2236
esp_sntp_get_sync_interval (C macro), 2237
esp_sntp_get_sync_mode (C macro), 2236
esp_sntp_get_sync_status (C macro), 2236
esp_sntp_getserver (C++ function), 2236
esp_sntp_getservername (C++ function), 2236
esp_sntp_init (C++ function), 2235
esp_sntp_initonly (C++ function), 2237
esp_sntp_operatingmode_t (C++ enum), 2237
esp_sntp_operatingmode_t::ESP_SNTP_OPMODE_LISTENONLY (C++ enumerator), 2237
esp_sntp_operatingmode_t::ESP_SNTP_OPMODE_POLLED (C++ enumerator), 2237
esp_sntp_restart (C macro), 2237
ESP_SNTP_SERVER_LIST (C macro), 1017
esp_sntp_set_sync_interval (C macro), 2237
esp_sntp_set_sync_mode (C macro), 2236
esp_sntp_set_sync_status (C macro), 2236
esp_sntp_set_time_sync_notification_cb (C macro), 2236
esp_sntp_setoperatingmode (C++ function), 2235
esp_sntp_setserver (C++ function), 2236
esp_sntp_setservername (C++ function), 2236
esp_sntp_stop (C++ function), 2235
esp_sntp_sync_time (C macro), 1017
esp_sntp_check (C++ function), 1869
esp_spiffs_check (C++ function), 1869
esp_spiffs_format (C++ function), 1869
esp_spiffs_gc (C++ function), 1869
esp_spiffs_info (C++ function), 1869
esp_spiffs_mouted (C++ function), 1869
esp_spp_c_b_event_t::ESP_SPP_CL_INIT_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_CLOSE_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_CONG_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_DATA_IND_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_DISCOVERY_COMP_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_INIT_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_OPEN_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_SRV_OPEN_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_SRV_STOP_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_START_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_UNINIT_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_VFS_REGISTER_EVT (C++ enumerator), 442
esp_spp_c_b_event_t::ESP_SPP_VFS_UNREGISTER_EVT (C++ enumerator), 443
esp_spp_c_b_event_t::ESP_SPP_WRITE_EVT (C++ enumerator), 442
esp_spp_c_b_param_t (C++ union), 434
esp_spp_c_b_param_t::cl_init (C++ member), 435
esp_spp_c_b_param_t::close (C++ member), 435
esp_spp_c_b_param_t::cong (C++ member), 435
esp_spp_c_b_param_t::esp_snft_opmode_listennon (C++ member), 435
esp_spp_c_b_param_t::data_ind (C++ member), 435
esp_spp_c_b_param_t::disc_comp (C++ member), 434
esp_spp_c_b_param_t::init (C++ member), 434
esp_spp_c_b_param_t::open (C++ member), 434
esp_spp_c_b_param_t::spp_cl_init_evt_param (C++ struct), 435
esp_spp_c_b_param_t::spp_cl_init_evt_param::handle (C++ member), 435
esp_spp_c_b_param_t::spp_cl_init_evt_param::sec_id (C++ member), 435
esp_spp_c_b_param_t::spp_cl_init_evt_param::status (C++ member), 435
esp_spp_c_b_param_t::spp_cl_init_evt_param::use_cong (C++ member), 435
esp_spp_c_b_param_t::spp_close_evt_param (C++ struct), 435
esp_spp_c_b_param_t::spp_close_evt_param::async (C++ member), 436
esp_spp_c_b_param_t::spp_close_evt_param::port_status (C++ member), 436
esp_spp_c_b_param_t::spp_close_evt_param::status (C++ member), 436
esp_spp_c_b_param_t::spp_cong_evt_param (C++ struct), 436
esp_spp_c_b_param_t::spp_cong_evt_param::cong (C++ member), 436
<table>
<thead>
<tr>
<th>Function/Type</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>esp_spp_init (C++ function)</td>
<td>432</td>
</tr>
<tr>
<td>ESP_SPP_MAX_MTU (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_MAX_SN (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_MAX_TX_BUFFER_SIZE (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_MIN_TX_BUFFER_SIZE (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>esp_supp_dpp_mode_t (C++ enum)</td>
<td>441</td>
</tr>
<tr>
<td>esp_supp_dpp_mode_t::ESP_SPP_MODE_CB (C++ enumerator)</td>
<td>442</td>
</tr>
<tr>
<td>esp_supp_dpp_register_callback (C++ function)</td>
<td>432</td>
</tr>
<tr>
<td>esp_supp_dpp_role_t (C++ enum)</td>
<td>441</td>
</tr>
<tr>
<td>esp_supp_dpp_role_t::ESP_SPP_ROLE_MASTER (C++ enumerator)</td>
<td>441</td>
</tr>
<tr>
<td>esp_supp_dpp_role_t::ESP_SPP_ROLE_SLAVE (C++ enumerator)</td>
<td>441</td>
</tr>
<tr>
<td>ESP_SPP_SEC_AUTHORIZE (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_SEC_ENCRYPT (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_SEC_IN_16_DIGITS (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_SEC_MITM (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_SEC_MODE4_LEVEL4 (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>ESP_SPP_SEC_NONE (C macro)</td>
<td>440</td>
</tr>
<tr>
<td>esp_supp_ssec_t (C++ type)</td>
<td>440</td>
</tr>
<tr>
<td>esp_supp_start_discovery (C++ function)</td>
<td>432</td>
</tr>
<tr>
<td>esp_supp_start_srv (C++ function)</td>
<td>433</td>
</tr>
<tr>
<td>esp_supp_status_t (C++ enum)</td>
<td>441</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_BUSY (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_FAILURE (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_NEED_DEINIT (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_NEED_INIT (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_NO_CONNECTION (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_NO_DATA (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_NO_RESOURCE (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_NO_SERVER (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_status_t::ESP_SPP_SUCCESS (C++ enumerator)</td>
<td>443</td>
</tr>
<tr>
<td>esp_supp_stop_srv (C++ function)</td>
<td>433</td>
</tr>
<tr>
<td>esp_supp_stop_srv_scn (C++ function)</td>
<td>433</td>
</tr>
<tr>
<td>esp_supp_vfs_register (C++ function)</td>
<td>434</td>
</tr>
<tr>
<td>esp_supp_vfs_unregister (C++ function)</td>
<td>434</td>
</tr>
<tr>
<td>esp_supp_write (C++ function)</td>
<td>434</td>
</tr>
<tr>
<td>esp_supp_dpp_bootstrap_gen (C++ function)</td>
<td>950</td>
</tr>
<tr>
<td>esp_supp_dpp_bootstrap_t (C++ type)</td>
<td>951</td>
</tr>
<tr>
<td>esp_supp_dpp_deinit (C++ function)</td>
<td>950</td>
</tr>
<tr>
<td>esp_supp_dpp_event_cb_t (C++ type)</td>
<td>951</td>
</tr>
<tr>
<td>esp_supp_dpp_event_t (C++ enum)</td>
<td>951</td>
</tr>
<tr>
<td>esp_supp_dpp_event_t::ESP_SPP_DPP_CFG_RECVD (C++ member)</td>
<td>2142</td>
</tr>
<tr>
<td>esp_supp_dpp_event_t::ESP_SUPP_DPP_FAIL (C++ enumerator)</td>
<td>952</td>
</tr>
<tr>
<td>esp_supp_dpp_event_t::ESP_SUPP_DPP_URI_READY (C++ enumerator)</td>
<td>952</td>
</tr>
<tr>
<td>esp_supp_dpp_init (C++ function)</td>
<td>950</td>
</tr>
<tr>
<td>esp_supp_dpp_start_listen (C++ function)</td>
<td>950</td>
</tr>
<tr>
<td>esp_supp_dpp_stop_listen (C++ function)</td>
<td>951</td>
</tr>
<tr>
<td>esp_system_abort (C++ function)</td>
<td>2167</td>
</tr>
<tr>
<td>esp_sysview_flush (C++ function)</td>
<td>1899</td>
</tr>
<tr>
<td>esp_sysview_heap_trace_alloc (C++ function)</td>
<td>1899</td>
</tr>
<tr>
<td>esp_sysview_heap_trace_free (C++ function)</td>
<td>1899</td>
</tr>
<tr>
<td>esp_sysview_heap_trace_start (C++ function)</td>
<td>1899</td>
</tr>
<tr>
<td>esp_sysview_heap_trace_stop (C++ function)</td>
<td>1899</td>
</tr>
<tr>
<td>esp_task_wdt_add (C++ function)</td>
<td>2276</td>
</tr>
<tr>
<td>esp_task_wdt_add_user (C++ function)</td>
<td>2276</td>
</tr>
<tr>
<td>esp_task_wdt_config_t (C++ struct)</td>
<td>2278</td>
</tr>
<tr>
<td>esp_task_wdt_config_t::idle_core_mask (C++ member)</td>
<td>2278</td>
</tr>
<tr>
<td>esp_task_wdt_config_t::timeout_ms (C++ member)</td>
<td>2278</td>
</tr>
<tr>
<td>esp_task_wdt_config_t::trigger_panic (C++ member)</td>
<td>2278</td>
</tr>
<tr>
<td>esp_task_wdt_deinit (C++ function)</td>
<td>2276</td>
</tr>
<tr>
<td>esp_task_wdt_delete (C++ function)</td>
<td>2277</td>
</tr>
<tr>
<td>esp_task_wdt_delete_user (C++ function)</td>
<td>2277</td>
</tr>
<tr>
<td>esp_task_wdt_init (C++ function)</td>
<td>2275</td>
</tr>
<tr>
<td>esp_task_wdt_isr_user_handler (C++ function)</td>
<td>2277</td>
</tr>
<tr>
<td>esp_task_wdt_reconfigure (C++ function)</td>
<td>2276</td>
</tr>
<tr>
<td>esp_task_wdt_reset (C++ function)</td>
<td>2277</td>
</tr>
<tr>
<td>esp_task_wdt_reset_user (C++ function)</td>
<td>2277</td>
</tr>
<tr>
<td>esp_task_wdt_status (C++ function)</td>
<td>2277</td>
</tr>
<tr>
<td>esp_task_wdt_user_handle_t (C++ type)</td>
<td>2278</td>
</tr>
<tr>
<td>esp_timer_cb_t (C++ type)</td>
<td>2143</td>
</tr>
<tr>
<td>esp_timer_create (C++ function)</td>
<td>2139</td>
</tr>
<tr>
<td>esp_timer_create_args_t (C++ struct)</td>
<td>2142</td>
</tr>
<tr>
<td>esp_timer_create_args_t::arg (C++ member)</td>
<td>2143</td>
</tr>
<tr>
<td>esp_timer_create_args_t::callback (C++ member)</td>
<td>2143</td>
</tr>
<tr>
<td>esp_timer_create_args_t::dispatch_method (C++ member)</td>
<td>2143</td>
</tr>
<tr>
<td>esp_timer_create_args_t::name (C++ member)</td>
<td>2143</td>
</tr>
<tr>
<td>esp_timer_create_args_t::skip_unhandled_events (C++ member)</td>
<td>2143</td>
</tr>
</tbody>
</table>
Index

esp_timer_deinit (C++ function), 2139
esp_timer_delete (C++ function), 2141
esp_timer_dispatch_t (C++ enum), 2143
esp_timer_dispatch_t::ESP_TIMER_MAX (C++ enumerator), 2143
esp_timer_dispatch_t::ESP_TIMER_TASK (C++ enumerator), 2143
esp_timer_dump (C++ function), 2141
esp_timer_early_init (C++ function), 2139
esp_timer_get_expiry_time (C++ function), 2141
esp_timer_get_next_alarm (C++ function), 2141
esp_timer_get_next_alarm_for_wake_up (C++ function), 2141
esp_timer_get_period (C++ function), 2141
esp_timer_get_time (C++ function), 2141
esp_timer_handle_t (C++ type), 2143
esp_timer_init (C++ function), 2139
esp_timer_is_active (C++ function), 2142
esp_timer_isr_dispatch_need_yield (C++ function), 2142
esp_timer_new_etm_alarm_event (C++ function), 2142
esp_timer_restart (C++ function), 2140
esp_timer_start_once (C++ function), 2140
esp_timer_start_periodic (C++ function), 2140
esp_timer_stop (C++ function), 2140
tls_addr_family (C++ enum), 157
tls_addr_family::ESP_TLS_AF_INET (C++ enumerator), 157
tls_addr_family::ESP_TLS_AF_INET6 (C++ enumerator), 157
tls_addr_family::ESP_TLS_AF_UNSPEC (C++ enumerator), 157
tls_addr_family_t (C++ type), 156
tls_cfg (C++ struct), 153
tls_cfg::addr_family (C++ member), 155
tls_cfg::alpn_protos (C++ member), 154
tls_cfg::cacert_buf (C++ member), 154
tls_cfg::cacert_bytes (C++ member), 154
tls_cfg::cacert_pem_buf (C++ member), 154
tls_cfg::cacert_pem_bytes (C++ member), 154
tls_cfg::clientcert_buf (C++ member), 154
tls_cfg::clientcert_bytes (C++ member), 154
tls_cfg::clientcert_pem_buf (C++ member), 154
tls_cfg::clientcert_pem_bytes (C++ member), 154
esp_timer_error_handle_t (C++ type), 159
esp_tls_cfg::clientkey_bytes (C++ member), 154
esp_tls_cfg::clientkey_password (C++ member), 154
esp_tls_cfg::clientkey_password_len (C++ member), 155
esp_tls_cfg::clientkey_pem_buf (C++ member), 154
esp_tls_cfg::clientkey_pem_bytes (C++ member), 154
esp_tls_cfg::common_name (C++ member), 155
esp_tls_cfg::crt_bundle_attach (C++ member), 155
esp_tls_cfg::ds_data (C++ member), 155
esp_tls_cfg::if_name (C++ member), 155
esp_tls_cfg::is_plain_tcp (C++ member), 155
esp_tls_cfg::keep_alive_cfg (C++ member), 155
esp_tls_cfg::non_block (C++ member), 155
esp_tls_cfg::psk_hint_key (C++ member), 155
esp_tls_cfg::skip_common_name (C++ member), 155
esp_tls_cfg::timeout_ms (C++ member), 155
esp_tls_cfg::use_global_ca_store (C++ member), 155
esp_tls_cfg::use_secure_element (C++ member), 155
esp_tls_cfg_t (C++ type), 156
esp_tls_conn_destroy (C++ function), 150
esp_tls_conn_http_new (C++ function), 148
esp_tls_conn_http_new_async (C++ function), 149
esp_tls_conn_http_new_async (C++ function), 149
esp_tls_conn_new_async (C++ function), 148
esp_tls_conn_new_async (C++ function), 148
esp_tls_conn_new_async (C++ function), 148
esp_tls_conn_new_sync (C++ function), 148
esp_tls_conn_read (C++ function), 150
esp_tls_conn_state (C++ enum), 156
esp_tls_conn_state::ESP_TLS_CONNECTING (C++ enumerator), 156
esp_tls_conn_state::ESP_TLS_DONE (C++ enumerator), 156
esp_tls_conn_state::ESP_TLS_FAIL (C++ enumerator), 156
esp_tls_conn_state::ESP_TLS_HANDSHAKE (C++ enumerator), 156
esp_tls_conn_state::ESP_TLS_INIT (C++ enumerator), 156
esp_tls_conn_state_t (C++ type), 156
esp_tls_conn_write (C++ function), 149
ESP_TLS_ERR_SSL_TIMEOUT (C macro), 159
ESP_TLS_SSL_WANT_READ (C macro), 159
ESP_TLS_SSL_WANT_WRITE (C macro), 159
esp_timer_error_handle_t (C++ type), 159
Index

esp_tls_error_type_t (C++ enum), 159
esp_tls_error_type_t::ESP_TLS_ERR_TYPE sys
(C++ enumerator), 160
esp_tls_error_type_t::ESP_TLS_ERR_TYPE TLS
(C++ enumerator), 160
esp_tls_error_type_t::ESP_TLS_ERR_TYPE ESP
(C++ enumerator), 160
esp_tls_error_type_t::ESP_TLS_ERR_TYPE MBEDTLS
(C++ function), 1884
esp_vfs_close (C++ function), 1875
esp_vfs_dev_uart_port_set_rx_line_endings
(C++ function), 1886
esp_vfs_dev_uart_port_set_tx_line_endings
(C++ function), 1884
esp_vfs_dev_uart_register (C++ function),
1883
esp_vfs_dev_uart_set_rx_line_endings
(C++ function), 1883
esp_vfs_dev_uart_set_tx_line_endings
(C++ function), 1883
esp_vfs_dev_use_driver (C++ function),
1883
esp_vfs_eventfd_unregister (C++ function),
1885
ESP_VFS_EVENTD_CONFIG_DEFAULT (C macro),
1886
esp_vfs_eventfd_config_t (C++ struct), 1885
esp_vfs_eventfd_config_t::max_fds
(C++ member), 1885
esp_vfs_eventfd_register (C++ function),
1885
esp_vfs_eventfd_unregister (C++ function),
1885
esp_vfs_file_info (C++ function), 1811
esp_vfs_file_mnt_config_t (C++ struct),
1811
esp_vfs_file_mnt_config_t::allocation_unit_size
(C++ member), 1811
esp_vfs_file_mnt_config_t::disk_status_check_enabled
(C++ member), 1811
esp_vfs_file_mnt_config_t::format_if_mount_failed
(C++ member), 1811
esp_vfs_file_mnt_config_t::max_files
(C++ member), 1811
esp_vfs_file_register (C++ function), 1806
esp_vfs_fsdevcard_format (C++ function),
1809
esp_vfs_file_sdcard_unmount (C++ function),
1809
esp_vfs_fsdevsdmmc_mount (C++ function),
1807
esp_vfs_fsdevsdmmc_mount_config_t (C++
type), 1811
esp_vfs_fsdevsdmmc_unmount (C++ function),
1808
esp_vfs_fsdevspi_mount (C++ function),
1808
esp_vfs_fsdevspi_format_rw_wl (C++ function),
1810
esp_vfs_fsdevspi_format_rw_wl (C++ function),
1810
esp_vfs_fsdevspi_format_rw_wl (C++ function),
1809
esp_vfs_fsdevspi_unmount_ro (C++
function), 1809

ESP_UUID_LEN_128 (C macro), 245
ESP_UUID_LEN_32 (C macro), 244
esp_vendor_le_cb_t (C++ type), 895
esp_vfs_dev_uart_port_set_rx_line_endings
(C++ function), 1886
esp_vfs_dev_uart_port_set_tx_line_endings
(C++ function), 1884
esp_vfs_dev_uart_register (C++ function),
1883
esp_vfs_dev_uart_set_rx_line_endings
(C++ function), 1883
esp_vfs_dev_uart_set_tx_line_endings
(C++ function), 1883
esp_vfs_dev_use_driver (C++ function),
1883
esp_vfs_eventfd_unregister (C++ function),
1885
ESP_VFS_EVENTD_CONFIG_DEFAULT (C macro),
1886
esp_vfs_eventfd_config_t (C++ struct), 1885
esp_vfs_eventfd_config_t::max_fds
(C++ member), 1885
esp_vfs_eventfd_register (C++ function),
1885
esp_vfs_eventfd_unregister (C++ function),
1885
esp_vfs_file_info (C++ function), 1811
esp_vfs_file_mnt_config_t (C++ struct),
1811
esp_vfs_file_mnt_config_t::allocation_unit_size
(C++ member), 1811
esp_vfs_file_mnt_config_t::disk_status_check_enabled
(C++ member), 1811
esp_vfs_file_mnt_config_t::format_if_mount_failed
(C++ member), 1811
esp_vfs_file_mnt_config_t::max_files
(C++ member), 1811
esp_vfs_file_register (C++ function), 1806
esp_vfs_fsdevcard_format (C++ function),
1809
esp_vfs_file_sdcard_unmount (C++ function),
1809
esp_vfs_fsdevsdmmc_mount (C++ function),
1807
esp_vfs_fsdevsdmmc_mount_config_t (C++
type), 1811
esp_vfs_fsdevsdmmc_unmount (C++ function),
1808
esp_vfs_fsdevspi_mount (C++ function),
1808
esp_vfs_fsdevspi_format_rw_wl (C++ function),
1810
esp_vfs_fsdevspi_format_rw_wl (C++ function),
1810
esp_vfs_fsdevspi_format_rw_wl (C++ function),
1809
esp_vfs_fsdevspi_unmount_ro (C++
function), 1809

Espressif Systems 2895 Release v5.1.2
Submit Document Feedback
func
cion), 1810
esp_vfsFat::unmount_RW (C++ function), 1809
esp_vfsFat::unregister_path (C++ function), 1807
ESP_VFS_FLAG_CONTEXT_PTR (C macro), 1883
ESP_VFS_FLAG_DEFAULT (C macro), 1883
esp_vfs_fstat (C++ function), 1875
esp_vfs_id_t (C++ type), 1883
esp_vfs_l2tap_eth_filter (C++ function), 1029
esp_vfs_l2tap_intf_register (C++ function), 1028
esp_vfs_l2tap_intf_unregister (C++ function), 1028
esp_vfs_link (C++ function), 1875
esp_vfs_lseek (C++ function), 1875
esp_vfs_open (C++ function), 1875
ESP_VFS_PATH_MAX (C macro), 1883
esp_vfs_pwrite (C++ function), 1877
esp_vfs_pwrite (C++ function), 1877
esp_vfs_read (C++ function), 1875
esp_vfs_register (C++ function), 1875
esp_vfs_register_fd (C++ function), 1876
esp_vfs_register_fd_range (C++ function),
1875
esp_vfs_register_fd_with_local_fd (C++ function), 1876
esp_vfs_register_with_id (C++ function), 1875
esp_vfs_rename (C++ function), 1875
esp_vfs_select (C++ function), 1876
esp_vfs_select_sem_t (C++ struct), 1877
esp_vfs_select_sem_t::is_sem_local (C++ member), 1877
esp_vfs_select_sem_t::sem (C++ member), 1877
esp_vfs_select_triggered (C++ function), 1877
esp_vfs_select_triggered_isr (C++ function), 1877
esp_vfs_spiffs_conf_t (C++ struct), 1870
esp_vfs_spiffs_conf_t::base_path (C++ member), 1870
esp_vfs_spiffs_conf_t::format_if_mount (C++ member), 1870
esp_vfs_spiffs_conf_t::max_files (C++ member), 1870
esp_vfs_spiffs_conf_t::partition_label (C++ member), 1870
esp_vfs_spiffs_register (C++ function), 1869
esp_vfs_spiffs_unregister (C++ function), 1869
esp_vfs_stat (C++ function), 1875
esp_vfs_t (C++ struct), 1878
esp_vfs_t::access (C++ member), 1881
esp_vfs_t::access_p (C++ member), 1881
esp_vfs_t::close (C++ member), 1879
esp_vfs_t::close_p (C++ member), 1879
esp_vfs_t::closedir (C++ member), 1880
esp_vfs_t::closedir_p (C++ member), 1880
esp_vfs_t::end select (C++ member), 1883
esp_vfs_t::fcntl (C++ member), 1880
esp_vfs_t::fcntl_p (C++ member), 1880
esp_vfs_t::flags (C++ member), 1878
esp_vfs_t::fstat (C++ member), 1879
esp_vfs_t::fstat_p (C++ member), 1879
esp_vfs_t::fsync (C++ member), 1881
esp_vfs_t::fsync_p (C++ member), 1881
esp_vfs_t::fruncate (C++ member), 1881
esp_vfs_t::fruncate_p (C++ member), 1881
esp_vfs_t::get_socket_select_semaphore (C++ member), 1882
esp_vfs_t::ioctl (C++ member), 1881
esp_vfs_t::ioctl_p (C++ member), 1881
esp_vfs_t::link (C++ member), 1879
esp_vfs_t::link_p (C++ member), 1879
esp_vfs_t::lseek (C++ member), 1878
esp_vfs_t::lseek_p (C++ member), 1878
esp_vfs_t::mkdir (C++ member), 1880
esp_vfs_t::mkdir_p (C++ member), 1880
esp_vfs_t::open (C++ member), 1879
esp_vfs_t::open_p (C++ member), 1879
esp_vfs_t::opendir (C++ member), 1879
esp_vfs_t::opendir_p (C++ member), 1879
esp_vfs_t::pread (C++ member), 1878
esp_vfs_t::pread_p (C++ member), 1878
esp_vfs_t::pwrite (C++ member), 1878
esp_vfs_t::pwrite_p (C++ member), 1878
esp_vfs_t::read (C++ member), 1878
esp_vfs_t::read_p (C++ member), 1878
esp_vfs_t::readdir (C++ member), 1880
esp_vfs_t::readdir_p (C++ member), 1880
esp_vfs_t::readdir (C++ member), 1880
esp_vfs_t::readdir_p (C++ member), 1880
esp_vfs_t::readdir_r (C++ member), 1880
esp_vfs_t::readdir_r_p (C++ member), 1880
esp_vfs_t::rename (C++ member), 1879
esp_vfs_t::rename_p (C++ member), 1879
esp_vfs_t::rmdir (C++ member), 1880
esp_vfs_t::rmdir_p (C++ member), 1880
esp_vfs_t::seekdir (C++ member), 1880
esp_vfs_t::seekdir_p (C++ member), 1880
dleft_t::socket_select (C++ member), 1882
esp_vfs_t::start_select (C++ member), 1882
esp_vfs_t::stop_socket_select (C++ member), 1882
esp_vfs_t::stop_socket_select_isr (C++ member), 1882
esp_vfs_t::tcdrain (C++ member), 1882
esp_vfs_t::tcdrain_p (C++ member), 1882
esp_vfs_t::tcflow (C++ member), 1882
esp_vfs_t::tcflow_p (C++ member), 1882

