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  8.5 Checking the Current Version .............................. 1997
This is the documentation for Espressif IoT Development Framework (esp-idf). ESP-IDF is the official development framework for the ESP32, ESP32-S and ESP32-C Series SoCs.

This document describes using ESP-IDF with the ESP32-S3 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-S3 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-S3 board.

Note: This is documentation for the master branch (latest version) of ESP-IDF. This version is under continual development. Stable version documentation is available, as well as other ESP-IDF Versions.

1.1 Introduction

ESP32-S3 is a system on a chip that integrates the following features:

- Wi-Fi (2.4 GHz band)
- Bluetooth Low Energy
- Dual high performance Xtensa® 32-bit LX7 CPU cores
- Ultra Low Power co-processor running either RISC-V or FSM core
- Multiple peripherals
- Built-in security hardware
- USB OTG interface
- USB Serial/JTAG Controller

Powered by 40 nm technology, ESP32-S3 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-S3 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-S3 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!
Chapter 1. Get Started

If you have one of ESP32-S3 official development boards listed below, you can click on the link to learn more about the hardware.

**ESP32-S3-DevKitC-1**

This user guide will help you get started with ESP32-S3-DevKitC-1 and will also provide more in-depth information. The ESP32-S3-DevKitC-1 is an entry-level development board equipped with either ESP32-S3-WROOM-1 or ESP32-S3-WROOM-1U, a general-purpose Wi-Fi + Bluetooth® LE MCU module that integrates complete Wi-Fi and Bluetooth LE functions.

Most of the I/O pins on the module are broken out to the pin headers on both sides of this board for easy interfacing. Developers can either connect peripherals with jumper wires or mount ESP32-S3-DevKitC-1 on a breadboard.

Fig. 1: ESP32-S3-DevKitC-1 with ESP32-S3-WROOM-1 Module

The document consists of the following major sections:

- **Getting started**: Overview of the board and hardware/software setup instructions to get started.
- **Hardware Reference**: More detailed information about the board’s hardware.
- **Hardware Revision Details**: Revision history, known issues, and links to user guides for previous versions (if any) of the board.
- **Related Documents**: Links to related documentation.

**Getting Started**  This section provides a brief introduction of ESP32-S3-DevKitC-1, instructions on how to do the initial hardware setup and how to flash firmware onto it.

![ESP32-S3-DevKitC-1 diagram](Figure 2)

**Description of Components**  The key components of the board are described in a counter-clockwise direction.
## Key Component

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-S3-WROOM-1/1U</td>
<td>ESP32-S3-WROOM-1 and ESP32-S3-WROOM-1U are two powerful, generic Wi-Fi+Bluetooth LE MCU modules that have a rich set of peripherals. They provide acceleration for neural network computing and signal processing workloads. ESP32-S3-WROOM-1 comes with a PCB antenna. ESP32-S3-WROOM-1U comes with an external antenna connector.</td>
</tr>
<tr>
<td>5 V to 3.3 V LDO</td>
<td>Power regulator that converts a 5 V supply into a 3.3 V output.</td>
</tr>
<tr>
<td>Pin Headers</td>
<td>All available GPIO pins (except for the SPI bus for flash) are broken out to the pin headers on the board for easy interfacing and programming. For details, please see Header Block.</td>
</tr>
<tr>
<td>USB-to-UART Port</td>
<td>A Micro-USB port used for power supply to the board, for flashing applications to the chip, as well as for communication with the chip via the on-board USB-to-UART bridge.</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>Press this button to restart the system.</td>
</tr>
<tr>
<td>ESP32-S3 USB Port</td>
<td>ESP32-S3 full-speed USB OTG interface, compliant with the USB 1.1 specification. The interface is used for power supply to the board, for flashing applications to the chip, for communication with the chip using USB 1.1 protocols, as well as for JTAG debugging.</td>
</tr>
<tr>
<td>USB-to-UART Bridge</td>
<td>Single USB-to-UART bridge chip provides transfer rates up to 3 Mbps.</td>
</tr>
<tr>
<td>RGB LED</td>
<td>Addressable RGB LED, driven by GPIO48.</td>
</tr>
<tr>
<td>3.3 V Power On LED</td>
<td>Turns on when the USB power is connected to the board.</td>
</tr>
</tbody>
</table>

### Start Application Development

Before powering up your board, please make sure that it is in good condition with no obvious signs of damage.