Index

Submit Document Feedback
Index

esp_vfs_t::tcflush (C++ member), 1882
esp_vfs_t::tcflush_p (C++ member), 1882
esp_vfs_t::tcgetattr (C++ member), 1881
esp_vfs_t::tcgetattr_p (C++ member), 1881
esp_vfs_t::tcgetsid (C++ member), 1882
esp_vfs_t::tcgetsid_p (C++ member), 1882
esp_vfs_t::tcsendbreak (C++ member), 1882
esp_vfs_t::tcsendbreak_p (C++ member), 1882

Index

esp_wifi_clear_ap_list (C++ function), 1030
esp_wifi_clear_fast_connect (C++ function), 876
esp_wifi_config_11b_rate (C++ function), 888
esp_wifi_config_80211_tx_rate (C++ function), 890
esp_wifi_config_espnnow_rate (C++ function), 826
esp_wifi_connect (C++ function), 875
ESP_WIFI_CONNECTIONLESS_INTERVAL_DEFAULT_MODE (C macro), 895
esp_wifi_connectionless_module_set_wake_interval (C++ function), 888
esp_wifi_deauth_sta (C++ function), 876
esp_wifi_deinit (C++ function), 874
esp_wifi_disable_pmf_config (C++ function), 878
esp_wifi_disconnect (C++ function), 890
esp_wifi_force_wakeup_acquire (C++ function), 889
esp_wifi_force_wakeup_release (C++ function), 889
esp_wifi_ftm_end_session (C++ function), 888
esp_wifi_ftm_initiate_session (C++ function), 887
esp_wifi_ftm_respond_with_offset (C++ function), 888
esp_wifi_get_ant_gpio (C++ function), 886
esp_wifi_get_bandwidth (C++ function), 879
esp_wifi_get_channel (C++ function), 879
esp_wifi_get_config (C++ function), 882
esp_wifi_get_country (C++ function), 880
esp_wifi_get_country_code (C++ function), 890
esp_wifi_get_event_mask (C++ function), 884
esp_wifi_get_inactive_time (C++ function), 887
esp_wifi_get_mac (C++ function), 881
esp_wifi_get_max_tx_power (C++ function), 884
esp_wifi_get_mode (C++ function), 874
esp_wifi_get_promiscuous (C++ function), 881
esp_wifi_get_promiscuous_ctrl_filter (C++ function), 882
esp_wifi_get_promiscuous_filter (C++ function), 881
esp_wifi_get_protocol (C++ function), 878
esp_wifi_get_ps (C++ function), 878
esp_wifi_get_tsf_time (C++ function), 886
esp_wifi_init (C++ function), 874
ESP_WIFI_MAX_CONN_NUM (C macro), 921
ESP_WIFI_MAX_FILTER_LEN (C macro), 922
ESP_WIFI_MAX_SVC_INFO_LEN (C macro), 922
ESP_WIFI_MAX_SVC_INFO_LEN (C macro), 922

Submit Document Feedback

Espressif Systems

2897

Release v5.1.2
ESP_WIFI_MAX_SVC_NAME_LEN (C macro), 922
esp_wifi_nan_cancel_service (C++ function), 953
esp_wifi_nan_datapath_end (C++ function), 954
ESP_WIFI_NAN_DATAPATH_MAX_PEERS (C macro), 922
esp_wifi_nan_datapath_req (C++ function), 953
esp_wifi_nan_datapath_resp (C++ function), 954
esp_wifi_nan_get_ipv6_linklocal_from_mac (C++ function), 954
esp_wifi_nan_get_own_svc_info (C++ function), 954
esp_wifi_nan_get_peer_info (C++ function), 955
esp_wifi_nan_get_peer_records (C++ function), 954
ESP_WIFI_NAN_MAX_SVC_SUPPORTED (C macro), 922
esp_wifi_nan_publish_service (C++ function), 953
esp_wifi_nan_send_message (C++ function), 953
esp_wifi_nan_start (C++ function), 952
esp_wifi_nan_stop (C++ function), 952
esp_wifi_nan_subscribe_service (C++ function), 953
ESP_WIFI_NDP_ROLE_INITIATOR (C macro), 922
ESP_WIFI_NDP_ROLE_RESPONDER (C macro), 922
esp_wifi_power_domain_off (C++ function), 2540
esp_wifi_power_domain_on (C++ function), 2540
esp_wifi_restore (C++ function), 875
esp_wifi_scan_get_ap_num (C++ function), 876
esp_wifi_scan_get_ap_records (C++ function), 877
esp_wifi_scan_start (C++ function), 876
esp_wifi_scan_stop (C++ function), 876
esp_wifi_set_ant (C++ function), 886
esp_wifi_set_ant_gpio (C++ function), 886
esp_wifi_set_bandwidth (C++ function), 878
esp_wifi_set_channel (C++ function), 879
esp_wifi_set_config (C++ function), 882
esp_wifi_set_country (C++ function), 879
esp_wifi_set_country_code (C++ function), 889
esp_wifi_set_csi (C++ function), 886
esp_wifi_set_csi_config (C++ function), 885
esp_wifi_set_csi_rx_cb (C++ function), 885
esp_wifi_set_default_wifi_ap_handlers (C++ function), 1030
esp_wifi_set_default_wifi_sta_handlers (C++ function), 1030
esp_wifi_set_dynamic_cs (C++ function), 891
esp_wifi_set_event_mask (C++ function), 884
esp_wifi_set_inactive_time (C++ function), 887
esp_wifi_set_mac (C++ function), 880
esp_wifi_set_max_tx_power (C++ function), 884
esp_wifi_set_mode (C++ function), 874
esp_wifi_set_promiscuous (C++ function), 881
esp_wifi_set_promiscuous_ctrl_filter (C++ function), 881
esp_wifi_set_promiscuous_filter (C++ function), 881
esp_wifi_set_promiscuous_rx_cb (C++ function), 881
esp_wifi_set_protocol (C++ function), 878
esp_wifi_set_ps (C++ function), 877
esp_wifi_set_rssi_threshold (C++ function), 887
esp_wifi_set_storage (C++ function), 883
esp_wifi_set_vendor_ie (C++ function), 883
esp_wifi_set_vendor_ie_cb (C++ function), 884
esp_wifi_sta_enterprise_disable (C++ function), 938
esp_wifi_sta_enterprise_enable (C++ function), 938
esp_wifi_sta_get_ap_info (C++ function), 890
esp_wifi_sta_get_negotiated_phymode (C++ function), 890
esp_wifi_sta_get_rssi (C++ function), 891
esp_wifi_start (C++ function), 875
esp_wifi_stats_dump (C++ function), 887
esp_wifi_stop (C++ function), 875
esp_wifi_wps_disable (C++ function), 943
esp_wifi_wps_enable (C++ function), 943
esp_wifi_wps_start (C++ function), 943
esp_wmm_is_btm_supported_connection (C++ function), 947
esp_wmm_send_bss_transition_mgmt_query (C++ function), 947
esp_wps_config_t (C++ struct), 945
esp_wps_config_t::factory_info (C++ member), 945
esp_wps_config_t::pin (C++ member), 945
esp_wps_config_t::wps_type (C++ member), 945
esssl_clear_intr (C++ function), 195
esssl_get_intr (C++ function), 195
esssl_get_intr_ena (C++ function), 196
esssl_get_packet (C++ function), 194
Index
gpio_mode_t::GPIO_MODE_INPUT (C++ enumerator), 1093
gpio_mode_t::GPIO_MODE_INPUT_OUTPUT (C++ enumerator), 1094
gpio_mode_t::GPIO_MODE_INPUT_OUTPUT_OD (C++ enumerator), 1094
gpio_mode_t::GPIO_MODE_OUTPUT (C++ enumerator), 1094
gpio_mode_t::GPIO_MODE_OUTPUT_OD (C++ enumerator), 1094
gpio_num_t (C++ enum), 1091
gpio_num_t::GPIO_NUM_0 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_1 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_10 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_11 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_12 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_13 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_14 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_15 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_16 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_17 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_18 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_19 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_2 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_20 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_21 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_22 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_23 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_24 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_25 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_26 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_27 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_28 (C++ enumerator), 1092
gpio_num_t::GPIO_NUM_29 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_3 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_30 (C++ enumerator), 1091
gpio_num_t::GPIO_NUM_31 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_32 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_33 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_34 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_35 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_36 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_37 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_38 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_39 (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_MAX (C++ enumerator), 1093
gpio_num_t::GPIO_NUM_NC (C macro), 1088
GPIO_PIN_COUNT (C macro), 1088
GPIO_PIN_REG_0 (C macro), 1088
GPIO_PIN_REG_1 (C macro), 1088
GPIO_PIN_REG_10 (C macro), 1089
GPIO_PIN_REG_11 (C macro), 1089
GPIO_PIN_REG_12 (C macro), 1089
GPIO_PIN_REG_13 (C macro), 1089
GPIO_PIN_REG_14 (C macro), 1089
GPIO_PIN_REG_15 (C macro), 1089
GPIO_PIN_REG_16 (C macro), 1089
GPIO_PIN_REG_17 (C macro), 1089
GPIO_PIN_REG_18 (C macro), 1089
GPIO_PIN_REG_19 (C macro), 1089
GPIO_PIN_REG_2 (C macro), 1088
GPIO_PIN_REG_20 (C macro), 1089
GPIO_PIN_REG_21 (C macro), 1089
GPIO_PIN_REG_22 (C macro), 1089
GPIO_PIN_REG_23 (C macro), 1089
GPIO_PIN_REG_24 (C macro), 1089
GPIO_PIN_REG_25 (C macro), 1089
GPIO_PIN_REG_26 (C macro), 1090
GPIO_PIN_REG_27 (C macro), 1090
gpio_reset_pin (C macro), 1090
GPIO_PIN_REG_29 (C macro), 1090
GPIO_PIN_REG_3 (C macro), 1089
GPIO_PIN_REG_30 (C macro), 1090
GPIO_PIN_REG_31 (C macro), 1090
GPIO_PIN_REG_32 (C macro), 1090
GPIO_PIN_REG_33 (C macro), 1090
GPIO_PIN_REG_34 (C macro), 1090
GPIO_PIN_REG_35 (C macro), 1090
GPIO_PIN_REG_36 (C macro), 1090
GPIO_PIN_REG_37 (C macro), 1090
GPIO_PIN_REG_38 (C macro), 1090
GPIO_PIN_REG_39 (C macro), 1090
GPIO_PIN_REG_4 (C macro), 1089
GPIO_PIN_REG_40 (C macro), 1090
GPIO_PIN_REG_41 (C macro), 1090
GPIO_PIN_REG_42 (C macro), 1089
GPIO_PIN_REG_43 (C macro), 1089
GPIO_PIN_REG_44 (C macro), 1089
GPIO_PIN_REG_45 (C macro), 1089
GPIO_PIN_REG_46 (C macro), 1089
GPIO_PIN_REG_47 (C macro), 1090
GPIO_PIN_REG_48 (C macro), 1090
GPIO_PIN_REG_49 (C macro), 1089
GPIO_PIN_REG_5 (C macro), 1089
GPIO_PIN_REG_50 (C macro), 1089
GPIO_PIN_REG_51 (C macro), 1089
GPIO_PIN_REG_52 (C macro), 1089
GPIO_PIN_REG_53 (C macro), 1089
GPIO_PIN_REG_54 (C macro), 1089
GPIO_PIN_REG_55 (C macro), 1089
GPIO_PIN_REG_56 (C macro), 1089
GPIO_PIN_REG_57 (C macro), 1089
GPIO_PIN_REG_58 (C macro), 1089
GPIO_PIN_REG_59 (C macro), 1089
gpio_port_t (C++ enum), 1091
gpio_port_t::GPIO_PORT_0 (C++ enumerator), 1091
gpio_port_t::GPIO_PORT_MAX (C++ enumerator), 1091
gpio_pull_mode_t (C++ enum), 1094
gpio_pull_mode_t::GPIO_FLOATING (C++ enumerator), 1095
gpio_pull_mode_t::GPIO_PULLDOWN_ONLY (C++ enumerator), 1095
gpio_pull_mode_t::GPIO_PULLUP_ONLY (C++ enumerator), 1095
gpio_pull_mode_t::GPIO_PULLUP_PULLDOWN (C++ enumerator), 1095
gpio_PULLDOWN_DISABLE (C++ enum), 1094
gpio_PULLDOWN_ENABLE (C++ enum), 1094
gpio_PULLDOWN_DISABLE (C++ enum), 1094
gpio_PULLDOWN_ENABLE (C++ enum), 1094
gpio_set_drive_capability (C++ function), 1085
gpio_set_intr_type (C++ function), 1082
gpio_set_level (C++ function), 1082
gpio_set_pull_mode (C++ function), 1083
gpio_sleep_sel_dis (C++ function), 1087
gpio_sleep_sel_en (C++ function), 1087
gpio_sleep_set_direction (C++ function), 1087
gpio_sleep_set_pull_mode (C++ function), 1087
gpio_uninstall_isr_service (C++ function), 1085
gpio_wakeup_disable (C++ function), 1084
gpio_wakeup_enable (C++ function), 1083
gptimer_alarm_cb_t (C++ type), 1112
gptimer_alarm_config_t (C++ struct), 1111
gptimer_alarm_config_t::alarm_count (C++ member), 1111
gptimer_alarm_config_t::auto_reload_on_alarm (C++ member), 1111
gptimer_alarm_config_t::flags (C++ member), 1111
gptimer_alarm_config_t::reload_count (C++ member), 1111
gptimer_alarm_event_data_t (C++ struct), 1112
gptimer_alarm_event_data_t::alarm_value (C++ member), 1112
gptimer_alarm_event_data_t::count_value (C++ member), 1112
gptimer_clock_source_t (C++ type), 1113
gptimer_config_t (C++ struct), 1110
gptimer_config_t::clk_src (C++ member), 1110
gptimer_config_t::direction (C++ member), 1110
gptimer_config_t::flags (C++ member), 1110
gptimer_config_t::intr_priority (C++ member), 1110
gptimer_config_t::intr_shared (C++ member), 1110
gptimer_config_t::resolution_hz (C++ member), 1110
gptimer_count_direction_t (C++ enum), 1113
gptimer_count_direction_t::GPTIMER_COUNT_DOWN (C++ enum), 1113
gptimer_count_direction_t::GPTIMER_COUNT_UP (C++ enum), 1113
gptimer_del_timer (C++ function), 1105
gptimer_disable (C++ function), 1109
gptimer_enable (C++ function), 1108
gptimer_etm_event_config_t (C++ struct), 1112
gptimer_etm_event_config_t::event_type (C++ member), 1112
Index

gptimer_etm_event_type_t (C++ enum), 1114
gptimer_etm_event_type_t::GPTIMER_ETM_EVENT_ALARM (C++ function), 2109
heap_caps_calloc_prefer (C++ function), 2111
heap_caps_calloc (C++ function), 2111
heap_caps_aligned_free (C++ function), 2111
heap_caps_aligned_calloc (C++ function), 2111
heap_caps_aligned_alloc (C++ function), 2111
heap_caps_add_region (C++ function), 2111
gptimer_task_config_t (C++ struct), 1112
gptimer_task_config_t::task_type (C++ member), 1112
gptimer_task_type_t (C++ enum), 1113
gptimer_task_type_t::GPTIMER_TASK_CAPTURE (C++ function), 2109
heap_caps_get_allocated_size (C++ function), 2112
gptimer_stop (C++ function), 2113
heap_caps_free (C++ function), 2107
heap_caps_get_free_size (C++ function), 2109
heap_caps_get_info (C++ function), 2109
heap_caps_get_largest_free_block (C++ function), 2109
heap_caps_get_minimum_free_size (C++ function), 2109
heap_caps_get_total_size (C++ function), 2109
heap_caps_malloc (C++ function), 2107
heap_caps_malloc_extmem_enable (C++ function), 2111
heaps_malloc (C++ function), 2111
heaps_malloc_prefer (C++ function), 2111
heaps_print_heap_info (C++ function), 2109
heaps_realloc (C++ function), 2108
heaps_realloc_free (C++ function), 2108
heaps_register_failed_alloc_callback (C++ function), 2107
HEAP_IRAM_ATTRIB (C macro), 2112
heaps_trace_dump (C++ function), 2135
heaps_trace_dump_caps (C++ function), 2135
heaps_trace_get (C++ function), 2134
heaps_trace_get_count (C++ function), 2134
heaps_trace_init_standalone (C++ function), 2134
heaps_trace_init_tohost (C++ function), 2133
heaps_trace_mode_t (C++ enum), 2136
heaps_trace_mode_t::HEAP_TRACE_ALL (C++ function), 2136
heaps_trace_mode_t::HEAP_TRACE_LEAKS (C++ function), 2136
heaps_trace_record_t (C++ struct), 2135
heaps_trace_record_t::capture (C++ type), 2136
heaps_trace_record_t::address (C++ member), 2135
heaps_trace_record_t::allocated_by (C++ member), 2135
heaps_trace_record_t::count (C++ member), 2135
heaps_trace_record_t::free_count (C++ member), 2135
heaps_trace_record_t::size (C++ member), 2135
heaps_trace_resume (C++ function), 2134
heaps_trace_start (C++ function), 2133

H

heap_caps_add_region (C++ function), 2113
heap_caps_add_region_with_caps (C++ function), 2114
heap_caps_aligned_alloc (C++ function), 2108
heap_capsAligned_alloc (C++ function), 2108
heap_caps_aligned_free (C++ function), 2108
heap_caps_alloc (C++ function), 2108
heap_caps_calls (C++ function), 2111
heap_caps_check_integrity (C++ function), 2110
heap_caps_check_integrity_addr (function), 2110

Submit Document Feedback
Index

httpd_query_key_value (C++ function), 213
httpd_queue_work (C++ function), 220
httpd_recv_func_t (C++ type), 229
httpd_register_err_handler (C++ function), 219
httpd_register_uri_handler (C++ function), 208
httpd_req (C++ struct), 225
httpd_req::aux (C++ member), 226
httpd_req::content_len (C++ member), 226
httpd_req::free_ctx (C++ member), 226
httpd_req::ignore_sess_ctx_changes (C++ member), 226
httpd_req::method (C++ member), 226
httpd_req::sess_ctx (C++ member), 226
httpd_req::uri (C++ member), 226
httpd_req::user_ctx (C++ member), 226
httpd_req_get_cookie_val (C++ function), 213
httpd_req_get_hdr_value_len (C++ function), 211
httpd_req_get_hdr_value_str (C++ function), 211
httpd_req_get_url_query_len (C++ function), 212
httpd_req_get_url_query_str (C++ function), 212
httpd_req_recv (C++ function), 211
httpd_req_toSockfd (C++ function), 210
httpd_resp_send (C++ function), 214
httpd_resp_send_404 (C++ function), 217
httpd_resp_send_408 (C++ function), 217
httpd_resp_send_500 (C++ function), 217
httpd_resp_send_chunk (C++ function), 214
httpd_resp_send_err (C++ function), 216
httpd_resp_sendstr (C++ function), 215
httpd_resp_sendstr_chunk (C++ function), 215
httpd_resp_set_hdr (C++ function), 216
httpd_resp_set_status (C++ function), 215
HTTPD_RESP_USE_STRLEN (C macro), 228
httpd_send (C++ function), 218
httpd_send_func_t (C++ type), 228
httpd_sess_get_ctx (C++ function), 221
httpd_sess_get_transport_ctx (C++ function), 221
httpd_sess_set_transport_ctx (C++ function), 221
httpd_sess_trigger_close (C++ function), 222
httpd_sess_update_lru_counter (C++ function), 222
HTTPD_SOCK_ERR_FAIL (C macro), 227
HTTPD_SOCK_ERR_INVALID (C macro), 227
HTTPD_SOCK_ERR_TIMEOUT (C macro), 227
httpd_socket_recv (C++ function), 219
httpd_socket_send (C++ function), 218
httpd_ssl_config (C++ struct), 234
httpd_ssl_config::alpn_protos (C++ member), 235
httpd_ssl_config::cacert_len (C++ member), 234
httpd_ssl_config::cacet cert (C++ member), 234
httpd_ssl_config::cert_select_cb (C++ member), 235
httpd_ssl_config::http (C++ member), 234
httpd_ssl_config::port_insecure (C++ member), 234
httpd_ssl_config::port_secure (C++ member), 234
httpd_ssl_config::prvtkey_len (C++ member), 234
httpd_ssl_config::prvtkey_pem (C++ member), 234
httpd_ssl_config::servercert (C++ member), 234
httpd_ssl_config::servercertlen (C++ member), 234
httpd_ssl_config::session_tickets (C++ member), 235
httpd_ssl_config::ssl_userdata (C++ member), 235
httpd_ssl_config::transport_mode (C++ member), 234
httpd_ssl_config::use_secure_element (C++ member), 235
httpd_ssl_config::user_cb (C++ member), 235
HTTPD_SSL_CONFIG_DEFAULT (C macro), 235
httpd_ssl_config_t (C++ type), 235
httpd_ssl_start (C++ function), 233
httpd_ssl_stop (C++ function), 233
httpd_ssl_transport_mode_t (C++ enum), 235
httpd_ssl_transport_mode_t::HTTPD_SSL_TRANSPORT_INSECURE (C++ enumerator), 236
httpd_ssl_transport_mode_t::HTTPD_SSL_TRANSPORT_SECURE (C++ enumerator), 236
httpd_ssl_user_cb_state_t (C++ enum), 236
httpd_ssl_user_cb_state_t::HTTPD_SSL_USER_CB_SESSCREATE (C++ enumerator), 236
httpd_ssl_user_cb_state_t::HTTPD_SSL_USER_CB_SESSCLOSE (C++ enumerator), 236
http_start (C++ function), 219
http_stop (C++ function), 220

Espressif Systems

i2c_hal_clk_config_t::setup (C++ member), 1130
i2c_hal_clk_config_t::tout (C++ member), 1130
i2c_hal_timing_config_t (C++ struct), 1130
i2c_hal_timing_config_t::high_period (C++ member), 1130
i2c_hal_timing_config_t::low_period (C++ member), 1130
i2c_hal_timing_config_t::restart_setup (C++ member), 1130
i2c_hal_timing_config_t::sda_hold (C++ member), 1130
i2c_hal_timing_config_t::sda_sample (C++ member), 1130
i2c_hal_timing_config_t::start_hold (C++ member), 1130
i2c_hal_timing_config_t::stop_hold (C++ member), 1130
i2c_hal_timing_config_t::stop_setup (C++ member), 1130
i2c_hal_timing_config_t::timeout (C++ member), 1130
i2c_hal_timing_config_t::wait_high_period (C++ member), 1130
I2C_INTERNAL_STRUCT_SIZE (C macro), 1129
I2C_LINK_RECOMMENDED_SIZE (C macro), 1129
i2c_master_cmd_begin (C++ function), 1124
i2c_master_read (C++ function), 1123
i2c_master_read_byte (C++ function), 1123
i2c_master_read_from_device (C++ function), 1121
i2c_master_start (C++ function), 1122
i2c_master_stop (C++ function), 1124
i2c_master_write (C++ function), 1123
i2c_master_write_byte (C++ function), 1123
i2c_master_write_read_device (C++ function), 1121
i2c_mode_t (C++ enum), 1131
i2c_mode_t::I2C_MODE_MASTER (C++ enumerator), 1131
i2c_mode_t::I2C_MODE_MAX (C++ enumerator), 1131
i2c_mode_t::I2C_MODE_SLAVE (C++ enumerator), 1131
i2c_param_config (C++ function), 1120
i2c_port_t (C++ enum), 1131
i2c_port_t::I2C_NUM_0 (C++ enumerator), 1131
i2c_port_t::I2C_NUM_1 (C++ enumerator), 1131
i2c_port_t::I2C_NUM_MAX (C++ enumerator), 1131
i2c_reset_rx_fifo (C++ function), 1120
i2c_reset_tx_fifo (C++ function), 1120
i2c_rw_t (C++ enum), 1131
i2c_rw_t::I2C_MASTER_READ (C++ enumerator), 1131
i2c_rw_t::I2C_MASTER_WRITE (C++ enumerator), 1131
I2C_SCLK_SRC_FLAG_AWARE_DFS (C macro), 1128
I2C_SCLK_SRC_FLAG_FOR_NOMAL (C macro), 1128
I2C_SCLK_SRC_FLAG_LIGHT_SLEEP (C macro), 1129
i2c_set_data_mode (C++ function), 1127
i2c_set_data_timing (C++ function), 1126
i2c_set_period (C++ function), 1125
i2c_set_pin (C++ function), 1121
i2c_set_start_timing (C++ function), 1126
i2c_set_stop_timing (C++ function), 1126
i2c_set_timeout (C++ function), 1127
i2c_slave_read_buffer (C++ function), 1124
i2c_slave_write_buffer (C++ function), 1124
i2c_trans_mode_t (C++ enum), 1131
i2c_trans_mode_t::I2C_DATA_MODE_LSB_FIRST (C++ enumerator), 1131
i2c_trans_mode_t::I2C_DATA_MODE_MAX (C++ enumerator), 1131
i2c_trans_mode_t::I2C_DATA_MODE_MSB_FIRST (C++ enumerator), 1131
i2s_chan_config_t (C++ struct), 1162
i2s_chan_config_t::auto_clear (C++ member), 1162
i2s_chan_config_t::dma_desc_num (C++ member), 1162
i2s_chan_config_t::dma_frame_num (C++ member), 1162
i2s_chan_config_t::id (C++ member), 1162
i2s_chan_config_t::role (C++ member), 1162
i2s_chan_handle_t (C++ type), 1164
i2s_chan_info_t (C++ struct), 1162
i2s_chan_info_t::dir (C++ member), 1163
i2s_chan_info_t::id (C++ member), 1163
i2s_chan_info_t::mode (C++ member), 1163
i2s_chan_info_t::pair_chan (C++ member), 1163
i2s_chan_info_t::role (C++ member), 1163
I2S_CHANNEL_DEFAULT_CONFIG (C macro), 1163
i2s_channel_disable (C++ function), 1159
i2s_channel_enable (C++ function), 1159
i2s_channel_get_info (C++ function), 1159
i2s_channel_init_pdm_rx_mode (C++ function), 1150
i2s_channel_init_pdm_rx_mode (C++ function), 1152
i2s_channel_init_std_mode (C++ function), 1146
i2s_channel_preload_data (C++ function), 1160
i2s_channel_read (C++ function), 1160
i2s_channel_reconfig_pdm_rx_clock

Espressif Systems 2907 Release v5.1.2
Submit Document Feedback
...
i2s_std_gpio_config_t::invert_flags (C++ member), 1149
i2s_std_gpio_config_t::mclk (C++ member), 1149
i2s_std_gpio_config_t::mclk_inv (C++ member), 1149
i2s_std_gpio_config_t::ws (C++ member), 1149
i2s_std_gpio_config_t::ws_inv (C++ member), 1149
I2S_STD_MSB_SLOT_DEFAULT_CONFIG (C macro), 1150
I2S_STD_PCM_SLOT_DEFAULT_CONFIG (C macro), 1150
I2S_STD_PHILIPS_SLOT_DEFAULT_CONFIG (C macro), 1150
i2s_std_slot_config_t (C++ struct), 1148
i2s_std_slot_config_t::bit_shift (C++ member), 1148
i2s_std_slot_config_t::data_bit_width (C++ member), 1148
i2s_std_slot_config_t::msb_right (C++ member), 1148
i2s_std_slot_config_t::slot_bit_width (C++ member), 1148
i2s_std_slot_config_t::slot_mask (C++ member), 1148
i2s_std_slot_config_t::slot_mode (C++ member), 1148
i2s_std_slot_config_t::ws_pol (C++ member), 1148
i2s_std_slot_config_t::ws_width (C++ member), 1148
i2s_std_slot_mask_t (C++ enum), 1167
i2s_std_slot_mask_t::I2S_STD_SLOT_BOTH (C++ enumerator), 1167
i2s_std_slot_mask_t::I2S_STD_SLOT_LEFT (C++ enumerator), 1167
i2s_std_slot_mask_t::I2S_STD_SLOT_RIGHT (C++ enumerator), 1167
I_ADC (C macro), 2264
I_ADD (C macro), 2265
I_ADDR (C macro), 2265
I_AND (C macro), 2265
I_ANDR (C macro), 2265
I_BGE (C macro), 2265
I_BGEI (C macro), 2265
I_BHI (C macro), 2265
I_BHI (C macro), 2265
I_BXR (C macro), 2264
I_BXZ (C macro), 2264
I_DELAY (C macro), 2263
I_END (C macro), 2263
I_HALT (C macro), 2263
I_I2C_READ (C macro), 2267
I_I2C_RW (C macro), 2267
I_I2C_WRITE (C macro), 2267
I_JUMP (C macro), 2267
I_LD (C macro), 2264
I_LSHI (C macro), 2265
I_LSHR (C macro), 2265
I_MOVI (C macro), 2265
I_MOV (C macro), 2265
I_MOV (C macro), 2265
I_ORI (C macro), 2265
I_ORR (C macro), 2265
I_RDI (C macro), 2265
I_RSHI (C macro), 2265
I_RSHR (C macro), 2265
I_SLEEP_CYCLE_SEL (C macro), 2263
I_ST (C macro), 2264
I_STAGE_DEC (C macro), 2266
I_STAGE_INC (C macro), 2266
i_latency_data_t (C++ type), 2009
intr_handler_data_t (C++ type), 2156
intr_handler_t (C++ type), 2156
IP2STR (C macro), 1027
IPADDR_Strlen_MAX (C macro), 1028
ip_event_add_ip6_t (C++ struct), 1019
ip_event_add_ip6_t::addr (C++ member), 1019
ip_event_add_ip6_t::preferred (C++ member), 1019
ip_event_ap_staipassigned_t (C++ struct), 1019
ip_event_ap_staipassigned_t::esp_netif (C++ member), 1019
ip_event_ap_staipassigned_t::ip (C++ member), 1019
ip_event_ap_staipassigned_t::mac (C++ member), 1019
ip_event_got_ip6_t (C++ struct), 1018
ip_event_got_ip6_t::esp_netif (C++ member), 1019
ip_event_got_ip6_t::ip_index (C++ member), 1019
ip_event_got_ip6_t::ip_info (C++ member), 1019
ip_event_got_ip6_t::ip_info (C++ member), 1018
ip_event_t (C++ enum), 1024
ip_event_t::IP_EVENT_AP_STAIPASSIGNED (C++ enum), 1025
Index

ledc_timer_bit_t::LEDC_TIMER_2_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_3_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_4_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_5_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_6_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_7_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_8_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_9_BIT  
(C++ enumerator), 1202

ledc_timer_bit_t::LEDC_TIMER_BIT_MAX  
(C++ enumerator), 1203

ledc_timer_config (C++ function), 1189

ledc_timer_config_t (C++ struct), 1197

ledc_timer_config_t::clk_cfg (C++ member), 1198

ledc_timer_config_t::duty_resolution  
(C++ member), 1198

ledc_timer_config_t::freq_hz (C++ member), 1198

ledc_timer_config_t::speed_mode (C++ member), 1198

ledc_timer_config_t::timer_num (C++ member), 1198

ledc_timer_pause (C++ function), 1193

ledc_timer_resume (C++ function), 1193

ledc_timer_rst (C++ function), 1192

ledc_timer_set (C++ function), 1192

ledc_timer_t (C++ enum), 1201

ledc_timer_t::LEDC_TIMER_0 (C++ enumerator), 1201

ledc_timer_t::LEDC_TIMER_1 (C++ enumerator), 1201

ledc_timer_t::LEDC_TIMER_2 (C++ enumerator), 1201

ledc_timer_t::LEDC_TIMER_3 (C++ enumerator), 1201

ledc_timer_t::LEDC_TIMER_MAX (C++ enumerator), 1201

ledc_update_duty (C++ function), 1189

linenoiseCompletions (C++ type), 1912

M

M_BGE (C macro), 2266
M_BL (C macro), 2266
M_BRANCH (C macro), 2265
M_BSEQ (C macro), 2267
M_BSGE (C macro), 2266
M_BSGT (C macro), 2267
M_BSLE (C macro), 2267
M_BSIT (C macro), 2266
M_BX (C macro), 2266
M_BXF (C macro), 2266
M_BXZ (C macro), 2266
M_LABEL (C macro), 2265
M_LABELPC (C macro), 2265
M_MOVL (C macro), 2265
MAC2STR (C macro), 2171
MACSTR (C macro), 2171
MALLOC_CAP_32BIT (C macro), 2112
MALLOC_CAP_8BIT (C macro), 2112
MALLOC_CAP_DEFAULT (C macro), 2113
MALLOC_CAP_DMA (C macro), 2112
MALLOC_CAP_EXEC (C macro), 2112
MALLOC_CAP_INTERNAL (C macro), 2112
MALLOC_CAP_INVALID (C macro), 2113
MALLOC_CAP_IRAM_8BIT (C macro), 2113
MALLOC_CAP_IRAM_9BIT (C macro), 2113
MALLOC_CAP_PID2 (C macro), 2112
MALLOC_CAP_PID3 (C macro), 2112
MALLOC_CAP_PID4 (C macro), 2112
MALLOC_CAP_PID5 (C macro), 2112
MALLOC_CAP_PID6 (C macro), 2112
MALLOC_CAP_PID7 (C macro), 2112
MALLOC_CAPRetention (C macro), 2113
MALLOC_CAP_RTICRAM (C macro), 2113
MALLOC_CAP_SPIRAM (C macro), 2112
MAX_BLE_DEVMNAME_LEN (C macro), 1777
MAX_BLE_MANUFACTURER_DATA_LEN (C macro), 1777
MAX_fds (C macro), 1883
MAX_PASSPHRASE_LEN (C macro), 923
MAX_SSID_LEN (C macro), 922
MAX_WPS_AP_CRED (C macro), 923
mcpwm_brake_config_t (C++ struct), 1230
mcpwm_brake_config_t::brake_mode (C++ member), 1230
mcpwm_brake_config_t::cbc_recover_on_tep  
(C++ member), 1230
mcpwm_brake_config_t::cbc_recover_on_tez  
(C++ member), 1230
mcpwm_brake_config_t::fault (C++ member), 1230
mcpwm_brake_config_t::flags (C++ member), 1230
mcpwm_brake_event_cb_t (C++ type), 1250
mcpwm_brake_event_data_t (C++ struct), 1249
mcpwm_cap_channel_handle_t (C++ type), 1250
mcpwm_cap_timer_handle_t (C++ type), 1250
mcpwm_capture_channel_config_t (C++ struct), 1247
mcpwm_capture_channel_config_t::flags  
(C++ member), 1248
mcpwm_capture_channel_config_t::gpio_num  
(C++ member), 1247
mcpwm_capture_channel_config_t::intr_priority  
(C++ member), 1247
mcpwm_capture_channel_config_t::invert_cap_signal  
(C++ member), 1248
mcpwm_capture_channel_config_t::io_loopback_capture_timer_stop (C++ function), 1248
mcpwm_capture_channel_config_t::keep_invariant_capture_timer_sync_phase_config_t (C++ struct), 1247
mcpwm_capture_channel_config_t::neg_edge_mcpwm_capture_timer_sync_phase_config_t::count_value (C++ member), 1247
mcpwm_capture_channel_config_t::pos_edge_mcpwm_capture_timer_sync_phase_config_t::direction (C++ member), 1247
mcpwm_capture_channel_config_t::prescaler_mcpwm_capture_timer_sync_phase_config_t::sync_src (C++ member), 1247
mcpwm_capture_channel_config_t::pull_down_mcpwm_capture_timer_stop (C++ function), 1248
mcpwm_capture_channel_disable (C++ function), 1246
mcpwm_capture_channel_enable (C++ function), 1245
mcpwm_capture_channel_register_event_callbacks (C++ function), 1246
mcpwm_capture_channel_trigger_soft_get (C++ function), 1246
mcpwm_capture_clock_source_t (C++ type), 1251
mcpwm_capture_edge_t (C++ type), 1251
mcpwm_capture_edge_t::MCPWM_CAP_EDGE_NEG (C++ enumerator), 1253
mcpwm_capture_edge_t::MCPWM_CAP_EDGE_POS (C++ enumerator), 1253
mcpwm_capture_event_data_t (C++ struct), 1248
mcpwm_capture_event_data_t::cap_edge (C++ member), 1249
mcpwm_capture_event_data_t::cap_value (C++ member), 1249
mcpwm_capture_timer_config_t (C++ struct), 1247
mcpwm_capture_timer_config_t::clk_src (C++ member), 1247
mcpwm_capture_timer_config_t::group_id (C++ member), 1247
mcpwm_capture_timer_config_t::resolution (C++ member), 1247
mcpwm_capture_timer_disable (C++ function), 1244
mcpwm_capture_timer_enable (C++ function), 1244
mcpwm_capture_timer_get_resolution (C++ function), 1244
mcpwm_capture_timer_set_phase_on_sync (C++ function), 1245
mcpwm_capture_timer_start (C++ function), 1244


mcpwm_dead_time_config_t::invert_output, 1238
mcpwm_gen_timer_event_action_t::action (C++ member), 1237
mcpwm_gen_timer_event_action_t::negedge_delay_ticks (C++ member), 1238
mcpwm_gen_timer_event_action_t::COMPARE (C++ member), 1238
mcpwm_gen_timer_event_action_t::posedge_delay_ticks (C++ member), 1238
mcpwm_del_capture_channel (C++ function), 1245
mcpwm_del_capture_timer (C++ function), 1243
mcpwm_del_comparator (C++ function), 1232
mcpwm_del_fault (C++ function), 1239
mcpwm_del_generator (C++ function), 1234
mcpwm_del_operator (C++ function), 1228
mcpwm_del_sync_src (C++ function), 1242
mcpwm_del_timer (C++ function), 1225
mcpwm_fault_event_callbacks_t (C++ struct), 1241
mcpwm_fault_event_callbacks_t::on_fault_exit (C++ member), 1241
mcpwm_fault_event_callbacks_t::on_fault_enter (C++ member), 1241
mcpwm_generator_action_t (C++ enum), 1252
mcpwm_generator_action_t::MCPWM_GEN_ACTION_HIGH (C++ enumerator), 1252
mcpwm_generator_action_t::MCPWM_GEN_ACTION_KEEP (C++ enumerator), 1252
mcpwm_generator_action_t::MCPWM_GEN_ACTION_LOW (C++ enumerator), 1252
mcpwm_generator_action_t::MCPWM_GEN_ACTION_TOGGLE (C++ enumerator), 1252
mcpwm_generator_config_t (C++ struct), 1237
mcpwm_generator_config_t::flags (C++ member), 1237
mcpwm_generator_config_t::gengpio_num (C++ member), 1237
mcpwm_generator_config_t::invert_pwm (C++ member), 1237
mcpwm_generator_config_t::io_loop_back (C++ member), 1237
mcpwm_generator_config_t::io_od_mode (C++ member), 1237
mcpwm_generator_config_t::pull_down (C++ member), 1237
mcpwm_generator_config_t::pull_up (C++ member), 1237
mcpwm_generator_set_action_on_brake_event (C++ function), 1236
mcpwm_generator_set_action_on_compare_event (C++ function), 1235
mcpwm_generator_set_action_on_timer_event (C++ function), 1234
mcpwm_generator_set_actions_on_brake_event (C++ function), 1236
mcpwm_generator_set_actions_on_compare_event (C++ function), 1235
mcpwm_generator_set_actions_on_timer_event (C++ function), 1235
mcpwm_generator_set_dead_time (C++ function), 1236
mcpwm_generator_set_force_level (C++ function), 1234
mcpwm_gpio_fault_config_t (C++ struct), 1234
mcpwm_gpio_fault_config_t::active_level (C++ member), 1240
mcpwm_gpio_fault_config_t::flags (C++ member), 1240
mcpwm_gpio_fault_config_t::gpio_num (C++ member), 1240
mcpwm_gpio_fault_config_t::group_id (C++ member), 1240
mcpwm_gpio_fault_config_t::intr_priority (C++ member), 1240

Espressif Systems Release v5.1.2

Submit Document Feedback
Index

mcpwm_gpio_fault_config_t::io_loop_backmcpwm_operator_config_t::update_dead_time_on_tep
(C++ member), 1240
(C++ member), 1230
mcpwm_gpio_fault_config_t::pull_down
mcpwm_operator_config_t::update_dead_time_on_tez
(C++ member), 1240
(C++ member), 1230
mcpwm_gpio_fault_config_t::pull_up
mcpwm_operator_config_t::update_gen_action_on_syn
(C++ member), 1240
(C++ member), 1230
mcpwm_gpio_sync_src_config_t (C++ struct), mcpwm_operator_config_t::update_gen_action_on_tep
1242
(C++ member), 1230
mcpwm_gpio_sync_src_config_t::active_neg
mcpwm_operator_config_t::update_gen_action_on_tez
(C++ member), 1243
(C++ member), 1230
mcpwm_gpio_sync_src_config_t::flags
mcpwm_operator_connect_timer (C++ func(C++ member), 1243
tion), 1228
mcpwm_gpio_sync_src_config_t::gpio_num mcpwm_operator_event_callbacks_t (C++
(C++ member), 1243
struct), 1230
mcpwm_gpio_sync_src_config_t::group_id mcpwm_operator_event_callbacks_t::on_brake_cbc
(C++ member), 1243
(C++ member), 1231
mcpwm_gpio_sync_src_config_t::io_loop_back
mcpwm_operator_event_callbacks_t::on_brake_ost
(C++ member), 1243
(C++ member), 1231
mcpwm_gpio_sync_src_config_t::pull_downmcpwm_operator_recover_from_fault
(C++ member), 1243
(C++ function), 1229
mcpwm_gpio_sync_src_config_t::pull_up mcpwm_operator_register_event_callbacks
(C++ member), 1243
(C++ function), 1229
mcpwm_new_capture_channel (C++ function), mcpwm_operator_set_brake_on_fault
1245
(C++ function), 1228
mcpwm_new_capture_timer (C++ function), mcpwm_soft_fault_activate (C++ function),
1243
1239
mcpwm_new_comparator (C++ function), 1232
mcpwm_soft_fault_config_t (C++ struct),
mcpwm_new_generator (C++ function), 1233
1240
mcpwm_new_gpio_fault (C++ function), 1239
mcpwm_soft_sync_activate (C++ function),
mcpwm_new_gpio_sync_src (C++ function),
1242
1241
mcpwm_soft_sync_config_t (C++ struct), 1243
mcpwm_new_operator (C++ function), 1228
mcpwm_sync_handle_t (C++ type), 1250
mcpwm_new_soft_fault (C++ function), 1239
mcpwm_timer_clock_source_t (C++ type),
mcpwm_new_soft_sync_src (C++ function),
1251
1242
mcpwm_timer_config_t (C++ struct), 1227
mcpwm_new_timer (C++ function), 1225
mcpwm_timer_config_t::clk_src
(C++
member), 1227
mcpwm_new_timer_sync_src (C++ function),
1241
mcpwm_timer_config_t::count_mode (C++
mcpwm_oper_handle_t (C++ type), 1249
member), 1227
mcpwm_operator_apply_carrier (C++ func- mcpwm_timer_config_t::flags (C++ memtion), 1229
ber), 1227
mcpwm_operator_brake_mode_t (C++ enum), mcpwm_timer_config_t::group_id
(C++
1253
member), 1227
mcpwm_operator_brake_mode_t::MCPWM_OPER_BRAKE_MODE_CBC
mcpwm_timer_config_t::intr_priority
(C++ enumerator), 1253
(C++ member), 1227
mcpwm_operator_brake_mode_t::MCPWM_OPER_BRAKE_MODE_INVALID
mcpwm_timer_config_t::period_ticks
(C++ enumerator), 1253
(C++ member), 1227
mcpwm_operator_brake_mode_t::MCPWM_OPER_BRAKE_MODE_OST
mcpwm_timer_config_t::resolution_hz
(C++ enumerator), 1253
(C++ member), 1227
mcpwm_operator_config_t (C++ struct), 1229
mcpwm_timer_config_t::update_period_on_empty
mcpwm_operator_config_t::flags
(C++
(C++ member), 1227
member), 1230
mcpwm_timer_config_t::update_period_on_sync
mcpwm_operator_config_t::group_id
(C++ member), 1227
(C++ member), 1229
mcpwm_timer_count_mode_t (C++ enum), 1251
mcpwm_operator_config_t::intr_priority mcpwm_timer_count_mode_t::MCPWM_TIMER_COUNT_MODE_
(C++ member), 1230
(C++ enumerator), 1252
mcpwm_operator_config_t::update_dead_time_on_sync
mcpwm_timer_count_mode_t::MCPWM_TIMER_COUNT_MODE_
(C++ member), 1230
(C++ enumerator), 1252