### Required Hardware

- ESP32-S3-DevKitC-1
- USB 2.0 cable (Standard-A to Micro-B)
- Computer running Windows, Linux, or macOS

**Note:** Be sure to use an appropriate USB cable. Some cables are for charging only and do not provide the needed data lines nor work for programming the boards.

### Hardware Setup

Connect the board with the computer using **USB-to-UART Port**. Connection using **ESP32-S3 USB Port** is not fully implemented in software. In subsequent steps, **USB-to-UART Port** will be used by default.

### 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 board.

### Contents and Packaging

#### Retail orders

If you order a few samples, each board 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.

Hardware Reference

Block Diagram The block diagram below shows the components of ESP32-S3-DevKitC-1 and their interconnections.

![Block Diagram](image)

Fig. 3: ESP32-S3-DevKitC-1 (click to enlarge)

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

- USB-to-UART Port and ESP32-S3 USB Port (either one or both), default power supply (recommended)
- 5V and G (GND) pins
- 3V3 and G (GND) pins

Header Block The two tables below provide the Name and Function of the pins on both sides of the board (J1 and J3). The pin names are shown in ESP32-S3-DevKitC-1 - front. The numbering is the same as in the Board Schematic (PDF).
### J1

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
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</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>3V3</td>
<td>P</td>
<td>3.3 V power supply</td>
</tr>
<tr>
<td>3</td>
<td>RST</td>
<td>I</td>
<td>EN</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>I/O/T</td>
<td>RTC_GPIO4, GPIO4, TOUCH4, ADC1_CH3</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>I/O/T</td>
<td>RTC_GPIO5, GPIO5, TOUCH5, ADC1_CH4</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>I/O/T</td>
<td>RTC_GPIO6, GPIO6, TOUCH6, ADC1_CH5</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>I/O/T</td>
<td>RTC_GPIO7, GPIO7, TOUCH7, ADC1_CH6</td>
</tr>
<tr>
<td>8</td>
<td>15</td>
<td>I/O/T</td>
<td>RTC_GPIO15, GPIO15, U0RTS, ADC2_CH4, XTAL_32K_P</td>
</tr>
<tr>
<td>9</td>
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<td>3</td>
<td>I/O/T</td>
<td>RTC_GPIO3, GPIO3, TOUCH3, ADC1_CH2</td>
</tr>
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<td>46</td>
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<td>GPIO46</td>
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<td>I/O/T</td>
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<td>I/O/T</td>
<td>RTC_GPIO10, GPIO10, TOUCH10, ADC1_CH9, FSPICS0, FSPII0, SUBSPIC0</td>
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<tr>
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<td>I/O/T</td>
<td>RTC_GPIO11, GPIO11, TOUCH11, ADC2_CH0, FSPID, FSPII0, SUBSPI0</td>
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<td>12</td>
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<td>RTC_GPIO12, GPIO12, TOUCH12, ADC2_CH1, FSPICKL, FSPII0, SUBSPI0</td>
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<td>RTC_GPIO13, GPIO13, TOUCH13, ADC2_CH2, FPIQ, FPIIO7, SUBSPIQ</td>
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<td>14</td>
<td>I/O/T</td>
<td>RTC_GPIO14, GPIO14, TOUCH14, ADC2_CH3, FPIWP, FPIPDQ, SUBSPIWP</td>
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<tr>
<td>21</td>
<td>5V</td>
<td>P</td>
<td>5 V power supply</td>
</tr>
<tr>
<td>22</td>
<td>G</td>
<td>G</td>
<td>Ground</td>
</tr>
</tbody>
</table>

For description of function names, please refer to Chip Datasheet (PDF).