Espressif Systems

2916
Submit Document Feedback

Release v5.1.2


Index

mcpwm_timer_count_mode_t::MCPWM_TIMER_COUNT_MODE
(C++ struct, 1242)
mcpwm_timer_count_mode_t::MCPWM_TIMER_COUNT_MODE
(C++ struct, 1242)
mcpwm_timer_count_mode_t::flags
(C++ member, 1242)
mcpwm_timer_count_mode_t::flags
(C++ member, 1242)
mcpwm_timer_sync_src_config_t::propagate_input_sync
(C++ member, 1242)
mcpwm_timer_sync_src_config_t::timer_event
(C++ member, 1242)
mesh_addr_t (C++ union), 854
mesh_addr_t::addr (C++ member), 854
mesh_addr_t::mip (C++ member), 854
mesh_ap_cfg_t (C++ struct), 860
mesh_ap_cfg_t::max_connection
(C++ member, 860)
mesh_ap_cfg_t::nonmesh_max_connection
(C++ member, 860)
mesh_ap_cfg_t::password (C++ member), 860
MESH_ASSOC_FLAG_NETWORK_FREE (C macro), 864
MESH_ASSOC_FLAG_ROOT_FIXED (C macro), 864
MESH_ASSOC_FLAG_ROOTS_FOUND (C macro), 864
MESH_ASSOC_FLAG_VOTE_IN_PROGRESS (C macro), 864
mesh_cfg_t (C++ struct), 860
mesh_cfg_t::allow_channel_switch
(C++ member, 860)
mesh_cfg_t::channel (C++ member, 860)
mesh_cfg_t::crypto_funcs
(C++ member, 861)
mesh_data_t (C macro), 864
MESH_DATA_NONBLOCK (C macro), 864
MESH_DATA_P2P (C macro), 864
data_t (C++ struct), 859
MESH_DATA_PROTO (C macro), 859
MESH_DATA_PROTO_EW (C++ member, 859)
mesh_data_t::tos (C++ member), 859
MESH_DATA_Size (C macro), 864
mesh_disconnect_reason_t (C++ enum), 868
mesh_disconnect_reason_t::MESH_REASON_CYCLIC
(C++ enum, 869)
mesh_disconnect_reason_t::MESH_REASON_DIFF_ID
(C++ enum, 869)
mesh_disconnect_reason_t::MESH_REASON_EMPTY_PASSWD
(C++ enum, 869)
mesh_disconnect_reason_t::MESH_REASON_IE_UNKNOWN
(C++ enum, 869)
mesh_disconnect_reason_t::MESH_REASON_LEAF
(C++ enum, 869)
mesh_disconnect_reason_t::MESH_REASON_PARENT_IDLE
(C++ enum, 869)

Espressif Systems 2917 Release v5.1.2
Submit Document Feedback
mesh_disconnect_reason_t::MESH_REASON_WAIVE_ROOT
(mesh_disconnect_reason_t::MESH_REASON_SCAN_FAIL
(mesh_disconnect_reason_t::MESH_REASON_ROOTS
(mesh_disconnect_reason_t::MESH_REASON_PARENT_WORSE
(mesh_disconnect_reason_t::MESH_REASON_PARENT_UNENCRYPTED
(mesh_disconnect_reason_t::MESH_REASON_PARENT_STOPPED
(mesh_event_find_network_t::channel
(mesh_event_connected_t::duty
(mesh_event_connected_t::connected
(mesh_event_child_disconnected_t::channel
(mesh_event_find_network_t::channel
(mesh_event_info_t::root_fixed
(mesh_event_info_t::root_conflict
(mesh_event_info_t::root_addr
(mesh_event_info_t::ps_duty
(mesh_event_info_t::no_parent
(mesh_event_info_t::network_state
(mesh_event_info_t::layer_change
(mesh_event_info_t::find_network
(mesh_event_info_t::ps_duty
(mesh_event_info_t::ps_device_duty
(mesh_event_info_t::ps_child_duty
(mesh_event_info_t::ps_parent_duty
(mesh_event_id_t::MESH_EVENT_VOTE_STARTED
(mesh_event_id_t::MESH_EVENT_TODS_STATE
(mesh_event_id_t::MESH_EVENT_ROUTING_TABLE_ADD
(mesh_event_id_t::MESH_EVENT_ROUTING_TABLE_REMOVE
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH_ACK
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH_REQ
(mesh_event_id_t::MESH_EVENT_NETWORK_STATE
(mesh_event_id_t::MESH_EVENT_MAX
(mesh_event_id_t::MESH_EVENT_CHANNEL_SWITCH
(mesh_event_id_t::MESH_EVENT_PS_PARENT_DUTY
(mesh_event_id_t::MESH_EVENT_PS_CHILD_DUTY
(mesh_event_id_t::MESH_EVENT_PARENT_DISCONNECTED
(mesh_event_id_t::MESH_EVENT_ROOT_FIXED
(mesh_event_id_t::MESH_EVENT_ROOT_ASKED_YIELD
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH
(mesh_event_id_t::MESH_EVENT_ROOT_ADDRESS
(mesh_event_id_t::MESH_EVENT_ROOT_REQUEST_YIELD
(mesh_event_id_t::MESH_EVENT_ROOTAsked_yield
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH_ACK
(mesh_event_id_t::MESH_EVENT_ROOT_SWITCH_REQ
(mesh_event_id_t::MESH_EVENT_ROUTER_SWITCH
(mesh_event_id_t::MESH_EVENT_ROUTING_TABLE_ADD
(mesh_event_id_t::MESH_EVENT_ROUTING_TABLE_REMOVE
(mesh_event_id_t::MESH_EVENT_SCAN_DONE
(mesh_event_id_t::MESH_EVENT_STARTED
(mesh_event_id_t::MESH_EVENT_STOP_RECONNECTION
(mesh_event_id_t::MESH_EVENT_STOPPED
(mesh_event_id_t::MESH_EVENT_TODS_STATE
(mesh_event_id_t::MESH_EVENT_VOTE_STARTED
(mesh_event_id_t::MESH_EVENT_VOTE_STOPPED
(mesh_event_info_t::router_bssid
(mesh_event_info_t::channel_switch
(mesh_event_info_t::child_connected
(mesh_event_info_t::child_disconnected
(mesh_event_info_t::connected
(mesh_event_id_t::MESH_EVENT_CHANNEL_SWITCH
(mesh_event_id_t::MESH_EVENT_CHILD_CONNECTED
(mesh_event_id_t::MESH_EVENT_CHILD_DISCONNECTED
(mesh_event_id_t::MESH_EVENT_FIND_NETWORK
(mesh_event_id_t::MESH_EVENT_LAYER_CHANGE
(mesh_event_id_t::MESH_EVENT_MAX
(mesh_event_id_t::MESH_EVENT_NETWORK_STATE
(mesh_event_id_t::MESH_EVENT_NO_PARENT_FOUND
(mesh_event_id_t::MESH_EVENT_PARENT_CONNECTED
(mesh_event_id_t::MESH_EVENT_PARENT_DISCONNECTED
(mesh_event_info_t::find_network
(mesh_event_info_t::layer_change
(mesh_event_info_t::ps_duty
(mesh_event_info_t::root_addr
(mesh_event_info_t::root_conflict
(mesh_event_info_t::root_fixed

multi_heap_info_t::allocated_blocks (C++ member), 2117
multi_heap_info_t::free_blocks (C++ member), 2117
multi_heap_info_t::largest_free_block (C++ member), 2117
multi_heap_info_t::minimum_free_bytes (C++ member), 2117
multi_heap_info_t::total_allocated_bytes (C++ member), 2117
multi_heap_info_t::total_blocks (C++ member), 2117
multi_heap_info_t::total_free_bytes (C++ member), 2117
multi_heap_malloc (C++ function), 2115
multi_heap_minimum_free_size (C++ function), 2117
multi_heap_realloc (C++ function), 2115
multi_heap_set_lock (C++ function), 2116

N
name_uuid (C++ struct), 1776
name_uuid::name (C++ member), 1776
name_uuid::uuid (C++ member), 1776
NAN_MAX_PEERS_RECORD (C macro), 955
nan_peer_record (C++ struct), 955
nan_peer_record::ndp_id (C++ member), 955
nan_peer_record::own_svc_id (C++ member), 955
nan_peer_record::peer_ndi (C++ member), 955
nan_peer_record::peer_nmi (C++ member), 955
nan_peer_record::peer_svc_id (C++ member), 955
nan_peer_record::peer_svc_type (C++ member), 955
NDP_STATUS_ACCEPTED (C macro), 955
NDP_STATUS_REJECTED (C macro), 955
neighbor_rep_request_cb (C++ type), 947
non_pref_chan (C++ struct), 948
non_pref_chan::chan (C++ member), 948
non_pref_chan::oper_class (C++ member), 948
non_pref_chan::preference (C++ member), 948
non_pref_chan::reason (C++ member), 948
non_pref_chan::reason::NON_PREF_CHAN_REASON_EXT_INT (C++ member), 949
non_pref_chan::reason::NON_PREF_CHAN_REASON_EXT_EXT (C++ member), 949
non_pref_chan::reason::NON_PREF_CHAN_REASON_EXT_UNSPEC (C++ member), 949
non_pref_chan::reason::NON_PREF_CHAN_REASON_RSSI (C++ member), 949
multi_heap_dump (C++ function), 2116
multi_heap_check (C++ function), 2116
multi_heap_dump (C++ function), 2116
multi_heap_free (C++ function), 2115
multi_heap_free_size (C++ function), 2116
multi_heap_get_allocated_size (C++ function), 2116
multi_heap_get_info (C++ function), 2117
multi_heap_handle_t (C++ type), 2118
multi_heap_info_t (C++ struct), 2117

Espressif Systems 2920 Release v5.1.2
Submit Document Feedback
non_pref-chan_s::chan (C++ member), 949
non_pref-chan_s::non_pref-chan_num (C++ member), 949
nvs_close (C++ function), 1832
nvs_commit (C++ function), 1832
NVS_DEFAULT_PART_NAME (C macro), 1837
nvs_entry_find (C++ function), 1833
nvs_entry_info (C++ function), 1834
nvs_entry_info_t::key (C++ member), 1834
nvs_entry_info_t::namespace_name (C++ member), 1834
nvs_entry_info_t::type (C++ member), 1834
nvs_entry_next (C++ function), 1834
nvs_erase_all (C++ function), 1824
nvs_entry_info_t::chan (C++ member), 1834
nvs_entry_info_t::non_pref-chan_num (C++ member), 1834
nvs_entry_info_t::non_pref-chan_s (C++ member), 1834
nvs_open (C++ function), 1830
nvs_open_from_partition (C++ function), 1830
nvs_open_mode (C++ type), 1837
nvs_open_mode_t (C++ enum), 1837
nvs_open_mode_t::NVSDONLY (C++ enumerator), 1837
nvs_open_mode_t::NVSDREADWRITE (C++ enumerator), 1837
NVS_PART_NAME_MAX_SIZE (C macro), 1837
nvs_release_iterator (C++ function), 1834
nvs_sec_cfg_t::eky (C++ member), 1826
nvs_sec_cfg_t::key (C++ member), 1826
nvs_set_blob (C++ function), 1831
nvs_set_i16 (C++ function), 1827
nvs_set_i32 (C++ function), 1827
nvs_set_i64 (C++ function), 1827
nvs_set_i8 (C++ function), 1827
nvs_set_str (C++ function), 1827
nvs_set_u16 (C++ function), 1827
nvs_set_u32 (C++ function), 1827
nvs_set_u64 (C++ function), 1827
nvs_set_u8 (C++ function), 1827
nvs_stats_t::free_entries (C++ member), 1835
nvs_stats_t::namespace_count (C++ member), 1835
nvs_stats_t::total_entries (C++ member), 1835
nvs_stats_t::used_entries (C++ member), 1835
nvs_type_t (C++ enum), 1837
nvs_type_t::NVSTYPE_ANY (C++ enumerator), 1838
nvs_type_t::NVSTYPE_BLOB (C++ enumerator), 1838
nvs_type_t::NVSTYPE_I16 (C++ enumerator), 1838
nvs_type_t::NVSTYPE_I32 (C++ enumerator), 1838
nvs_type_t::NVSTYPE_I64 (C++ enumerator), 1838
nvs_type_t::NVSTYPE_I8 (C++ enumerator), 1837
nvs_type_t::NVSTYPE_STR (C++ enumerator), 1838
nvs_type_t::NVSTYPE_U16 (C++ enumerator), 1838
nvs_type_t::NVSTYPE_U32 (C++ enumerator), 1838
nvs_type_t::NVSTYPE_U64 (C++ enumerator), 1838
nvs_type_t::NVSTYPE_U8 (C++ enumerator), 1837

OPCODE_ADC (C macro), 2260
OPCODE_ALU (C macro), 2260
OPCODE_BRANCH (C macro), 2261

Submit Document Feedback

Index
pcnt_glitch_filter_config_t (C++ struct), 1266
pcnt_glitch_filter_config_t::max_glitch_ns (C++ member), 1267
pcnt_new_channel (C++ function), 1264
pcnt_new_unit (C++ function), 1259
pcnt_unit_add_watch_point (C++ function), 1263
pcnt_unit_clear_count (C++ function), 1262
pcnt_unit_config_t (C++ struct), 1265
pcnt_unit_config_t::accum_count (C++ member), 1266
pcnt_unit_config_t::flags (C++ member), 1266
pcnt_unit_config_t::high_limit (C++ member), 1266
pcnt_unit_config_t::intr_limit (C++ member), 1266
pcnt_unit_config_t::low_limit (C++ member), 1265
pcnt_unit_disable (C++ function), 1261
pcnt_unit_enable (C++ function), 1260
pcnt_unit_get_count (C++ function), 1262
pcnt_unit_handle_t (C++ type), 1267
pcnt_unit_register_event_callbacks (C++ function), 1263
pcnt_unit_remove_watch_point (C++ function), 1263
pcnt_unit_set_glitch_filter (C++ function), 1260
pcnt_unit_stop (C++ function), 1262
pcnt_unit_zero_cross_mode_t (C++ enum), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG_POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS POS POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS NEG NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_NEG POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS_POS POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS NEG NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS NEG ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT_ZERO_CROSS NEG POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT ZERO CROSS POS ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO_CROSS POS NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO_CROSS NEG ZERO (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO_CROSS NEG POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO_CROSS POS NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO_CROSS POS POS (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO_CROSS NEG NEG (C++ enumerator), 1268
pcnt_unit_zero_cross_mode_t::PCNT_UNIT.ZERO C O M M O N (C++ struct), 1265
pcnt_unit_zero_cross_mode_t::zero_cross_mode (C++ member), 1265
pcQueueGetName (C++ function), 2010
pcTaskGetName (C++ function), 2043
PendedFunction_t (C++ type), 2055
phy_802_3_t::link_status (C++ struct), 987
phy_802_3_t::addr (C++ member), 987
phy_802_3_t::autonego_timeout_ms (C++ member), 987
phy_802_3_t::eth (C++ member), 987
phy_802_3_t::link_status (C++ member),
phy_802_3_t::parent (C++ member), 987
phy_802_3_t::reset_gpio_num (C++ member), 987
phy_802_3_t::reset_timeout_ms (C++ member), 987
phy_init_param_set (C++ function), 2539
phy_wifi_enable_set (C++ function), 2539
PIN_LEN (C macro), 945
protocomm_add_endpoint (C++ function), 1768
protocomm_ble_config (C++ struct), 1776
protocomm_ble_config::ble_link_encryption (C++ member), 1777
protocomm_ble_config::ble_sm_sc (C++ member), 1777
protocomm_ble_config::device_name (C++ member), 1777
protocomm_ble_config::manufacturer_data (C++ member), 1777
protocomm_ble_config::manufacturer_data_len (C++ member), 1777
protocomm_ble_config::nu_lookup (C++ member), 1777
protocomm_ble_config::nu_lookup_count (C++ member), 1777
protocomm_ble_config::service_uuid (C++ member), 1777
protocomm_ble_config_t (C++ type), 1777
protocomm_ble_name_uuid_t (C++ type), 1777
protocomm_ble_start (C++ function), 1776
protocomm_ble_stop (C++ function), 1776
protocomm_close_session (C++ function), 1769
protocomm_delete (C++ function), 1768
protocomm_http_server_config_t (C++ struct), 1775
protocomm_http_server_config_t::port (C++ member), 1775
protocomm_http_server_config_t::stack_size (C++ member), 1775
protocomm_http_server_config_t::task_priority (C++ member), 1775
protocomm_http_server_config_t::task_priority (C++ member), 1775
protocomm_httpd_stop (C++ function), 1774
protocomm_new (C++ function), 1768
protocomm_open_session (C++ function), 1769
protocomm_remove_endpoint (C++ function), 1769
protocomm_reg_handle (C++ function), 1770
protocomm_reg_handler_t (C++ type), 1771
protocomm_security (C++ struct), 1772
protocomm_security1_params (C++ struct), 1772
protocomm_security1_params::data (C++ member), 1772
protocomm_security1_params::len (C++ member), 1772
protocomm_security2_params (C++ struct), 1772
protocomm_security2_params::salt (C++ member), 1772
protocomm_security2_params::salt_len (C++ member), 1772
protocomm_security2_params::verifier (C++ member), 1772
protocomm_security2_params::verifier_len (C++ member), 1772
protocomm_security2_params_t (C++ type), 1773
protocomm_security::cleanup (C++ member), 1773
protocomm_security::close_transport_session (C++ member), 1773
protocomm_security::decrypt (C++ member), 1773
protocomm_security::encrypt (C++ member), 1773
protocomm_security::init (C++ member), 1773
protocomm_security::new_transport_session (C++ member), 1773
protocomm_security::security_reg_handler (C++ member), 1773
protocomm_security::ver (C++ member), 1773
protocomm_security_handler_t (C++ type), 1773
protocomm_security_pop_t (C++ type), 1773
protocomm_security_session_event_t (C++ enum), 1774
protocomm_security_session_event_t::PROTOCOL_SEC_ERROR (C++ enumerator), 1774
protocomm_security_session_event_t::PROTOCOL_SEC_SECURITY_LEVEL (C++ enumerator), 1774
protocomm_security::set (C++ function), 1773
protocomm_security_t (C++ type), 1773
protocomm_set_security (C++ function), 1770
protocomm_set_version (C++ function), 1771

987

Index

phy_802_3_t::parent (C++ member), 987
phy_802_3_t::reset_gpio_num (C++ member), 987
phy_802_3_t::reset_timeout_ms (C++ member), 987
phy_init_param_set (C++ function), 2539
phy_wifi_enable_set (C++ function), 2539
PIN_LEN (C macro), 945
protocomm_add_endpoint (C++ function), 1768
protocomm_ble_config (C++ struct), 1776
protocomm_ble_config::ble_link_encryption (C++ member), 1777
protocomm_ble_config::ble_sm_sc (C++ member), 1777
protocomm_ble_config::device_name (C++ member), 1777
protocomm_ble_config::manufacturer_data (C++ member), 1777
protocomm_ble_config::manufacturer_data_len (C++ member), 1777
protocomm_ble_config::nu_lookup (C++ member), 1777
protocomm_ble_config::nu_lookup_count (C++ member), 1777
protocomm_ble_config::service_uuid (C++ member), 1777
protocomm_ble_config_t (C++ type), 1777
protocomm_ble_name_uuid_t (C++ type), 1777
protocomm_ble_start (C++ function), 1776
protocomm_ble_stop (C++ function), 1776
protocomm_close_session (C++ function), 1769
protocomm_delete (C++ function), 1768
protocomm_http_server_config_t (C++ struct), 1775
protocomm_http_server_config_t::port (C++ member), 1775
protocomm_http_server_config_t::stack_size (C++ member), 1775
protocomm_http_server_config_t::task_priority (C++ member), 1775
protocomm_httpd_stop (C++ function), 1774
protocomm_new (C++ function), 1768
protocomm_open_session (C++ function), 1769
protocomm_remove_endpoint (C++ function), 1769
protocomm_reg_handle (C++ function), 1770
protocomm_reg_handler_t (C++ type), 1771
protocomm_security (C++ struct), 1772
protocomm_security1_params (C++ struct), 1772
protocomm_security1_params::data (C++ member), 1772
protocomm_security1_params::len (C++ member), 1772
protocomm_security2_params (C++ struct), 1772
protocomm_security2_params::salt (C++ member), 1772
protocomm_security2_params::salt_len (C++ member), 1772
protocomm_security2_params::verifier (C++ member), 1772
protocomm_security2_params::verifier_len (C++ member), 1772
protocomm_security2_params_t (C++ type), 1773
protocomm_security::cleanup (C++ member), 1773
protocomm_security::close_transport_session (C++ member), 1773
protocomm_security::decrypt (C++ member), 1773
protocomm_security::encrypt (C++ member), 1773
protocomm_security::init (C++ member), 1773
protocomm_security::new_transport_session (C++ member), 1773
protocomm_security::security_reg_handler (C++ member), 1773
protocomm_security::ver (C++ member), 1773
protocomm_security_handler_t (C++ type), 1773
protocomm_security_pop_t (C++ type), 1773
protocomm_security_session_event_t (C++ enum), 1774
protocomm_security_session_event_t::PROTOCOL_SEC_ERROR (C++ enumerator), 1774
protocomm_security_session_event_t::PROTOCOL_SEC_SECURITY_LEVEL (C++ enumerator), 1774
protocomm_security::set (C++ function), 1773
protocomm_security_t (C++ type), 1773
protocomm_set_security (C++ function), 1770
protocomm_set_version (C++ function), 1771

Espressif Systems

Submit Document Feedback
protocomm_t (C++ type), 1772
protocomm_transport_ble_event_t::PROTOCOL_STACK_RESET (C++ enumerator), 1778
protocomm_transport_ble_event_t::PROTOCOL_STACK_RESET (C++ enumerator), 1778
protocomm_transport_ble_event_t::PROTOCOL_STACK_RESET (C++ enumerator), 1778
protocomm_unset_security (C++ function), 1771
protocomm_unset_version (C++ function), 1771
PROV_DATA_FLAGS_FLAG (C macro), 578
PROV_DATA_IV_INDEX_FLAG (C macro), 578
psk_hint_key_t (C++ type), 153
psk_key_hint::key (C++ member), 153
psk_key_hint::key (C++ member), 153
psk_key_hint::key_size (C++ member), 153
PENDING_TX_STACK_MIN (C macro), 2205
pvTaskGetThreadLocalStoragePointer (C++ function), 1987
pvTimerGetTimerID (C++ function), 2040
pxTaskGetStackStart (C++ function), 1986
Q
QueueHandle_t (C++ type), 2022
QueueSetHandle_t (C++ type), 2022
QueueSetMemberHandle_t (C++ type), 2022
R
R0 (C macro), 2259
R1 (C macro), 2259
R2 (C macro), 2259
R3 (C macro), 2259
RD_REG_PERIPH_RTC_CNTL (C macro), 2260
RD_REG_PERIPH_RTC_CNTL (C macro), 2260
RD_REG_PERIPH_RTC_CNTL (C macro), 2260
RD_REG_PERIPH_SENS (C macro), 2260
RingbufferType_t (C++ enum), 2098
RingbufferType_t::RINGBUF_TYPE_ALLOW_SPLIT (C++ enumerator), 2098
RingbufferType_t::RINGBUF_TYPE_BYTEBUF (C++ enumerator), 2098
RingbufferType_t::RINGBUF_TYPE_MAX (C++ enumerator), 2099
RingbufferType_t::RINGBUF_TYPE_MAX (C++ enumerator), 2098
RingbufferHandle_t (C++ type), 2098
rmt_apply_carrier (C++ function), 1288
rmt_bytes_encoder_config_t (C++ struct), 1291
rmt_bytes_encoder_config_t::msb_first (C++ member), 1291
rmt_carrier_config_t (C++ struct), 1289
rmt_carrier_config_t::flags (C++ member), 1289
rmt_carrier_config_t::flags (C++ member), 1289
rmt_carrier_config_t::flags (C++ member), 1289
rmt_carrier_config_t::frequency_hz (C++ member), 1289
rmt_carrier_config_t::frequency_hz (C++ member), 1289
rmt_carrier_config_t::frequency_hz (C++ member), 1289
rmt_channel_handle_t (C++ type), 1292
rmt_clock_source_t (C++ type), 1294
rmt_copy_encoder_config_t (C++ struct), 1291
rmt_del_channel (C++ function), 1288
rmt_del_encoder (C++ function), 1290
rmt_del_sync_manager (C++ function), 1283
rmt_disable (C++ function), 1289
rmt_enable (C++ function), 1288
rmt_encode_state_t (C++ enum), 1291
rmt_encode_state_t::RMT_ENCODING_COMPLETE (C++ enumerator), 1292
rmt_encode_state_t::RMT_ENCODING_MEM_FULL (C++ enumerator), 1292
rmt_encode_state_t::RMT_ENCODING_RESET (C++ enumerator), 1292
rmt_encoder_handle_t (C++ type), 1292
rmt_encoder_network (C++ function), 1290
rmt_encoder_t (C++ struct), 1290
rmt_encoder_t::del (C++ member), 1291
rmt_encoder_t::encode (C++ function), 1290
rmt_encoder_t::reset (C++ member), 1291
rmt_new_bytes_encoder (C++ function), 1289
rmt_new_copy_encoder (C++ function), 1290
rmt_new_tx_channel (C++ function), 1286
rmt_new_sync_manager (C++ function), 1283
rmt_new_tx_channel (C++ function), 1281
rmt_receive (C++ function), 1286
rmt_receive_config_t (C++ struct), 1288
rmt_receive_config_t::signal_range_max_ns (C++ member), 1288
rmt_receive_config_t::signal_range_max_ns (C++ member), 1288
rmt_rx_channel_config_t (C++ struct), 1287
rmt_rx_channel_config_t::clk_src (C++ member), 1287
rmt_rx_channel_config_t::flags (C++ member), 1287
rmt_rx_channel_config_t::flags (C++ member), 1287
rmt_rx_channel_config_t::intr_priority (C++ member), 1287
rmt_rx_channel_config_t::invert_in (C++ member), 1287
rmt_rx_channel_config_t::io_loop_back (C++ member), 1287

Espressif Systems 2924 Release v5.1.2
Submit Document Feedback
Espressif Systems

Submit Document Feedback
sdmmc_can_trim (C++ function), 1847
sdmmc_card_init (C++ function), 1846
sdmmc_card_print_info (C++ function), 1846
sdmmc_card_t (C++ struct), 1855
sdmmc_card_t::cid (C++ member), 1855
sdmmc_card_t::csd (C++ member), 1855
sdmmc_card_t::ext_csd (C++ member), 1855
sdmmc_card_t::host (C++ member), 1855
sdmmc_card_t::is_ddr (C++ member), 1856
sdmmc_card_t::is_mem (C++ member), 1856
sdmmc_card_t::is_mmc (C++ member), 1856
sdmmc_card_t::is_sdio (C++ member), 1856
sdmmc_card_t::log_bus_width (C++ member), 1856
sdmmc_card_t::max_freq_khz (C++ member), 1855
sdmmc_card_t::num_io_functions (C++ member), 1856
sdmmc_card_t::ocr (C++ member), 1855
sdmmc_card_t::raw_cid (C++ member), 1855
sdmmc_card_t::rca (C++ member), 1855
sdmmc_card_t::real_freq_khz (C++ member), 1856
sdmmc_card_t::reserved (C++ member), 1856
sdmmc_card_t::sr (C++ member), 1855
sdmmc_card_t::ssr (C++ member), 1855
sdmmc_cid_t (C++ struct), 1851
sdmmc_cid_t::date (C++ member), 1851
sdmmc_cid_t::fig_id (C++ member), 1851
sdmmc_cid_t::hid (C++ member), 1851
sdmmc_cid_t::oem_id (C++ member), 1851
sdmmc_cid_t::revision (C++ member), 1851
sdmmc_card_t::serial (C++ member), 1851
sdmmc_command_t (C++ struct), 1853
sdmmc_command_t::arg (C++ member), 1853
sdmmc_command_t::blklen (C++ member), 1853
sdmmc_command_t::data (C++ member), 1853
sdmmc_command_t::datalen (C++ member), 1853
sdmmc_command_t::error (C++ member), 1853
sdmmc_command_t::flags (C++ member), 1853
sdmmc_command_t::opcode (C++ member), 1853
sdmmc_command_t::response (C++ member), 1853
sdmmc_command_t::timeout_ms (C++ member), 1854
sdmmc_csd_t (C++ struct), 1850
sdmmc_csd_t::capacity (C++ member), 1851
sdmmc_csd_t::card_command_class (C++ member), 1851
sdmmc_csd_t::csdver (C++ member), 1851
sdmmc_csd_t::mmcver (C++ member), 1851
sdmmc_csd_t::read_block_len (C++ member), 1851
sdmmc_csd_t::sector_size (C++ member), 1851
sdmmc_csd_t::tr_speed (C++ member), 1851
sdmmc_erase_arg_t (C++ enum), 1857
sdmmc_erase_arg_t::SDMMC_DISCARD_ARG (C++ enumerator), 1857
sdmmc_erase_arg_t::SDMMC_ERASE_ARG (C++ enumerator), 1857
sdmmc_erase_sectors (C++ function), 1846
sdmmc_ext_csd_t (C++ struct), 1852
sdmmc_ext_csd_t::erase_mem_state (C++ member), 1853
sdmmc_ext_csd_t::power_class (C++ member), 1853
sdmmc_ext_csd_t::rev (C++ member), 1853
sdmmc_ext_csd_t::sec_feature (C++ member), 1853
SDMMC_FREQ_26M (C macro), 1857
SDMMC_FREQ_52M (C macro), 1857
SDMMC_FREQ_DEFAULT (C macro), 1856
SDMMC_FREQ_HIGHSPEED (C macro), 1856
SDMMC_FREQ_PROBING (C macro), 1857
sdmmc_full_erase (C++ function), 1847
sdmmc_get_status (C++ function), 1846
SDMMC_HOST_DEFAULT (C macro), 1303
sdmmc_host_deinit (C++ function), 1302
sdmmc_host_do_transaction (C++ function), 1301
SDMMC_HOST_FLAG_1BIT (C macro), 1856
SDMMC_HOST_FLAG_4BIT (C macro), 1856
SDMMC_HOST_FLAG_8BIT (C macro), 1856
SDMMC_HOST_FLAG_DDR (C macro), 1856
SDMMC_HOST_FLAG_DEINIT_ARG (C macro), 1856
SDMMC_HOST_FLAG_SPI (C macro), 1856
sdmmc_host_get_real_freq (C++ function), 1302
sdmmc_host_get_slot_width (C++ function), 1300
sdmmc_host_init (C++ function), 1299
sdmmc_host_init_slot (C++ function), 1299
sdmmc_host_io_int_enable (C++ function), 1301
sdmmc_host_io_int_wait (C++ function), 1301
sdmmc_host_set_bus_ddr_mode (C++ function), 1300
sdmmc_host_set_bus_width (C++ function), 1300
sdmmc_host_set_card_clk (C++ function), 1300
sdmmc_host_set_card_clk_always_on (C++ function), 1301
SDMMC_HOST_SLOT_0 (C macro), 1303
SDMMC_HOST_SLOT_1 (C macro), 1303
sdmmc_host_t (C++ struct), 1854
sdmmc_host_t::command_timeout_ms (C++ member), 1855
sdmmc_host_t::deinit (C++ member), 1854
sdmmc_host_t::deinit_p (C++ member), 1854
sdmmc_host_t::do_transaction (C++ member), 1854
Index

sdmmc_host_t::flags (C++ member), 1854
sdmmc_host_t::get_bus_width (C++ member), 1854
sdmmc_host_t::get_real_freq (C++ member), 1855
sdmmc_host_t::init (C++ member), 1854
sdmmc_host_t::io_int_enable (C++ member), 1855
sdmmc_host_t::io_int_wait (C++ member), 1855
sdmmc_host_t::io_voltage (C++ member), 1854
sdmmc_host_t::max_freq_khz (C++ member), 1854
sdmmc_host_t::set_bus_addr_mode (C++ member), 1854
sdmmc_host_t::set_bus_width (C++ member), 1854
sdmmc_host_t::set_card_clk (C++ member), 1854
sdmmc_host_t::set_cclk_always_on (C++ member), 1854
sdmmc_host_t::slot (C++ member), 1854
dsmmc_io_enable_int (C++ function), 1849
dsmmc_io_enable_int (C++ function), 1850
sdmmc_io_print_cis_info (C++ function), 1850
sdmmc_io_read_blocks (C++ function), 1849
sdmmc_io_read_byte (C++ function), 1848
sdmmc_io_read_bytes (C++ function), 1848
sdmmc_io_read_bytes (C++ function), 1849
sdmmc_io_write_blocks (C++ function), 1849
sdmmc_io_write_byte (C++ function), 1848
sdmmc_io_write_bytes (C++ function), 1848
sdmmc_mmc_can_sanitize (C++ function), 1847
sdmmc_mmc_initi (C++ function), 1847
dsmmc_read_sectors (C++ function), 1846
dsmmc_response_t (C++ type), 1857
sdmmc_ssr_t (C++ struct), 1851
sdmmc_ssr_t::bus_width (C++ member), 1852
sdmmc_ssr_t::erase_mem_state (C++ member), 1852
sdmmc_ssr_t::reserved (C++ member), 1852
sdmmc_ssr_t::reserved (C++ member), 1852
sdmmc_ssr_t::rsvd_mnf (C++ member), 1852
sdmmc_ssr_t::sd_spec (C++ member), 1852
SDMMC_SLOT_CONFIG_DEFAULT (C macro), 1303
dsmmc_slot_config_t (C++ struct), 1302
sdmmc_slot_config_t::cd (C++ member), 1302
sdmmc_slot_config_t::flags (C++ member), 1302
sdmmc_slot_config_t::gpio_cd (C++ member), 1302
sdmmc_slot_config_t::gpio_wp (C++ member), 1302
sdmmc_slot_config_t::width (C++ member), 1302
sdmmc_slot_config_t::wp (C++ member), 1302
SDMMC_SLOT_FLAG_INTERNAL_PULLUP (C macro), 1303
SDMMC_SLOT_NO_CD (C macro), 1303
SDMMC_SLOT_NO_WP (C macro), 1303
SDMMC_SLOT_WIDTH_DEFAULT (C macro), 1303
sdmmc_ssr_t (C++ struct), 1852
sdmmc_ssr_t::alloc_unit_kb (C++ member), 1852
sdmmc_ssr_t::cur_bus_width (C++ member), 1852
sdmmc_ssr_t::discard_support (C++ member), 1852
sdmmc_ssr_t::erase_offset (C++ member), 1852
sdmmc_ssr_t::erase_size_au (C++ member), 1852
sdmmc_ssr_t::erase_timeout (C++ member), 1852
sdmmc_ssr_t::fule_support (C++ member), 1852
sdmmc_ssr_t::reserved (C++ member), 1852
sdmmc_switch_func_rsp_t::data (C++ member), 1853
SDP_OFF_SUPPORTED_FORMATS_MAX_LENGTH (C macro), 520
SDSPI_DEFAULT_DMA (C macro), 1308
SDSPI_DEFAULT_HOST (C macro), 1308
sdspi_dev_handle_t (C++ type), 1308
SDSPI устройство CONFIG_DEFAULT (C macro), 1308
sdspi_device_config_t (C++ struct), 1307
sdspi_device_config_t::gpio_cd (C++ member), 1308
sdspi_device_config_t::gpio_cs (C++ member), 1308
sdspi_device_config_t::gpio_int (C++ member), 1308
sdspi_device_config_t::gpio_wp (C++ member), 1308
sdspi_device_config_t::host_id (C++ member), 1308
SDSPI_HOST_DEFAULT (C macro), 1308
sdspi_host_deinit (C++ function), 1307
sdspi_host_do_transaction (C++ function), 1306
sdspi_host_get_real_freq (C++ function), 1307
sdspi_host_init (C++ function), 1305
sdspi_host_init_device (C++ function), 1306
sdspi_host_io_int_enable (C++ function), 1307
sdspi_host_io_int_wait (C++ function), 1307
sdspi_host_remove_device (C++ function), 1306
sdspi_host_set_card_clk (C++ function), 1307
Espressif Systems 2928 Release v5.1.2
Submit Document Feedback
index

SOC_AES_SUPPORTED (C macro), 2222
SOC_APLL_MAX_HZ (C macro), 2230
SOC_APLL_MIN_HZ (C macro), 2230
SOC_APLL_MULTIPLIER_OUT_MAX_HZ (C macro), 2230
SOC_APLL_MULTIPLIER_OUT_MIN_HZ (C macro), 2230
SOC_BLE_DEVICE_PRIVACY_SUPPORTED (C macro), 2231
SOC_BLE_MESH_SUPPORTED (C macro), 2231
SOC_BLE_SUPPORTED (C macro), 2231
SOC_BLUFI_SUPPORTED (C macro), 2231
SOC_BOD_SUPPORTED (C macro), 2222
SOC_BT_CLASSIC_SUPPORTED (C macro), 2231
SOC_BT_SUPPORTED (C macro), 2221
SOC_CAPS_ECO_VER_MAX (C macro), 2221
SOC_CCOMP_TIMER_SUPPORTED (C macro), 2221
SOC_CLK_APLL_SUPPORTED (C macro), 2230
SOC_CLK_RC_FAST_D256_FREQ_APPROX (C macro), 1057
SOC_CLK_RC_FAST_D256_SUPPORTED (C macro), 2230
SOC_CLK_RC_FAST_FREQ_APPROX (C macro), 1057
SOC_CLK_RC_FAST_SUPPORT_CALIBRATION (C macro), 2230
SOC_CLK_XTAL32K_FREQ_APPROX (C macro), 1057
SOC_CLK_XTAL32K_SUPPORTED (C macro), 2230
SOC_CONFIGURABLE_VDDSDIO_SUPPORTED (C macro), 2230
SOC_CPU_BREAKPOINTS_NUM (C macro), 2223
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_APLL (C macro), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_APLL (C++ enumerator), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_INV (C++ enumerator), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_INV (C++ enumerator), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_PLL (C++ enumerator), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_PLL (C++ enumerator), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_RC (C++ enumerator), 1059
soc_cpu_clk_src_t::SOC_CPU_CLK_SRC_XTAL (C++ enumerator), 1059
SOC_CPU_CORES_NUM (C macro), 2223
SOC_CPU_HAS_FPU (C macro), 2223
SOC_CPU_INTR_NUM (C macro), 2223
SOC_CPU_WATCHPOINT_SIZE (C macro), 2224
SOC_CPU_WATCHPOINTS_NUM (C macro), 2223
SOC_DAC_CHAN_NUM (C macro), 2224
SOC_DAC_COSINE_CLKS (C macro), 1058
SOC_DAC_DIGI_CLKS (C macro), 1058
SOC_DAC_DMA_16BIT_ALIGN (C macro), 2224
SOC_DAC_RESOLUTION (C macro), 2224
SOC_DAC_SUPPORTED (C macro), 2221
SOC_DPORT_WORKAROUND (C macro), 2222
SOC_DPORT_WORKAROUND_DIS_INTERRUPT_LVL (C macro), 2222
SOC_EFUSE_SECURE_BOOT_KEY_DIGESTS (C macro), 2229
SOC_EMAC_SUPPORTED (C macro), 2221
SOC_FLASH_ENC_SUPPORTED (C macro), 2222
SOC_FLASH_ENCRYPTED_XTS_AES_BLOCK_MAX (C macro), 2229
SOC_GPIO_PIN_COUNT (C macro), 2224
SOC_GPIO_PORT (C macro), 2224
SOC_GPIO_VALID_DIGITAL_IO_PAD_MASK (C macro), 2224
SOC_GPIO_VALID_GPIO_MASK (C macro), 2224
SOC_GPIO_VALID_OUTPUT_GPIO_MASK (C macro), 2224
SOC_GSPI_SUPPORTED (C macro), 2222
SOC_GTIMER_CLKS (C macro), 1057
SOC_GTIMER_SUPPORTED (C macro), 2221
SOC_I2C_CLKS (C macro), 1058
SOC_I2C_CMD_REG_NUM (C macro), 2224
SOC_I2C_FIFO_LEN (C macro), 2224
SOC_I2C_NUM (C macro), 2224
SOC_I2C_SUPPORT_APB (C macro), 2224
SOC_I2C_SUPPORT_SLAVE (C macro), 2224
SOC_I2C_SUPPORTED (C macro), 2222
SOC_I2S_CLKS (C macro), 1057
SOC_I2S_HW_VERSION_1 (C macro), 2224
SOC_I2S_LCD_I80_VARIANT (C macro), 2225
SOC_I2S_NUM (C macro), 2224
SOC_I2S_PDM_MAX_RX_LINES (C macro), 2225
SOC_I2S_PDM_MAX_TX_LINES (C macro), 2224
SOC_I2S_SUPPORTED (C macro), 2222
SOC_I2S_SUPPORTS_ADC (C macro), 2225
SOC_I2S_SUPPORTS_ADC_DAC (C macro), 2225
SOC_I2S_SUPPORTS_APLL (C macro), 2224
SOC_I2S_SUPPORTS_DAC (C macro), 2225
SOC_IDCACHE_PER_CORE (C macro), 2223
SOC_LCD_CLKS (C macro), 1057
SOC_LCD_I80_BUS_WIDTH (C macro), 2225
SOC_LCD_I80_BUSES (C macro), 2225
SOC_LCD_I80_SUPPORTED (C macro), 2225
SOC_LEDC_CHANNEL_NUM (C macro), 2225
SOC_LEDC_CLKS (C macro), 1058
SOC_LEDC_HAS_TIMER_SPECIFIC_MUX (C macro), 2225
SOC_LEDC_SUPPORT_APB_CLOCK (C macro), 2225
SOC_LEDC_SUPPORT_HS_MODE (C macro), 2225
SOC_LEDC_SUPPORT_REF_TICK (C macro), 2225
SOC_LEDC_SUPPORTED (C macro), 2222
SOC_LEDC TIMER_BIT_WIDTH (C macro), 2225
Index

soc_module_clk_t::SOC_MOD_CLK_XTAL32K (C++ enumerator), 1060
soc_module_clk_t::SOC_MOD_CLK_XTAL (C++ enumerator), 1060
soc_module_clk_t::SOC_MOD_CLK_RTC_SLOW (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_RTC_FAST (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_REF_TICK (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_RC_FAST_D256 (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_RC_FAST (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_PLL_F160M (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_INVALID (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_CPU (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_APB (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_APLL (C macro), 2226
soc_module_clk_t::SOC_MOD_CLK_APB (C macro), 2226