---

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>I/O/T</td>
<td>U0TXD, GPIO43, CLK_OUT1</td>
</tr>
<tr>
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<td>RX</td>
<td>I/O/T</td>
<td>U0RXD, GPIO44, CLK_OUT2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>I/O/T</td>
<td>RTC_GPIO1, GPIO1, TOUCH1, ADC1_CH0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>I/O/T</td>
<td>RTC_GPIO2, GPIO2, TOUCH2, ADC1_CH1</td>
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<td>42</td>
<td>I/O/T</td>
<td>MTMS, GPIO42</td>
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<td>41</td>
<td>I/O/T</td>
<td>MTDO, GPIO40, CLK_OUT2</td>
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<td>I/O/T</td>
<td>MTCK, GPIO39, CLK_OUT3, SUBSPIC5</td>
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<td>38</td>
<td>I/O/T</td>
<td>GPIO38, FSPIWP, SUBSPIWP</td>
</tr>
<tr>
<td>9</td>
<td>37</td>
<td>I/O/T</td>
<td>SPIDQS, GPIO37, FSPIQ, SUBSPIQ</td>
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<td>36</td>
<td>I/O/T</td>
<td>SPI07, GPIO36, FSPICKL, SUBSPICLK</td>
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<td>I/O/T</td>
<td>SPIO6, GPIO35, FSPID, SUBSPI</td>
</tr>
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<td>0</td>
<td>I/O/T</td>
<td>RTC_GPIO00, GPIO0</td>
</tr>
<tr>
<td>13</td>
<td>45</td>
<td>I/O/T</td>
<td>GPIO45</td>
</tr>
<tr>
<td>14</td>
<td>48</td>
<td>I/O/T</td>
<td>GPIO48, SPICLK_N, SUBSPICLK_N_DIF, RGB LED</td>
</tr>
<tr>
<td>15</td>
<td>47</td>
<td>I/O/T</td>
<td>SPIK_P, SUBSPICLK_P_DIF</td>
</tr>
<tr>
<td>16</td>
<td>21</td>
<td>I/O/T</td>
<td>RTC_GPIO21, GPIO21</td>
</tr>
<tr>
<td>17</td>
<td>20</td>
<td>I/O/T</td>
<td>RTC_GPIO20, GPIO20, U1CTS, ADC2_CH9, CLK_OUT1, USB_D+</td>
</tr>
<tr>
<td>18</td>
<td>19</td>
<td>I/O/T</td>
<td>RTC_GPIO19, GPIO19, U1RTS, ADC2_CH8, CLK_OUT2, USB_D-</td>
</tr>
<tr>
<td>19</td>
<td>G</td>
<td>G</td>
<td>Ground</td>
</tr>
<tr>
<td>20</td>
<td>G</td>
<td>G</td>
<td>Ground</td>
</tr>
</tbody>
</table>

---

P: Power supply; I: Input; O: Output; T: High impedance.
Chapter 1. Get Started

Fig. 4: ESP32-S3-DevKitC-1 Pin Layout (click to enlarge)

Pin Layout

Hardware Revision Details  This is the first revision of this board released.

Related Documents
- ESP32-S3 Datasheet (PDF)
- ESP32-S3-WROOM-1 & ESP32-S3-WROOM-1U Datasheet (PDF)
- ESP32-S3-DevKitC-1 Schematic (PDF)
- ESP32-S3-DevKitC-1 PCB layout (PDF)
- ESP32-S3-DevKitC-1 Dimensions (PDF)
- ESP32-S3-DevKitC-1 Dimensions source file (DXF) - You can view it with Autodesk Viewer online

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

ESP32-S3-DevKitM-1

This user guide will help you get started with ESP32-S3-DevKitM-1 and will also provide more in-depth information.