SOC_MMU_PERIPH_NUM (C macro), 2226
SOC_MMU_LINEAR_ADDRESS_REGION_NUM (C macro), 2226
SOC_MMU_SRC_FREQ_20M_SUPPORTED (C macro), 2226
SOC_MMU_SRC_FREQ_26M_SUPPORTED (C macro), 2226
SOC_MMU_SRC_FREQ_40M_SUPPORTED (C macro), 2226

soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_APB (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_APB (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_APB (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1065
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_APB (C++ enum), 1065

soc_periph_adc_rtc_clk_src_t::ADC_RTC_CLK_SRC_RC_FAST (C++ enum), 1065
soc_periph_adc_rtc_clk_src_t::ADC_RTC_CLK_SRC_DEFAULT (C++ enum), 1065
soc_periph_adc_rtc_clk_src_t::ADC_RTC_CLK_SRC_RC_FAST (C++ enum), 1065
soc_periph_adc_rtc_clk_src_t::ADC_RTC_CLK_SRC_DEFAULT (C++ enum), 1065

soc_periph_dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_DEFAULT (C++ enum), 1064

soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_APB (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_APB (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_APB (C++ enum), 1064

soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_APB (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_APB (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C++ enum), 1064
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_APB (C++ enum), 1064

soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_DEFAULT (C++ enum), 1061
soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_APB (C++ enum), 1061
soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_DEFAULT (C++ enum), 1061
soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_APB (C++ enum), 1061
soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_DEFAULT (C++ enum), 1061
soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_APB (C++ enum), 1061

soc_periph_i2s_clk_src_t::I2S_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_i2s_clk_src_t::I2S_CLK_SRC_APB (C macro), 1057

soc_periph_i2c_clk_src_t::I2C_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_i2c_clk_src_t::I2C_CLK_SRC_APB (C macro), 1057

soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_gptimer_clk_src_t::GPTIMER_CLK_SRC_APB (C macro), 1057

soc_periph_dac_cosine_clk_src_t::DAC_COSINE_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_dac_digi_clk_src_t::DAC_DIGI_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_adc_rtc_clk_src_t::ADC_RTC_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_adc_rtc_clk_src_t::ADC_RTC_CLK_SRC_APB (C macro), 1057
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_DEFAULT (C macro), 1057
soc_periph_adc_digi_clk_src_t::ADC_DIGI_CLK_SRC_APB (C macro), 1057
<table>
<thead>
<tr>
<th>Function/Member</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>spi_flash_host_driver_t</td>
<td>1347</td>
</tr>
<tr>
<td>spi_flash_host_inst_t</td>
<td>1346</td>
</tr>
<tr>
<td>spi_flash_host_inst_t::driver</td>
<td>1346</td>
</tr>
<tr>
<td>spi_flash_mmap</td>
<td>1342</td>
</tr>
<tr>
<td>spi_flash_mmap_dump</td>
<td>1343</td>
</tr>
<tr>
<td>spi_flash_mmap_get_free_pages</td>
<td>1343</td>
</tr>
<tr>
<td>spi_flash_mmap_handle_t</td>
<td>1344</td>
</tr>
<tr>
<td>spi_flash_mmap_memory_t</td>
<td>1344</td>
</tr>
<tr>
<td>spi_flash_mmap_memory_t::SPI_FLASH_MMAP_FLAG</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_mmap_pages</td>
<td>1342</td>
</tr>
<tr>
<td>SPI_FLASH_MMU_PAGE_SIZE</td>
<td>1344</td>
</tr>
<tr>
<td>SPI_FLASH_OPI_FLAG</td>
<td>1348</td>
</tr>
<tr>
<td>SPI_FLASH_OS_IS_ERASING_STATUS_FLAG</td>
<td>1342</td>
</tr>
<tr>
<td>spi_flash_phys2cache</td>
<td>1343</td>
</tr>
<tr>
<td>SPI_FLASH_READ_MODE_MIN</td>
<td>1349</td>
</tr>
<tr>
<td>SPI_FLASH_SEC_SIZE</td>
<td>1344</td>
</tr>
<tr>
<td>spi_flash_sus_cmd_conf</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_sus_cmd_conf::cmd_rdsr</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_sus_cmd_conf::res_cmd</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_sus_cmd_conf::reserved</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_sus_cmd_conf::sus_cmd</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_sus_cmd_conf::sus_mask</td>
<td>1345</td>
</tr>
<tr>
<td>SPI_FLASH_TRANS_FLAG_BYTE_SWAP</td>
<td>1348</td>
</tr>
<tr>
<td>SPI_FLASH_TRANS_FLAG_BYTE_SWAP</td>
<td>1348</td>
</tr>
<tr>
<td>spi_flash_trans_t</td>
<td>1344</td>
</tr>
<tr>
<td>spi_flash_trans_t::mosi_data</td>
<td>1345</td>
</tr>
<tr>
<td>spi_flash_trans_t::mosi_len</td>
<td>1344</td>
</tr>
<tr>
<td>SPI_FLASH_YIELD_REQ_SUSPEND</td>
<td>1344</td>
</tr>
<tr>
<td>SPI_FLASH_YIELD_REQ_YIELD</td>
<td>1341</td>
</tr>
<tr>
<td>SPI_FLASH_YIELD_STA_RESUME</td>
<td>1342</td>
</tr>
<tr>
<td>spi_get_actual_clock</td>
<td>1373</td>
</tr>
<tr>
<td>spi_get_freq_limit</td>
<td>1374</td>
</tr>
<tr>
<td>spi_get_timing</td>
<td>1373</td>
</tr>
<tr>
<td>spi_host_device_t::SPI1_HOST</td>
<td>1364</td>
</tr>
<tr>
<td>spi_host_device_t::SPI2_HOST</td>
<td>1364</td>
</tr>
<tr>
<td>spi_host_device_t::SPI3_HOST</td>
<td>1364</td>
</tr>
<tr>
<td>spi_host_device_t::SPI_HOST_MAX</td>
<td>1364</td>
</tr>
<tr>
<td>spi_line_mode_t</td>
<td>1364</td>
</tr>
<tr>
<td>spi_line_mode_t::addr_lines</td>
<td>1364</td>
</tr>
<tr>
<td>spi_line_mode_t::cmd_lines</td>
<td>1364</td>
</tr>
<tr>
<td>spi_line_mode_t::data_lines</td>
<td>1364</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_10M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_11M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_13M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_16M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_20M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_26M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_40M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_80M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MASTER_FREQ_8M</td>
<td>1377</td>
</tr>
<tr>
<td>SPI_MAX_DMA_LEN</td>
<td>1368</td>
</tr>
<tr>
<td>SPI_SLAVE_BIT_LSBFIRST</td>
<td>1386</td>
</tr>
<tr>
<td>spi_slave_free</td>
<td>1384</td>
</tr>
<tr>
<td>spi_slave_get_trans_result</td>
<td>1384</td>
</tr>
<tr>
<td>spi_slave_initialize</td>
<td>1383</td>
</tr>
<tr>
<td>spi_slave_interface_config_t</td>
<td>1385</td>
</tr>
<tr>
<td>spi_slave_interface_config_t::flags</td>
<td>1385</td>
</tr>
<tr>
<td>spi_slave_interface_config_t::mode</td>
<td>1385</td>
</tr>
<tr>
<td>spi_slave_interface_config_t::post_setup_cb</td>
<td>1385</td>
</tr>
<tr>
<td>spi_slave_interface_config_t::post_trans_cb</td>
<td>1385</td>
</tr>
<tr>
<td>spi_slave_interface_config_t::queue_size</td>
<td>1385</td>
</tr>
<tr>
<td>spi_slave_interface_config_t::spics_io_num</td>
<td>1385</td>
</tr>
</tbody>
</table>
SPI_SLAVE_NO_RETURN_RESULT (C macro), 1386
spi_slave_queue_trans (C++ function), 1384
SPI_SLAVE_RXBIT_LSBFIRST (C macro), 1386
spi_slave_transaction_t (C++ struct), 1385
spi_slave_transaction_t::length (C++ member), 1386
spi_slave_transaction_t::rx_buffer (C++ member), 1386
spi_slave_transaction_t::trans_len (C++ member), 1386
spi_slave_transaction_t::tx_buffer (C++ member), 1386
spi_slave_transaction_t::user (C++ member), 1386
spi_slave_transmit (C++ function), 1384
SPI_SLAVE_TXBIT_LSBFIRST (C macro), 1386
SPI_SWAP_DATA_RX (C macro), 1368
SPI_SWAP_DATA_TX (C macro), 1368
SPI_TRANS_CS_KEEP_ACTIVE (C macro), 1378
SPI_TRANS_MODE_DIO (C macro), 1378
SPI_TRANS_MODE_DIOQIO_ADDR (C macro), 1378
SPI_TRANS_MODE_DIOQIO_CMD (C macro), 1378
SPI_TRANS_MODE_OCT (C macro), 1378
SPI_TRANS_MODE_OCTAL (C macro), 1369
SPI_TRANS_MODE_QUAD (C macro), 1369
SPI_TRANS_MODE_SCLK (C macro), 1369
SPI_TRANS_MODE_SLAVE (C macro), 1368
SPI_TRANS_MODE_WPHD (C macro), 1369
SPI_TRANS_VARIABLE_DUMMY (C macro), 1378
spi_transaction_ext_t (C++ struct), 1376
spi_transaction_ext_t::address_bits (C++ member), 1376
spi_transaction_ext_t::base (C++ member), 1376
spi_transaction_ext_t::command_bits (C++ member), 1376
spi_transaction_ext_t::dummy_bits (C++ member), 1376
spi_transaction_t (C++ struct), 1375
spi_transaction_t::addr (C++ member), 1376
spi_transaction_t::cmd (C++ member), 1375
spi_transaction_t::flags (C++ member), 1375
spi_transaction_t::length (C++ member), 1376
spi_transaction_t::rx_buffer (C++ member), 1376
spi_transaction_t::rx_data (C++ member), 1376
spi_transaction_t::rxlength (C++ member), 1376
spi_transaction_t::tx_buffer (C++ member), 1376
spi_transaction_t::tx_data (C++ member), 1376
spi_transaction_t::user (C++ member), 1376

T

taskDISABLE_INTERRUPTS (C macro), 2000
taskENABLE_INTERRUPTS (C macro), 2000
taskENTER_CRITICAL (C macro), 1999
taskENTER_CRITICAL_FROM_ISR (C macro), 1999
taskENTER_CRITICAL_ISR (C macro), 2000
taskEXIT_CRITICAL (C macro), 2000
taskEXIT_CRITICAL_FROM_ISR (C macro), 2000
taskEXIT_CRITICAL_ISR (C macro), 2000
TaskHandle_t (C++ type), 2002
TaskHookFunction_t (C++ type), 2002
taskSCHEDULER_NOT_STARTED (C macro), 2000
taskSCHEDULER_RUNNING (C macro), 2000
taskSCHEDULER_SUSPENDED (C macro), 2000
taskYIELD (C macro), 1999
TimerCallbackFunction_t (C++ type), 2055
TimerHandle_t (C++ type), 2055
tls_keep_alive_cfg (C++ struct), 153
tls_keep_alive_cfg::keep_alive_count (C++ member), 153
tls_keep_alive_cfg::keep_alive_enable (C++ member), 153
tls_keep_alive_cfg::keep_alive_idle
(C++ member), 153
tls_keep_alive_cfg::keep_alive_interval
(C++ member), 153
tls_keep_alive_cfg_t (C++ type), 156
TlsDeleteCallbackFunction_t (C++ type), 2002
tmrCOMMAND_CHANGE_PERIOD (C macro), 2045
tmrCOMMAND_CHANGE_PERIOD_FROM_ISR (C macro), 2045
tmrCOMMAND_DELETE (C macro), 2045
tmrCOMMAND_EXECUTE_CALLBACK (C macro), 2045
tmrCOMMAND_EXECUTE_CALLBACK_FROM_ISR (C macro), 2045
tmrCOMMAND_RESET (C macro), 2045
tmrCOMMAND_RESET_FROM_ISR (C macro), 2045
tmrFIRST_FROM_ISR_COMMAND (C macro), 2045
topic_t (C++ struct), 141
topic_t::filter (C++ member), 141
topic_t::qos (C++ member), 141
touch_cnt_slope_t::TOUCH_PAD_SLOPE_0
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_1
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_2
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_3
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_4
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_5
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_6
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_7
(C++ enumerator), 1403
touch_cnt_slope_t::TOUCH_PAD_SLOPE_MAX
(C++ enumerator), 1403
TOUCH_FSM_MODE_DEFAULT (C macro), 1400
touch_fsm_mode_t (C++ enum), 1403
touch_fsm_mode_t::TOUCH_FSM_MODE_MAX
(C++ enumerator), 1404
touch_fsm_mode_t::TOUCH_FSM_MODE_SW
(C++ enumerator), 1404
touch_fsm_mode_t::TOUCH_FSM_MODE_TIMER
(C++ enumerator), 1403
touch_high_volt_t (C++ enum), 1401
touch_high_volt_t::TOUCH_HVOLT_2V4
(C++ enumerator), 1401
touch_high_volt_t::TOUCH_HVOLT_2V5
(C++ enumerator), 1401
touch_high_volt_t::TOUCH_HVOLT_2V6
(C++ enumerator), 1401
touch_high_volt_t::TOUCH_HVOLT_2V7
(C++ enumerator), 1402
touch_high_volt_t::TOUCH_HVOLT_KEEP
(C++ enumerator), 1401
touch_high_volt_t::TOUCH_HVOLT_MAX
(C++ enumerator), 1401
touch_low_volt_t (C++ enum), 1402
touch_low_volt_t::TOUCH_LVOLT_0V5
(C++ enumerator), 1402
touch_low_volt_t::TOUCH_LVOLT_0V6
(C++ enumerator), 1402
touch_low_volt_t::TOUCH_LVOLT_0V7
(C++ enumerator), 1402
touch_low_volt_t::TOUCH_LVOLT_0V8
(C++ enumerator), 1402
touch_low_volt_t::TOUCH_LVOLT_KEEP
(C++ enumerator), 1402
TOUCH_PAD_ATTEN_VOLTAGE_THRESHOLD (C macro), 1400
TOUCH_PAD_BIT_MASK_ALL (C macro), 1400
TOUCH_PAD_BIT_MASK_MAX (C macro), 1400
touch_pad_clear_group_mask (C++ function), 1395
touch_pad_clear_status (C++ function), 1398
touch_pad_config (C++ function), 1390
touch_pad_deinit (C++ function), 1396
touch_pad_filter_delete (C++ function), 1396
touch_pad_filter_start (C++ function), 1395
touch_pad_filter_stop (C++ function), 1396
touch_pad_get_cnt_mode (C++ function), 1397
touch_pad_get_filter_period (C++ function), 1395
touch_pad_get_fsm_mode (C++ function), 1398
touch_pad_get_group_mask (C++ function), 1394
touch_pad_get_meas_time (C++ function), 1393
touch_pad_get_measurement_clock_cycles
(C++ function), 1392
touch_pad_get_measurement_interval
(C++ function), 1393
touch_pad_get_status (C++ function), 1398
touch_pad_get_threshold (C++ function), 1393
touch_pad_get_trigger_mode (C++ function), 1394
touch_pad_get_trigger_source (C++ function), 1394
touch_pad_get_voltgage (C++ function), 1397
touch_pad_get_wakeup_status (C++ function), 1398
TOUCH_PAD_GPIO12_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO012_CHANNEL (C macro), 1399

Espressif Systems 2938 Release v5.1.2
Submit Document Feedback
TOUCH_PAD_GPIO4_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO33_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO2_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO15_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO14_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO13_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO12_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO11_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO10_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO9_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO8_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO7_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO6_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO5_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO4_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO3_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO2_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO1_CHANNEL (C macro), 1399
TOUCH_PAD_GPIO0_CHANNEL (C macro), 1399
TOUCH_PAD_MAX (C macro), 1399
TOUCH_PAD_NUM9_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM8_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM7_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM6_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM5_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM4_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM3_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM2_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM1_GPIO_NUM (C macro), 1399
TOUCH_PAD_NUM0_GPIO_NUM (C macro), 1399
TOUCH_PAD_MEASURE_CYCLE_DEFAULT (C macro), 1399
touch_pad_set_trigger_source (C++ function), 1394
touch_pad_set_voltage (C++ function), 1397
TOUCH_PAD_SLEEP_CYCLE_DEFAULT (C macro), 1400
TOUCH_PAD_SLOPE_DEFAULT (C macro), 1400
touch_pad_sw_start (C++ function), 1393
touch_pad_t (C++ enum), 1401
touch_pad_t::TOUCH_PAD_MAX (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM0 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM1 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM2 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM3 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM4 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM5 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM6 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM7 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM8 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM9 (C++ enumerator), 1401
TOUCH_PAD_THRESHOLD_MAX (C macro), 1400
touch_tie_opt_t (C++ enum), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT_MAX (C++ enumerator), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT High (C++ enumerator), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT Low (C++ enumerator), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT_MAX (C++ enumerator), 1403
TOUCH_TRIGGER_MODE_DEFAULT (C macro), 1400
touch_trigger_mode_t (C++ enum), 1404
touch_trigger_mode_t::TOUCH_TRIGGER ABOVE (C++ enumerator), 1404
touch_trigger_mode_t::TOUCH_TRIGGER BELOW (C++ enumerator), 1404
touch_trigger_mode_t::TOUCH_TRIGGER_MAX (C++ enumerator), 1404
TOUCH_TRIGGER_SOURCE_DEFAULT (C macro), 1400
touch_trigger_src_t (C++ enum), 1404
touch_trigger_src_t::TOUCH_TRIGGER SOURCE BOTH (C++ enumerator), 1404
touch_trigger_src_t::TOUCH_TRIGGER SOURCE_MAX (C++ enumerator), 1404
touch_trigger_src_t::TOUCH_TRIGGER SOURCE SET1 (C++ enumerator), 1404
touch_volt_atten_t (C++ enum), 1402
touch_volt_atten_t::TOUCH_HVOLT_ATTEN_0V (C macro), 1400
TOUCH_PAD_IDLE_CH_CONNECT_DEFAULT (C macro), 1400
touch_pad_init (C++ function), 1396
touch_pad_intr_clear (C++ function), 1395
touch_pad_intr_disable (C++ function), 1395
touch_pad_intr_enable (C++ function), 1395
touch_pad_io_init (C++ function), 1397
touch_pad_isr_deregister (C++ function), 1398
touch_pad_isr_register (C++ function), 1392
touch_pad_meas_is_done (C++ function), 1398
TOUCH_PAD_MEASURE_CYCLE_DEFAULT (C macro), 1400
touch_pad_read (C++ function), 1390
touch_pad_read_filtered (C++ function), 1391
touch_pad_read_raw_data (C++ function), 1391
touch_pad_set_cnt_mode (C++ function), 1397
touch_pad_set_filter_period (C++ function), 1395
touch_pad_set_filter_read_cb (C++ function), 1391
touch_pad_set_fsm_mode (C++ function), 1398
touch_pad_set_group_mask (C++ function), 1394
touch_pad_set_meas_time (C++ function), 1393
touch_pad_set_measurement_clock_cycles (C++ function), 1392
touch_pad_set_measurement_interval (C++ function), 1392
touch_pad_set_thresh (C++ function), 1393
touch_pad_set_trigger_mode (C++ function), 1394
TOUCH_PAD_HIGH_VOLTAGE_THRESHOLD (C macro), 1400
touch_pad_set_trigger_mode (C++ function), 1394
TOUCH_PAD_SET_VOLTAGE (C++ function), 1397
TOUCH_PAD_SLEEP_CYCLE_DEFAULT (C macro), 1400
TOUCH_PAD_SLOPE_DEFAULT (C macro), 1400
touch_pad_sw_start (C++ function), 1393
touch_pad_t (C++ enum), 1401
touch_pad_t::TOUCH_PAD_MAX (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM0 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM1 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM2 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM3 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM4 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM5 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM6 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM7 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM8 (C++ enumerator), 1401
touch_pad_t::TOUCH_PAD_NUM9 (C++ enumerator), 1401
TOUCH_PAD_THRESHOLD_MAX (C macro), 1400
touch_tie_opt_t (C++ enum), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT_HIGH (C++ enumerator), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT_LOW (C++ enumerator), 1403
touch_tie_opt_t::TOUCH_PAD_TIE_OPT_MAX (C++ enumerator), 1403
TOUCH_TRIGGER_MODE_DEFAULT (C macro), 1400
touch_trigger_mode_t (C++ enum), 1404
touch_trigger_mode_t::TOUCH_TRIGGER ABOVE (C++ enumerator), 1404
touch_trigger_mode_t::TOUCH_TRIGGER BELOW (C++ enumerator), 1404
touch_trigger_mode_t::TOUCH_TRIGGER_MAX (C++ enumerator), 1404
TOUCH_TRIGGER_SOURCE_DEFAULT (C macro), 1400
touch_trigger_src_t (C++ enum), 1404
touch_trigger_src_t::TOUCH_TRIGGER SOURCE BOTH (C++ enumerator), 1404
touch_trigger_src_t::TOUCH_TRIGGER SOURCE_MAX (C++ enumerator), 1404
touch_trigger_src_t::TOUCH_TRIGGER SOURCE SET1 (C++ enumerator), 1404
touch_volt_atten_t (C++ enum), 1402
touch_volt_atten_t::TOUCH_HVOLT_ATTEN_0V (C macro), 1400
twai_status_info_t::rx_error_counter (C++ member), 1421
uw_status_info_t::tx_error_counter (C++ member), 1421
twai_status_info_t::tx_failed_count (C++ member), 1421
twai_status_info_t::state (C++ member), 1421
twai_status_info_t::tx_error_counter (C++ member), 1421
twai_status_info_t::tx_failed_count (C++ member), 1421
TWAI_STD_ID_MASK (C macro), 1416
twai_stop (C++ function), 1417
twai_timing_config_t::tseg_1 (C++ struct), 1415
twai_timing_config_t::tseg_2 (C++ member), 1415
twai_timing_config_t::clk_src (C++ member), 1415
twai_timing_config_t::quanta_resolution (C++ member), 1415
twai_timing_config_t::sjw (C++ member), 1415
twai_timing_config_t::tseg_2 (C++ member), 1415
twai_transfer (C++ function), 1418

twai_status_info_t::tx_error_counter (C++ member), 1421
twai_status_info_t::tx_failed_count (C++ member), 1421
UART_BITRATE_MAX (C macro), 1440
twai_clear_intr_status (C++ function), 1431
twai_config_t::tseg_1 (C++ struct), 1422
ntwai_config_t::tseg_2 (C++ member), 1422
UART_CONFIG (C struct), 1422
uart_config_t::data_bits (C++ member), 1422
uart_config_t::flow_ctrl (C++ member), 1422
uart_config_t::parity (C++ member), 1422
uart_config_t::rflow_ctrl_thresh (C++ member), 1443
uart_config_t::source_clk (C++ member), 1443
uart_config_t::stop_bits (C++ member), 1442
UART_CTS_GPIO19DIRECT_CHANNEL (C macro), 1446
UART_CTS_GPIO6DIRECT_CHANNEL (C macro), 1447
UART_CTS_GPIO8DIRECT_CHANNEL (C macro), 1447
uart_disable_intr_mask (C++ function), 1431
uart_disable_pattern_det_intr (C++ function), 1435
uart_disable_rx_intr (C++ function), 1431
uart_disable_tx_intr (C++ function), 1432
uart_driver_delete (C++ function), 1428
uart_driver_install (C++ function), 1428
uart_enable_intr_mask (C++ function), 1431
uart_enable_pattern_det_baud_intr (C++ function), 1435
uart_enable_rx_intr (C++ function), 1431
uart_enable_tx_intr (C++ function), 1432
uart_event_t::tseg_1 (C++ struct), 1440
uart_event_t::size (C++ member), 1440
uart_event_t::timeout_flag (C++ member), 1440
uart_event_t::type (C++ member), 1440
uart_event_type_t::UART_BREAK (C++ enumerator), 1441
uart_event_type_t::UART_FRAME_ERR (C++ enumerator), 1441
uart_event_type_t::UART_PARITY_ERR (C++ enumerator), 1441
uart_event_type_t::UART_PATTERN_ERR (C++ enumerator), 1441
uart_event_type_t::UART_STATUS (C++ function), 1429
uart_get_buffered_data_len (C++ function), 1430
uart_get_stop_bits (C++ function), 1429
uart_get_tx_buffer_free_size (C++ function), 1435
uart_enable_pattern_det_baud_intr (C++ function), 1431
uart_enable_pattern_det_intr (C++ function), 1435
uart_enable_rx_intr (C++ function), 1431
uart_enable_tx_intr (C++ function), 1432
uart_event_t::tseg_1 (C++ member), 1415
uart_event_t::tseg_2 (C++ member), 1415
twai_transmit (C++ function), 1418
U
uart_at_cmd_t (C++ struct), 1441
uart_at_cmd_t::char_num (C++ member), 1441
uart_at_cmd_t::cmd_char (C++ member), 1441
uart_at_cmd_t::gap_tout (C++ member), 1442
uart_at_cmd_t::post_idle (C++ member), 1442
uart_at_cmd_t::pre_idle (C++ member), 1442
UART_BITRATE_MAX (C macro), 1440
twai_clear_intr_status (C++ function), 1431
twai_config_t::tseg_1 (C++ struct), 1442
twai_config_t::baud_rate (C++ member), 1442
uart_config_t::data_bits (C++ member), 1422
uart_config_t::flow_ctrl (C++ member), 1422
uart_config_t::parity (C++ member), 1442
uart_config_t::rflow_ctrl_thresh (C++ member), 1443
uart_config_t::source_clk (C++ member), 1443
uart_config_t::stop_bits (C++ member), 1442
UART_CTS_GPIO19DIRECT_CHANNEL (C macro), 1446
UART_CTS_GPIO6DIRECT_CHANNEL (C macro), 1447
UART_CTS_GPIO8DIRECT_CHANNEL (C macro), 1447
uart_disable_intr_mask (C++ function), 1431
uart_disable_pattern_det_intr (C++ function), 1435
uart_disable_rx_intr (C++ function), 1431
uart_disable_tx_intr (C++ function), 1432
uart_driver_delete (C++ function), 1428
uart_driver_install (C++ function), 1428
uart_enable_intr_mask (C++ function), 1431
uart_enable_pattern_det_baud_intr (C++ function), 1435
uart_enable_rx_intr (C++ function), 1431
uart_enable_tx_intr (C++ function), 1432
uart_event_t::tseg_1 (C++ struct), 1440
uart_event_t::size (C++ member), 1440
uart_event_t::timeout_flag (C++ member), 1440
uart_event_t::type (C++ member), 1440
uart_event_type_t::UART_BREAK (C++ enumerator), 1441
uart_event_type_t::UART_FRAME_ERR (C++ enumerator), 1441
uart_event_type_t::UART_PARITY_ERR (C++ enumerator), 1441
uart_event_type_t::UART_STATUS (C++ function), 1429
uart_get_buffered_data_len (C++ function), 1430
uart_get_stop_bits (C++ function), 1429
uart_get_tx_buffer_free_size (C++ function), 1435
Index

ulp_insn::sign (C++ member), 2257
ulp_insn::sleep (C++ member), 2259
ulp_insn::sreg (C++ member), 2256
ulp_insn::st (C++ member), 2256
ulp_insn::sub_opcode (C++ member), 2256
ulp_insn::treg (C++ member), 2257
ulp_insn::tsens (C++ member), 2258
ulp_insn::type (C++ member), 2257
ulp_insn::unused1 (C++ member), 2255
ulp_insn::unused2 (C++ member), 2256
ulp_insn::wait_delay (C++ member), 2258
ulp_insn::wakeup (C++ member), 2259
ulp_insn::wr_reg (C++ member), 2258
ulp_insn_t (C++ type), 2272
ulp_isr_deregister (C++ function), 2270
ulp_isr_register (C++ function), 2270
ulp_load_binary (C++ function), 2271
ulp_process_macros_and_load (C++ function), 2271
ulp_run (C++ function), 2271
ulp_set_wakeup_period (C++ function), 2272
ulp_timer_resume (C++ function), 2273
ulp_timer_stop (C++ function), 2272
ulTaskGenericNotifyTake (C++ function), 1995
ulTaskGenericNotifyValueClear (C++ function), 1997
ulTaskGetIdleRunTimeCounter (C++ function), 1990
ulTaskNotifyTake (C macro), 2002
ulTaskNotifyTakeIndexed (C macro), 2002
ulTaskNotifyValueClear (C macro), 2002
ulTaskNotifyValueClearIndexed (C macro), 2002
uxQueueMessagesWaiting (C++ function), 2007
uxQueueMessagesWaitingFromISR (C++ function), 2009
uxSemaphoreGetCount (C macro), 2036
uxTaskGenericNotifyGiveFromISR (C++ function), 1985
uxTaskGetStackHighWaterMark (C++ function), 1985
uxTaskGetStackHighWaterMark2 (C++ function), 1986
uxTaskGetSystemState (C++ function), 1988
uxTaskPriorityGet (C++ function), 1978
uxTaskPriorityGetFromISR (C++ function), 1979
uxTimerGetReloadMode (C++ function), 2044

v

vApplicationGetIdleTaskMemory (C++ function), 1987
vApplicationGetTimerTaskMemory (C++ function), 2044
vendor_ie_data_t (C++ struct), 904
vendor_ie_data_t::element_id (C++ member), 904
vendor_ie_data_t::length (C++ member), 905
vendor_ie_data_t::payload (C++ member), 905
vendor_ie_data_t::vendor_oui (C++ member), 905
vendor_ie_data_t::vendor_oui_type (C++ member), 905
vEventGroupDelete (C++ function), 2061
vEventGroupDeleteWithCaps (C++ function), 2104
vMessageBufferDelete (C macro), 2078
vMessageBufferDeleteWithCaps (C++ function), 2104
vprintf_like_t (C++ type), 2163
vQueueAddToRegistry (C++ function), 2009
vQueueDelete (C++ function), 2007
vQueueDeleteWithCaps (C++ function), 2102
vQueueUnregisterQueue (C++ function), 2007
vRingbufferDelete (C++ function), 2096
vRingbufferGetInfo (C++ function), 2097
vRingbufferReturnItem (C++ function), 2096
vRingbufferReturnItemFromISR (C++ function), 2096
vSemaphoreCreateBinary (C macro), 2022
vSemaphoreDelete (C macro), 2035
vSemaphoreDeleteWithCaps (C++ function), 2103
vStreamBufferDelete (C++ function), 2068
vStreamBufferDeleteWithCaps (C++ function), 2103
tTaskAllocateMPURegions (C++ function), 1973
tTaskDelay (C++ function), 1977
tTaskDelayUntil (C macro), 2000
tTaskDelete (C++ function), 1976
vTaskDeleteWithCaps (C++ function), 2101
taskEndScheduler (C++ function), 1983
taskGenericNotifyGiveFromISR (C++ function), 1994
taskGetInfo (C++ function), 1979
taskGetRunTimeStats (C++ function), 1990
taskList (C++ function), 1989
taskNotifyGiveFromISR (C macro), 2001
taskNotifyGiveIndexedFromISR (C macro), 2002
taskPrioritySet (C++ function), 1980
taskResume (C++ function), 1981
taskSetApplicationTaskTag (C++ function), 1986
taskSetThreadLocalStoragePointer (C++ function), 1986
taskSetThreadLocalStoragePointerAndDelCallback (C++ function), 1987
taskSetTimeOutState (C++ function), 1997
taskStartScheduler (C++ function), 1982
vTaskSuspend (C++ function), 1981
vTaskSuspendAll (C++ function), 1983
vTimerSetReloadMode (C++ function), 2044
vTimerSetTimerID (C++ function), 2041

W
wifi_action_rx_cb_t (C++ type), 923
wifi_action_tx_req_t (C++ struct), 909
wifi_action_tx_req_t::data (C++ member), 909
wifi_action_tx_req_t::data_len (C++ member), 909
wifi_action_tx_req_t::dest_mac (C++ member), 909
wifi_action_tx_req_t::fx (C++ member), 909
wifi_action_tx_req_t::no_ack (C++ member), 909
wifi_action_tx_req_t::rx_cb (C++ member), 909
wifi_action_tx_req_t::rx_cb (C++ struct), 897
wifi_action_tx_req_t::max (C++ member), 897
wifi_action_tx_req_t::min (C++ member), 897
WIFI_AMPU_RX_ENABLED (C macro), 894
WIFI_AMPU_TX_ENABLED (C macro), 894
WIFI_AMSDU_TX_ENABLED (C macro), 894
wifi_ant_config_t (C++ struct), 909
wifi_ant_config_t::enabled_ant0 (C++ member), 909
wifi_ant_config_t::enabled_ant1 (C++ member), 909
wifi_ant_config_t::rx_ant_default (C++ member), 909
wifi_ant_config_t::rx_ant_mode (C++ member), 909
wifi_ant_config_t::tx_ant_mode (C++ member), 909
wifi_ant_gpio_config_t (C++ struct), 908
wifi_ant_gpio_config_t::gpio_cfg (C++ member), 908
wifi_ant_gpio_t (C++ struct), 908
wifi_ant_gpio_t::gpio_num (C++ member), 908
wifi_ant_gpio_t::gpio_select (C++ member), 908
wifi_ant_mode_t (C++ enum), 932
wifi_ant_mode_t::WIFI_ANT_MODE_ANT0 (C++ enumerator), 932
wifi_ant_mode_t::WIFI_ANT_MODE_ANT1 (C++ enumerator), 932
wifi_ant_mode_t::WIFI_ANT_MODE_AUTO (C++ enumerator), 932
wifi_ant_mode_t::WIFI_ANT_MODE_MAX (C++ enumerator), 932
wifi_ant_t (C++ enum), 929
wifi_ant_t::WIFI_ANT_ANT0 (C++ enumerator), 929
wifi_ant_t::WIFI_ANT_ANT1 (C++ enumerator), 929
wifi_ant_t::WIFI_ANT_MAX (C++ enumerator), 929
wifi_ap_config_t (C++ struct), 900
wifi_ap_config_t::authmode (C++ member), 900
wifi_ap_config_t::beacon_interval (C++ member), 901
wifi_ap_config_t::channel (C++ member), 901
wifi_ap_config_t::fmt_responder (C++ member), 901
wifi_ap_config_t::max_connection (C++ member), 900
wifi_ap_config_t::pairwise_cipher (C++ member), 901
wifi_ap_config_t::password (C++ member), 900
wifi_ap_config_t::pmf_cfg (C++ member), 901
wifi_ap_config_t::sae_pwe_h2e (C++ member), 901
wifi_ap_config_t::ssid (C++ member), 900
wifi_ap_config_t::ssid_hidden (C++ member), 900
wifi_ap_config_t::ssid_len (C++ member), 900
wifi_ap_record_t (C++ struct), 898
wifi_ap_record_t::ant (C++ member), 899
wifi_ap_record_t::authmode (C++ member), 899
wifi_ap_record_t::bssid (C++ member), 898
wifi_ap_record_t::country (C++ member), 899
wifi_ap_record_t::fmt_initiator (C++ member), 899
wifi_ap_record_t::fmt_responder (C++ member), 899
wifi_ap_record_t::group_cipher (C++ member), 899
wifi_ap_record_t::he_ap (C++ member), 899
wifi_ap_record_t::pairwise_cipher (C++ member), 899
wifi_ap_record_t::phy_11ax (C++ member), 899
wifi_ap_record_t::phy_11b (C++ member), 899
wifi_ap_record_t::phy_11g (C++ member), 899
wifi_ap_record_t::phy_11n (C++ member), 899
wifi_ap_record_t::phy_lr (C++ member), 899
wifi_ap_record_t::primary (C++ member), 898
Index

wifi_ap_record_t::reserved (C++ member),
(C++ enumerator), 928
899
wifi_cipher_type_t::WIFI_CIPHER_TYPE_CCMP
wifi_ap_record_t::rssi (C++ member), 898
(C++ enumerator), 928
wifi_ap_record_t::second (C++ member), wifi_cipher_type_t::WIFI_CIPHER_TYPE_GCMP
898
(C++ enumerator), 928
wifi_ap_record_t::ssid (C++ member), 898
wifi_cipher_type_t::WIFI_CIPHER_TYPE_GCMP256
wifi_ap_record_t::wps (C++ member), 899
(C++ enumerator), 928
wifi_auth_mode_t (C++ enum), 924
wifi_cipher_type_t::WIFI_CIPHER_TYPE_NONE
wifi_auth_mode_t::WIFI_AUTH_ENTERPRISE
(C++ enumerator), 928
(C++ enumerator), 924
wifi_cipher_type_t::WIFI_CIPHER_TYPE_SMS4
wifi_auth_mode_t::WIFI_AUTH_MAX (C++
(C++ enumerator), 928
enumerator), 925
wifi_cipher_type_t::WIFI_CIPHER_TYPE_TKIP
(C++ enumerator), 928
wifi_auth_mode_t::WIFI_AUTH_OPEN (C++
enumerator), 924
wifi_cipher_type_t::WIFI_CIPHER_TYPE_TKIP_CCMP
wifi_auth_mode_t::WIFI_AUTH_OWE (C++
(C++ enumerator), 928
wifi_cipher_type_t::WIFI_CIPHER_TYPE_UNKNOWN
enumerator), 925
wifi_auth_mode_t::WIFI_AUTH_WAPI_PSK
(C++ enumerator), 929
wifi_cipher_type_t::WIFI_CIPHER_TYPE_WEP104
(C++ enumerator), 925
(C++ enumerator), 928
wifi_auth_mode_t::WIFI_AUTH_WEP (C++
enumerator), 924
wifi_cipher_type_t::WIFI_CIPHER_TYPE_WEP40
wifi_auth_mode_t::WIFI_AUTH_WPA2_ENTERPRISE (C++ enumerator), 928
wifi_config_t (C++ union), 896
(C++ enumerator), 924
wifi_auth_mode_t::WIFI_AUTH_WPA2_PSK
wifi_config_t::ap (C++ member), 896
(C++ enumerator), 924
wifi_config_t::nan (C++ member), 896
wifi_auth_mode_t::WIFI_AUTH_WPA2_WPA3_PSK
wifi_config_t::sta (C++ member), 896
(C++ enumerator), 924
wifi_country_policy_t (C++ enum), 924
wifi_auth_mode_t::WIFI_AUTH_WPA3_ENT_192
wifi_country_policy_t::WIFI_COUNTRY_POLICY_AUTO
(C++ enumerator), 925
(C++ enumerator), 924
wifi_auth_mode_t::WIFI_AUTH_WPA3_PSK
wifi_country_policy_t::WIFI_COUNTRY_POLICY_MANUAL
(C++ enumerator), 924
(C++ enumerator), 924
wifi_auth_mode_t::WIFI_AUTH_WPA_PSK
wifi_country_t (C++ struct), 896
(C++ enumerator), 924
wifi_country_t::cc (C++ member), 896
wifi_auth_mode_t::WIFI_AUTH_WPA_WPA2_PSK
wifi_country_t::max_tx_power (C++ mem(C++ enumerator), 924
ber), 896
wifi_bandwidth_t (C++ enum), 929
wifi_country_t::nchan (C++ member), 896
wifi_bandwidth_t::WIFI_BW_HT20
(C++ wifi_country_t::policy (C++ member), 897
enumerator), 930
wifi_country_t::schan (C++ member), 896
wifi_bandwidth_t::WIFI_BW_HT40
(C++ wifi_csi_cb_t (C++ type), 895
enumerator), 930
wifi_csi_config_t (C++ struct), 907
wifi_beacon_monitor_config_t (C++ struct), wifi_csi_config_t::channel_filter_en
(C++ member), 907
910
wifi_beacon_monitor_config_t::delta_intr_early
wifi_csi_config_t::htltf_en (C++ mem(C++ member), 910
ber), 907
wifi_beacon_monitor_config_t::delta_loss_timeout
wifi_csi_config_t::lltf_en (C++ member),
(C++ member), 910
907
wifi_beacon_monitor_config_t::enable
wifi_csi_config_t::ltf_merge_en (C++
(C++ member), 910
member), 907
wifi_beacon_monitor_config_t::loss_threshold
wifi_csi_config_t::manu_scale
(C++
(C++ member), 910
member), 907
wifi_beacon_monitor_config_t::loss_timeout
wifi_csi_config_t::shift (C++ member),
(C++ member), 910
908
WIFI_CACHE_TX_BUFFER_NUM (C macro), 894
wifi_csi_config_t::stbc_htltf2_en
wifi_cipher_type_t (C++ enum), 928
(C++ member), 907
wifi_cipher_type_t::WIFI_CIPHER_TYPE_AES_CMAC128
WIFI_CSI_ENABLED (C macro), 894
wifi_csi_info_t (C++ struct), 908
(C++ enumerator), 928
wifi_cipher_type_t::WIFI_CIPHER_TYPE_AES_GMAC128
wifi_csi_info_t::buf (C++ member), 908
wifi_csi_info_t::dmac (C++ member), 908
(C++ enumerator), 928
wifi_cipher_type_t::WIFI_CIPHER_TYPE_AES_GMAC256
wifi_csi_info_t::first_word_invalid

Espressif Systems

2946
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Release v5.1.2


<table>
<thead>
<tr>
<th>wifi_err_reason_t::WIFI_REASON_GROUP_CIPHER_INVALID</th>
<th>wifi_csi_info_t::rx_ctrl</th>
<th>wifi_err_reason_t::WIFI_REASON_BSS_TRANSITION_DISASSOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_EXCEEDED_TXOP</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_UNSPECIFIED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_END_BA</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_UNREACHABLE</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_DISASSOC_SUPCHAN_BAD</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_DISASSOC_PWRCAP_BAD</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_UNSPECIFIED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_CIPHER_SUITE_REJECTED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_BSS_TRANSITION_DISASSOC</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_CIPHER_SUITE_REJECTED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_BSS_TRANSITION_DISASSOC</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_BEACON_TIMEOUT</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_AUTH_LEAVE</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_AUTH_FAIL</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_AUTH_EXPIRE</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_ASSOC_TOOMANY</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_ASSOC_LEAVE</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_ASSOC_EXPIRE</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON_ASSOC_COMEBACK_TIME_TOO_LONG</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP TSF_RESET</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP_INITIATED</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP TSF_RESET</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
<tr>
<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
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<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
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<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
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</tr>
<tr>
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<td>wifi_csi_info_t::mac</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
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<td>wifi_err_reason_t::WIFI_REASON/AP INITIATED</td>
<td>wifi_csi_info_t::mac</td>
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<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
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<td>wifi_csi_info_t::len</td>
<td>wifi_err_reason_t::WIFI_REASON_TDLS_PEER_INITIATED</td>
</tr>
</tbody>
</table>
Index

919

wifi_event_ndp_indication_t::ndp_id
(C++ member), 919
wifi_event_ndp_indication_t::peer_ndi
(C++ member), 919
wifi_event_ndp_indication_t::peer_nmi
(C++ member), 919
wifi_event_ndp_indication_t::publish_id
(C++ member), 919
wifi_event_ndp_indication_t::svc_info
(C++ member), 919
wifi_event_ndp_terminated_t (C++ struct), 920
wifi_event_ndp_terminated_t::init_ndi
(C++ member), 920
wifi_event_ndp_terminated_t::ndp_id
(C++ member), 920
wifi_event_ndp_terminated_t::reason
(C++ member), 920
wifi_event_roc_done_t (C++ struct), 917
wifi_event_roc_done_t::context (C++ member), 917
wifi_event_sta_authmode_change_t (C++ struct), 914
wifi_event_sta_authmode_change_t::new_mode
(C++ member), 914
wifi_event_sta_authmode_change_t::old_mode
(C++ member), 914
wifi_event_sta_connected_t (C++ struct), 915
wifi_event_sta_connected_t::aid (C++ member), 915
wifi_event_sta_connected_t::authmode
(C++ member), 915
wifi_event_sta_connected_t::bssid
(C++ member), 915
wifi_event_sta_connected_t::channel
(C++ member), 915
wifi_event_sta_connected_t::ssid (C++ member), 915
wifi_event_sta_connected_t::ssid_len
(C++ member), 915
wifi_event_sta_disconnected_t (C++ struct), 913
wifi_event_sta_disconnected_t::bssid
(C++ member), 914
wifi_event_sta_disconnected_t::reason
(C++ member), 914
wifi_event_sta_disconnected_t::rssi
(C++ member), 914
wifi_event_sta_disconnected_t::ssid
(C++ member), 914
wifi_event_sta_disconnected_t::ssid_len
(C++ member), 914
wifi_event_sta_scan_done_t (C++ struct), 913
wifi_event_sta_scan_done_t::number
(C++ member), 913
wifi_event_sta_scan_done_t::scan_id
(C++ member), 913
wifi_event_sta_scan_done_t::status
(C++ member), 913
wifi_event_sta_wps_er_pin_t (C++ struct), 914
wifi_event_sta_wps_er_pin_t::pin_code
(C++ member), 914
wifi_event_sta_wps_er_success_t (C++ struct), 914
wifi_event_sta_wps_er_success_t::ap_cred
(C++ member), 915
wifi_event_sta_wps_er_success_t::ap_cred_cnt
(C++ member), 914
wifi_event_sta_wps_er_success_t::passphrase
(C++ member), 914
wifi_event_sta_wps_er_success_t::ssid
(C++ member), 914
wifi_event_sta_wps_fail_reason_t (C++ enum), 937
wifi_event_sta_wps_fail_reason_t::WPS_FAIL_REASON
(C++ enumerator), 937
wifi_event sta_wps_fail_reason_t::WPS_FAIL_REASON
(C++ enumerator), 937
wifi_event sta_wps_fail_reason_t::WPS_FAIL_REASON
(C++ enumerator), 937
wifi_event sta_wps_fail_reason_t::WPS_FAIL_REASON
(C++ enumerator), 937
wifi_event t::WIFI_EVENT_ACTION_TX_STATUS
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_AP_PROBERECEIVED
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_AP_STACONNECTED
(C++ enumerator), 935
wifi_event t::WIFI_EVENT_AP_STADISCONNECTED
(C++ enumerator), 935
wifi_event t::WIFI_EVENT_AP_START
(C++ enumerator), 935
wifi_event t::WIFI_EVENT_AP_STOP (C++
enumerator), 935
wifi_event t::WIFI_EVENT_AP_WPS_RG_FAILED
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_AP_WPS_RG_PBC_OVERLAP
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_AP_WPS_RG_PIN
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_AP_WPS_RG_SUCCESS
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_AP_WPS_RG_TIMEOUT
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_CONNECTIONLESS_MODULE_WAKE_INTERVAL_START
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_FTM_REPORT
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_ITWT_PROBE
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_ITWT_SETUP
(C++ enumerator), 936
wifi_event t::WIFI_EVENT_ITWT_SUSPEND