The ESP32-S3-DevKitM-1 is an entry-level development board equipped with either ESP32-S3-MINI-1 or ESP32-S3-MINI-1U, a module named for its small size. This board integrates complete Wi-Fi and Bluetooth Low Energy functions.

Most of the I/O pins on the module are broken out to the pin headers on both sides of this board for easy interfacing. Developers can either connect peripherals with jumper wires or mount ESP32-S3-DevKitM-1 on a breadboard.

The document consists of the following major sections:
- Getting Started: Overview of the board and hardware/software setup instructions to get started.
Fig. 5: ESP32-S3-DevKitM-1 with ESP32-S3-MINI-1 Module
Chapter 1. Get Started

- **Hardware Reference**: More detailed information about the board’s hardware.
- **Related Documents**: Links to related documentation.

**Getting Started**  This section provides a brief introduction of ESP32-S3-DevKitM-1, instructions on how to do the initial hardware setup and how to flash firmware onto it.

![ESP32-S3-DevKitM-1-front](image)

**Description of Components**  The key components of the board are described in a counter-clockwise direction, starting from the ESP32-S3-MINI-1/1U module.
### Chapter 1. Get Started

#### Key Component

<table>
<thead>
<tr>
<th>Key Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-S3-MINI-1/1U</td>
<td>ESP32-S3-MINI-1 and ESP32-S3-MINI-1U are two general-purpose Wi-Fi and Bluetooth LE combo modules that have a rich set of peripherals. ESP32-S3-MINI-1 comes with a PCB antenna. ESP32-S3-MINI-1U comes with an external antenna connector. At the core of the modules is ESP32-S3FN8, a chip equipped with an 8 MB flash. Since flash is packaged in the chip, rather than integrated into the module, ESP32-S3-MINI-1/1U has a smaller package size.</td>
</tr>
<tr>
<td>5 V to 3.3 V LDO</td>
<td>Power regulator that converts a 5 V supply into a 3.3 V output.</td>
</tr>
<tr>
<td>Pin Headers</td>
<td>All available GPIO pins (except for the SPI bus for flash) are broken out to the pin headers on the board for easy interfacing and programming. For details, please see Header Block.</td>
</tr>
<tr>
<td>USB-to-UART Port</td>
<td>A Micro-USB port used for power supply to the board, for flashing applications to the chip, as well as for communication with the chip via the on-board USB-to-UART bridge.</td>
</tr>
<tr>
<td>Boot Button</td>
<td>Download button. Holding down Boot and then pressing Reset initiates Firmware Download mode for downloading firmware through the serial port.</td>
</tr>
<tr>
<td>Reset Button</td>
<td>Press this button to restart ESP32-S3.</td>
</tr>
<tr>
<td>ESP32-S3 USB Port</td>
<td>ESP32-S3 full-speed USB OTG interface, compliant with the USB 1.1 specification. The interface is used for power supply to the board, for flashing applications to the chip, for communication with the chip using USB 1.1 protocols, as well as for JTAG debugging.</td>
</tr>
<tr>
<td>USB-to-UART Bridge</td>
<td>Single USB-to-UART bridge chip provides transfer rates up to 3 Mbps.</td>
</tr>
<tr>
<td>RGB LED</td>
<td>Addressable RGB LED, driven by GPIO48.</td>
</tr>
<tr>
<td>3.3 V Power On LED</td>
<td>Turns on when the USB power is connected to the board.</td>
</tr>
</tbody>
</table>

#### Start Application Development

Before powering up your board, please make sure that it is in good condition with no obvious signs of damage.

#### Required Hardware

- ESP32-S3-DevKitM-1
- USB 2.0 cable (Standard-A to Micro-B)
- Computer running Windows, Linux, or macOS

**Note:** Be sure to use an appropriate USB cable. Some cables are for charging only and do not provide the needed data lines nor work for programming the boards.