Espressif Systems 2949 Release v5.1.2
Submit Document Feedback
wifi_event_t::WIFI_EVENT_ITWT_TEARDOWN
(C++ member), 936

wifi_event_t::WIFI_EVENT_NAN_RECEIVE
(C++ member), 937

wifi_event_t::WIFI_EVENT_NAN_REPLIED
(C++ member), 937

wifi_event_t::WIFI_EVENT_NAN_STARTED
(C++ member), 937

wifi_event_t::WIFI_EVENT_NAN_STOPPED
(C++ member), 937

wifi_event_t::WIFI_EVENT_NAN_SVC_MATCH
wifi_ftm_report_entry_t::rssi
(C++ member), 916

wifi_ftm_report_entry_t::rtt
(C++ member), 916

wifi_ftm_report_entry_t::t1
(C++ member), 916

wifi_ftm_report_entry_t::t2
(C++ member), 916

wifi_ftm_status_t::FTM_STATUS_FAIL
(C++ member), 937

wifi_ftm_status_t::FTM_STATUS_NO_RESPONSE
(C++ member), 937

wifi_ftm_status_t::FTM_STATUS_SUCCESS
(C++ member), 937

wifi_ftm_status_t::FTM_STATUS_CONF_REJECTED
(C++ member), 937

wifi_ftm_report_entry_t::dlog_token
(C++ member), 937

wifi_ftm_report_entry_t::t2
(C++ member), 937

wifi_ftm_report_entry_t::T1
(C++ member), 937

wifi_ftm_report_entry_t::T2
(C++ member), 937

wifi_ftm_report_entry_t::T3
(C++ member), 937

wifi_ftm_report_entry_t::T4
(C++ member), 937

wifi_ftm_report_entry_t::rtt
(C++ member), 937

wifi_ftm_report_entry_t::t1
(C++ member), 937

wifi_ftm_report_entry_t::t2
(C++ member), 937

wifi_ftm_report_entry_t::t3
(C++ member), 937

wifi_ftm_report_entry_t::t4
(C++ member), 937

wifi_ftm_initiator_cfg_t::resp_mac
(C++ member), 910

wifi_ftm_initiator_cfg_t::channel
(C++ member), 910

wifi_ftm_initiator_cfg_t::burst_period
(C++ member), 910

wifi_ftm_initiator_cfg_t::csa_enable
(C++ member), 910

wifi_ftm_initiator_cfg_t::csi_enable
(C++ member), 910

wifi_init_config_t::dynamic_tx_buf_num
(C++ member), 909

wifi_init_config_t::dynamic_rx_buf_num
(C++ member), 910

wifi_init_config_t::dynamic_tx_buf_num
(C++ member), 910

wifi_init_config_t::espnow_max_encrypt_num
(C++ member), 910
Index

wifi_init_config_t::feature_caps (C++ member), 892
wifi_init_config_t::magic (C++ member), 893
wifi_init_config_t::mgmt_sbuf_num (C++ member), 892
wifi_init_config_t::nano_enable (C++ member), 892
wifi_init_config_t::nvs_enable (C++ member), 892
wifi_init_config_t::osi_funcs (C++ member), 891
wifi_init_config_t::rx_ba_win (C++ member), 892
wifi_init_config_t::rx_mgmt_buf_num (C++ member), 892
wifi_init_config_t::rx_mgmt_buf_type (C++ member), 892
wifi_init_config_t::sta_disconnected_pm (C++ member), 891
wifi_init_config_t::static_rx_buf_num (C++ member), 891
wifi_init_config_t::static_tx_buf_num (C++ member), 891
wifi_init_config_t::tx_buf_type (C++ member), 891
wifi_init_config_t::wifi_task_core_id (C++ member), 892
wifi_init_config_t::wpa_crypto_funcs (C++ member), 891
wifi_interface_t (C++ enum), 923
wifi_interface_t::WIFI_IF_AP (C++ enum), 924
wifi_interface_t::WIFI_IF_MAX (C++ enum), 924
wifi_interface_t::WIFI_IF_NAN (C++ enum), 924
wifi_interface_t::WIFI_IF_STA (C++ enum), 924
WIFI_MGMT_SBUF_NUM (C macro), 895
wifi_mode_t (C++ enum), 923
wifi_mode_t::WIFI_MODE_AP (C++ enumerator), 923
wifi_mode_t::WIFI_MODE_APSTA (C++ enumerator), 923
wifi_mode_t::WIFI_MODE_MAX (C++ enumerator), 923
wifi_mode_t::WIFI_MODE_NAN (C++ enumerator), 923
wifi_mode_t::WIFI_MODE_NULL (C++ enumerator), 923
wifi_mode_t::WIFI_MODE_STA (C++ enumerator), 923
WIFI_NAN_CONFIG_DEFAULT (C macro), 955
wifi_nan_config_t (C++ struct), 903
wifi_nan_config_t::master_pref (C++ member), 903
wifi_nan_config_t::op_channel (C++ member), 903
wifi_nan_config_t::scan_time (C++ member), 903
wifi_nan_config_t::warm_up_sec (C++ member), 903
wifi_nan_datapath_end_req_t (C++ struct), 912
wifi_nan_datapath_end_req_t::ndp_id (C++ member), 912
wifi_nan_datapath_end_req_t::peer_mac (C++ member), 913
wifi_nan_datapath_req_t (C++ struct), 912
wifi_nan_datapath_req_t::confirm_required (C++ member), 912
wifi_nan_datapath_req_t::peer_mac (C++ member), 912
wifi_nan_datapath_req_t::pub_id (C++ member), 912
wifi_nan_followup_params_t::inst_id (C++ member), 911
wifi_nan_followup_params_t::peer_inst_id (C++ member), 912
wifi_nan_followup_params_t::peer_mac (C++ member), 912
wifi_nan_followup_params_t::svc_mac (C++ member), 912
wifi_nan_mem_cache_data_list (C++ struct), 910
wifi_nan_mem_cache_data_list::data (C++ member), 910
wifi_nan_mem_cache_data_list::data_list (C++ member), 910
wifi_nan_mem_cache_data_list::index (C++ member), 910
wifi纳米配置函数(wifi_nan_config_t)
WIFI_PROMIS_CTRL_FILTER_MASK_RTS
(WIFI_PROMIS_CTRL_FILTER_MASK_PSPOLL
(WIFI_PROMIS_CTRL_FILTER_MASK_CTS
(WIFI_PROMIS_CTRL_FILTER_MASK_CFENDACK
(WIFI_PROMIS_CTRL_FILTER_MASK_CFEND
(WIFI_PROMIS_CTRL_FILTER_MASK_BAR
(WIFI_PROMIS_CTRL_FILTER_MASK_BA
(wifi_pmf_config_t::required
(wifi_pmf_config_t::capable
(wifi_pmf_config_t
(wifi_pkt_rx_ctrl_t::stbc
(wifi_pkt_rx_ctrl_t::smoothing
(wifi_pkt_rx_ctrl_t::sig_mode
(wifi_pkt_rx_ctrl_t::secondary_channel
(wifi_pkt_rx_ctrl_t::rx_state
(wifi_pkt_rx_ctrl_t::rssi
(wifi_pkt_rx_ctrl_t::rate
(wifi_pkt_rx_ctrl_t::not_sounding
(wifi_pkt_rx_ctrl_t::noise_floor
(wifi_pkt_rx_ctrl_t::mcs
(wifi_pkt_rx_ctrl_t::fec_coding
(wifi_pkt_rx_ctrl_t::cwb
(wifi_pkt_rx_ctrl_t::channel
(wifi_pkt_rx_ctrl_t::ant
(wifi_pkt_rx_ctrl_t::ampdu_cnt
(wifi_prov_cb_func_t
(wifi_prov_cb_event_t::WIFI_PROV_START
(wifi_prov_cb_event_t::WIFI_PROV_INIT
(wifi_prov_cb_event_t::WIFI_PROV_END
(wifi_prov_cb_event_t::WIFI_PROV_DEINIT
(wifi_prov_cb_event_t::WIFI_PROV_CRED_SUCCESS
(wifi_prov_cb_event_t::WIFI_PROV_CRED_RECV
(wifi_prov_cb_event_t::WIFI_PROTOCOL_LR
(wifi_prov_cb_event_t::WIFI_PROTOCOL_11N
(wifi_prov_cb_event_t::WIFI_PROTOCOL_11G
(wifi_prov_cb_event_t::WIFI_PROTOCOL_11B
(wifi_prov_cb_event_t::WIFI_PROTOCOL_11AX
(wifi_promiscuous_pkt_type_t::WIFI_PKT_MISC
(wifi_promiscuous_pkt_type_t::WIFI_PKT_MGMT
(wifi_promiscuous_pkt_type_t::WIFI_PKT_DATA
(wifi_promiscuous_pkt_type_t::WIFI_PKT_CTRL
(wifi_promiscuous_pkt_t::rx_ctrl
(wifi_promiscuous_pkt_t::payload
(wifi_promiscuous_filter_t::filter_mask
(wifi_promiscuous_filter_t::WIFI_PROMIS_FILTER_MASK_MISC
(wifi_promiscuous_filter_t::WIFI_PROMIS_FILTER_MASK_MGMT
(wifi_promiscuous_filter_t::WIFI_PROMIS_FILTER_MASK_FCSFAIL
(wifi_promiscuous_filter_t::WIFI_PROMIS_FILTER_MASK_DATA
(wifi_promiscuous_filter_t::WIFI_PROMIS_FILTER_MASK_CTRL
(wifi_promiscuous_filter_t::WIFI_PROMIS_FILTER_MASK_WRAPPER
(wifi_promiscuous_cb_t
(wifi_pkt_rx_ctrl_t::aggregation
(wifi_pkt_rx_ctrl_t::ampdu_cnt
(wifi_pkt_rx_ctrl_t::ant
(wifi_pkt_rx_ctrl_t::channel
(wifi_pkt_rx_ctrl_t::cwb
(wifi_pkt_rx_ctrl_t::sec_coding
(wifi_pkt_rx_ctrl_t::mcs
(wifi_pkt_rx_ctrl_t::noise_floor
(wifi_pkt_rx_ctrl_t::not_sounding
(wifi_pkt_rx_ctrl_t::rate
(wifi_pkt_rx_ctrl_t::not_sounding
(wifi_pkt_rx_ctrl_t::smoothing
(wifi_pkt_rx_ctrl_t::stbc
(wifi_pkt_rx_ctrl_t::secondary_channel
(wifi_pkt_rx_ctrl_t::rx_state
(wifi_pkt_rx_ctrl_t::rssi
(wifi_pkt_rx_ctrl_t::rate
(wifi_pkt_rx_ctrl_t::not_sounding
(wifi_pkt_rx_ctrl_t::channel
(wifi_pkt_rx_ctrl_t::ant
(wifi_pkt_rx_ctrl_t::ampdu_cnt
(wifi_pkt_rx_ctrl_t::sec_coding
(wifi_pkt_rx_ctrl_t::mcs
(wifi_pkt_rx_ctrl_t::noise_floor
(wifi_pkt_rx_ctrl_t::not_sounding
(wifi_pkt_rx_ctrl_t::smoothing
(wifi_pkt_rx_ctrl_t::stbc

wifi_prov_security_t::WIFI_PROV_SECURITY_0
(wifi_prov_security_t C++ enumerator, 897)

wifi_prov_security_t::WIFI_PROV_SECURITY_1
(wifi_prov_security_t C++ enumerator, 897)

wifi_prov_security_t::WIFI_PROV_SECURITY_2
(wifi_prov_security_t C++ enumerator, 897)

wifi_prov_security_t::WIFI_PROV_SECURITY_3
(wifi_prov_security_t C++ enumerator, 901)

wifi_scan_config_t::ssid (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::home_chan_dwell_time
(wifi_scan_config_t C++ member, 898)

wifi_scan_config_t::scan_time (wifi_scan_config_t C++ member, 898)

wifi_scan_config_t::scan_type (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::show_hidden (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::bssid (wifi_scan_config_t C++ member, 897)

wifi_scan_method_t::WIFI_ALL_CHANNEL_SCAN
(wifi_scan_method_t C++ enum, 929)

wifi_scan_threshold_t::rssi (wifi_scan_threshold_t C++ member, 900)

wifi_scan_threshold_t::authmode (wifi_scan_threshold_t C++ member, 900)

wifi_scan_config_t::scan_type
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::scan_time
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::show_hidden (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::bssid (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::ip_addr (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::ssp (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::btm_enabled
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::bssid
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::home_chan_dwell_time
(wifi_scan_config_t C++ member, 898)

wifi_scan_config_t::scan_time (wifi_scan_config_t C++ member, 898)

wifi_scan_config_t::scan_type (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::show_hidden (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::ssid (wifi_scan_config_t C++ member, 897)

wifi_scan_method_t::WIFI_FAST_SCAN
(wifi_scan_method_t C++ enum, 929)

wifi_scan_threshold_t::rssi (wifi_scan_threshold_t C++ member, 900)

wifi_scan_threshold_t::authmode (wifi_scan_threshold_t C++ member, 900)

wifi_scan_config_t::scan_type
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::scan_time
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::show_hidden (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::bssid (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::ip_addr (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::ssp (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::btm_enabled
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::bssid
(wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::home_chan_dwell_time
(wifi_scan_config_t C++ member, 898)

wifi_scan_config_t::scan_time (wifi_scan_config_t C++ member, 898)

wifi_scan_config_t::scan_type (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::show_hidden (wifi_scan_config_t C++ member, 897)

wifi_scan_config_t::ssid (wifi_scan_config_t C++ member, 897)
wps_factory_information_t::model_name (C++ member), 944
wps_factory_information_t::model_number (C++ member), 944
wps_fail_reason_t (C++ enum), 938
wps_fail_reason_t::WPS_AP_FAIL_REASON_ (C++ enum), 938
wps_fail_reason_t::WPS_AP_FAIL_REASON_CONFIG (C++ enum), 938
wps_fail_reason_t::WPS_AP_FAIL_REASON_ (C++ enum), 938
wps_fail_reason_t::WPS_AP_FAIL_REASON_ (C++ enum), 938
wps_fail_reason_t::WPS_AP_FAIL_REASON_ (C++ enum), 938
WPS_MAX_DEVICE_NAME_LEN (C macro), 945
WPS_MAX_MANUFACTURER_LEN (C macro), 945
WPS_MAX_MODEL_NAME_LEN (C macro), 945
WPS_MAX_MODEL_NUMBER_LEN (C macro), 945
wps_type (C++ enum), 946
wps_type::WPS_TYPE_DISABLE (C++ enumerator), 946
wps_type::WPS_TYPE_MAX (C++ enumerator), 946
wps_type::WPS_TYPE_PBC (C++ enumerator), 946
wps_type::WPS_TYPE_PIN (C++ enumerator), 946
wps_type_t (C++ type), 946

xEventGroupClearBits (C++ function), 2058
xEventGroupClearBitsFromISR (C macro), 2061
xEventGroupCreate (C++ function), 2055
xEventGroupCreateStatic (C++ function), 2056
xEventGroupCreateWithCaps (C++ function), 2104
xEventGroupGetBits (C macro), 2063
xEventGroupGetBitsFromISR (C++ function), 2061
xEventGroupGetStaticBuffer (C++ function), 2061
xEventGroupSetBits (C++ function), 2058
xEventGroupSetBitsFromISR (C macro), 2062
xEventGroupSync (C++ function), 2059
xEventGroupWaitBits (C++ function), 2056
xMessageBufferCreate (C macro), 2072
xMessageBufferCreateStatic (C macro), 2073
xMessageBufferCreateWithCaps (C++ function), 2103
xMessageBufferGetStaticBuffers (C macro), 2074
xMessageBufferIsEmpty (C macro), 2079
xMessageBufferIsFull (C macro), 2079
xMessageBufferNextLengthBytes (C macro), 2079
xMessageBufferReceive (C macro), 2076
xMessageBufferReceiveCompletedFromISR (C macro), 2080
xMessageBufferReceiveFromISR (C macro), 2077
xMessageBufferReset (C macro), 2079
xMessageBufferSend (C macro), 2074
xMessageBufferSendCompletedFromISR (C macro), 2079
xMessageBufferSendFromISR (C macro), 2075
xMessageBufferSpaceAvailable (C macro), 2079
xMessageBufferSpacesAvailable (C macro), 2079
xQueueAddToSet (C++ function), 2111
xQueueCreate (C macro), 2012
xQueueCreateSet (C++ function), 2010
xQueueCreateStatic (C macro), 2013
xQueueCreateWithCaps (C++ function), 2101
xQueueGenericCreate (C++ function), 2100
xQueueGenericCreateStatic (C++ function), 2100
xQueueGenericGetStaticBuffers (C++ function), 2100
xQueueGenericSend (C++ function), 2003
xQueueGenericSendFromISR (C++ function), 2007
xQueueGetStaticBuffers (C macro), 1908
xQueueGiveFromISR (C macro), 2008
xQueueIsQueueEmptyFromISR (C++ function), 2009
xQueueIsQueueFullFromISR (C++ function), 1909
xQueueIsQueueFullFromISR (C++ function), 2009
xQueueOverwrite (C macro), 2017
xQueueOverwriteFromISR (C macro), 2020
xQueuePeek (C++ function), 2004
xQueuePeekFromISR (C++ function), 2005
xQueueReceive (C++ function), 2006
xQueueReceiveFromISR (C++ function), 2008
xQueueRemoveFromSet (C++ function), 2011
xQueueReset (C macro), 2022
xQueueSelectFromSet (C++ function), 2011
xQueueSelectFromSetFromISR (C++ function), 2012
xQueueSend (C macro), 2016
xQueueSendFromISR (C macro), 2021
xQueueSendToBack (C macro), 2015
xQueueSendToBackFromISR (C macro), 2019
xQueueSendToFront (C macro), 2014
xQueueSendToFrontFromISR (C macro), 2018
xRingbufferAddToQueueSetRead (C++ function), 2097
xRingbufferCanRead (C++ function), 2097
xRingbufferCreate (C++ function), 2090
xRingbufferCreateNoSplit (C++ function), 2091
xRingbufferCreateStatic (C++ function), 2091
xRingbufferGetCurFreeSize (C++ function),
xRingbufferGetMaxItemSize (C++ function), 2096
xRingbufferPrintInfo (C++ function), 2098
xRingbufferReceive (C++ function), 2093
xRingbufferReceiveFromISR (C++ function), 2093
xRingbufferReceiveSplit (C++ function), 2094
xRingbufferReceiveSplitFromISR (C++ function), 2094
xRingbufferReceiveUpTo (C++ function), 2095
xRingbufferReceiveUpToFromISR (C++ function), 2095
xRingbufferRemoveFromQueueSetRead (C++ function), 2097
xRingbufferSend (C++ function), 2091
xRingbufferSendAcquire (C++ function), 2092
xRingbufferSendComplete (C++ function), 2092
xRingbufferSendFromISR (C++ function), 2091
xSemaphoreCreateBinary (C macro), 2023
xSemaphoreCreateBinaryStatic (C macro), 2024
xSemaphoreCreateBinaryWithCaps (C++ function), 2102
xSemaphoreCreateCounting (C macro), 2032
xSemaphoreCreateCountingStatic (C macro), 2034
xSemaphoreCreateCountingWithCaps (C++ function), 2102
xSemaphoreCreateMutex (C macro), 2030
xSemaphoreCreateMutexStatic (C macro), 2031
xSemaphoreCreateMutexWithCaps (C++ function), 2102
xSemaphoreCreateRecursiveMutexWithCaps (C++ function), 2103
xSemaphoreGetMutexHolder (C macro), 2036
xSemaphoreGetMutexHolderFromISR (C macro), 2036
xSemaphoreGetStaticBuffer (C macro), 2036
xSemaphoreGive (C macro), 2027
xSemaphoreGiveFromISR (C macro), 2029
xSemaphoreGiveRecursive (C macro), 2027
xSemaphoreTake (C macro), 2024
xSemaphoreTakeFromISR (C macro), 2030
xSemaphoreTakeRecursive (C macro), 2025
xSemaphoreTakeRecursive (C macro), 2025
xSemaphoreGetMutexHolderFromISR (C macro), 2036
bSTATIC_RINGBUFFER (C++ struct), 2098
xStreamBufferBytesAvailable (C++ function), 2069
xStreamBufferCreate (C macro), 2070
xStreamBufferCreateStatic (C macro), 2071
xStreamBufferCreateWithCaps (C++ function), 2103
xStreamBufferGetStaticBuffers (C++ function), 2064
xStreamBufferIsEmpty (C++ function), 2068
xStreamBufferIsFull (C++ function), 2068
xStreamBufferReceive (C++ function), 2066
xStreamBufferReceiveCompletedFromISR (C++ function), 2070
xStreamBufferReceiveFromISR (C++ function), 2067
xStreamBufferReset (C++ function), 2068
xStreamBufferSend (C++ function), 2064
xStreamBufferSendCompletedFromISR (C++ function), 2069
xStreamBufferSendFromISR (C++ function), 2065
xStreamBufferSetTriggerLevel (C++ function), 2069
xStreamBufferSpacesAvailable (C++ function), 2069
xTaskAbortDelay (C++ function), 1978
xTaskCallApplicationTaskHook (C++ function), 1987
xTaskCatchUpTicks (C++ function), 1999
xTaskCheckForTimeOut (C++ function), 1998
xTaskCreate (C++ function), 1971
xTaskCreatePinnedToCore (C++ function), 2068
xTaskCreatePinnedToCoreWithCaps (C++ function), 2100
xTaskCreateStatic (C++ function), 1972
xTaskCreateStaticPinnedToCore (C++ function), 1969
xTaskCreateWithCaps (C++ function), 2101
xTaskDelay (C++ function), 1977
xTaskGenericNotify (C++ function), 1991
xTaskGenericNotifyFromISR (C++ function), 1992
xTaskGenericNotifyStateClear (C++ function), 2004
xTaskGenericNotifyWait (C++ function), 2003
xTaskGetApplicationTaskTag (C++ function), 2000
xTaskGetApplicationTaskTagFromISR (C++ function), 1986
xTaskGetHandle (C++ function), 1985
xTaskGetIdleTaskHandle (C++ function), 1988
xTaskGetStaticBuffers (C++ function), 1985
xTaskGetTickCount (C++ function), 1985
xTaskGetTickCountFromISR (C++ function), 1985
xTaskNotify (C macro), 2000
xTaskNotifyAndQuery (C macro), 2000
xTaskNotifyAndQueryFromISR (C macro), 2001
xTaskNotifyAndQueryIndexed (C macro), 2000
xTaskNotifyAndQueryIndexedFromISR (C macro), 2000
xTaskNotifyGive (C macro), 2001
xTaskNotifyGiveIndexed (C macro), 2001
xTaskNotifyIndexed (C macro), 2000
xTaskNotifyIndexedFromISR (C macro), 2000
xTaskNotifyStateClear (C macro), 2002
xTaskNotifyStateClearIndexed (C macro), 2002
xTaskNotifyWait (C macro), 2001
xTaskNotifyWaitIndexed (C macro), 2001
xTaskResumeAll (C++ function), 1984
xTaskResumeFromISR (C++ function), 1982
xtensa_perfmon_config (C++ struct), 2193
xtensa_perfmon_config::call_function (C++ member), 2193
xtensa_perfmon_config::call_params (C++ member), 2193
xtensa_perfmon_config::callback (C++ member), 2193
xtensa_perfmon_config::callback_params (C++ member), 2193
xtensa_perfmon_config::counters_size (C++ member), 2194
xtensa_perfmon_config::max_deviation (C++ member), 2193
xtensa_perfmon_config::repeat_count (C++ member), 2193
xtensa_perfmon_config::select_mask (C++ member), 2194
xtensa_perfmon_config::tracelevel (C++ member), 2193
xtensa_perfmon_config_t (C++ type), 2194
xtensa_perfmon_dump (C++ function), 2192
xtensa_perfmon_exec (C++ function), 2193
xtensa_perfmon_init (C++ function), 2192
xtensa_perfmon_overflow (C++ function), 2192
xtensa_perfmon_reset (C++ function), 2192
xtensa_perfmon_start (C++ function), 2192
xtensa_perfmon_stop (C++ function), 2192
xtensa_perfmon_value (C++ function), 2192
xtensa_perfmon_view_cb (C++ function), 2193
xTimerChangePeriod (C macro), 2046
xTimerChangePeriodFromISR (C macro), 2052
xTimerCreate (C++ function), 2036
xTimerCreateStatic (C++ function), 2038
xTimerDelete (C macro), 2048
xTimerGetExpiryTime (C++ function), 2044
xTimerGetPeriod (C++ function), 2044
xTimerGetStaticBuffer (C++ function), 2044
xTimerGetTimerDaemonTaskHandle (C++ function), 2042
xTimerIsTimerActive (C++ function), 2041
xTimerPendFunctionCall (C++ function), 2043
xTimerPendFunctionCallFromISR (C++ function), 2042
xTimerReset (C macro), 2048
xTimerResetFromISR (C macro), 2053
xTimerStart (C macro), 2045
xTimerStartFromISR (C macro), 2050
xTimerStop (C macro), 2046
xTimerStopFromISR (C macro), 2051