#### Hardware Setup

Connect the board with the computer using USB-to-UART Port. Connection using ESP32-S3 USB Port is not fully implemented in software. In subsequent steps, USB-to-UART Port will be used by default.

#### 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 board.

#### Contents and Packaging

##### Retail Orders

If you order a few samples, each board comes in an individual package in either antistatic bag or any packaging depending on your retailer.

For retail orders, please go to https://www.espressif.com/en/company/contact/buy-a-sample.
**Wholesale Orders**  If you order in bulk, the boards come in large cardboard boxes.


**Hardware Reference**

**Block Diagram**  The block diagram below shows the components of ESP32-S3-DevKitM-1 and their interconnections.

![Block Diagram](image)

_Fig. 7: ESP32-S3-DevKitM-1 (click to enlarge)_

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

- USB-to-UART Port and ESP32-S3 USB Port (either one or both), default power supply (recommended)
- 5V and G (GND) pins
- 3V3 and G (GND) pins

**Header Block**  The two tables below provide the **Name** and **Function** of the pins on both sides of the board (J1 and J3). The pin names are shown in _ESP32-S3-DevKitM-1-front_. The numbering is the same as in the **Board Schematic** (PDF).
### J1

<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>0</td>
<td>I/O/T</td>
<td>RTC_GPIO0, GPIO0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>I/O/T</td>
<td>RTC_GPIO1, GPIO1, TOUCH1, ADC1_CH0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>I/O/T</td>
<td>RTC_GPIO2, GPIO2, TOUCH2, ADC1_CH1</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>I/O/T</td>
<td>RTC_GPIO3, GPIO3, TOUCH3, ADC1_CH2</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>I/O/T</td>
<td>RTC_GPIO4, GPIO4, TOUCH4, ADC1_CH3</td>
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<td>7</td>
<td>5</td>
<td>I/O/T</td>
<td>RTC_GPIO5, GPIO5, TOUCH5, ADC1_CH4</td>
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<td>I/O/T</td>
<td>RTC_GPIO6, GPIO6, TOUCH6, ADC1_CH5</td>
</tr>
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<td>7</td>
<td>I/O/T</td>
<td>RTC_GPIO7, GPIO7, TOUCH7, ADC1_CH6</td>
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<td>10</td>
<td>8</td>
<td>I/O/T</td>
<td>RTC_GPIO8, GPIO8, TOUCH8, ADC1_CH7, SUBSPICS1</td>
</tr>
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<td>11</td>
<td>9</td>
<td>I/O/T</td>
<td>RTC_GPIO9, GPIO9, TOUCH9, ADC1_CH8, FSPIH3, SUBSPIHD</td>
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<tr>
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<td>10</td>
<td>I/O/T</td>
<td>RTC_GPIO10, GPIO10, TOUCH10, ADC1_CH9, FSPICS0, FSPIO4, SUBSPICS0</td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>I/O/T</td>
<td>RTC_GPIO11, GPIO11, TOUCH11, ADC2_CH0, FSPID, FSPIO5, SUBSPID</td>
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<tr>
<td>14</td>
<td>12</td>
<td>I/O/T</td>
<td>RTC_GPIO12, GPIO12, TOUCH12, ADC2_CH1, FSPICLK, FSPIO6, SUBSPI-CLK</td>
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<td>15</td>
<td>13</td>
<td>I/O/T</td>
<td>RTC_GPIO13, GPIO13, TOUCH13, ADC2_CH2, FSPIQ, FSPIO7, SUBSPIQ</td>
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<td>16</td>
<td>14</td>
<td>I/O/T</td>
<td>RTC_GPIO14, GPIO14, TOUCH14, ADC2_CH3, FSPIWP, FSPIDQS, SUBSPIWP</td>
</tr>
<tr>
<td>17</td>
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<td>P</td>
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<td>22</td>
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<td>G</td>
<td>Ground</td>
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For description of function names, please refer to ESP32-S3 Datasheet (PDF).

P: Power supply; I: Input; O: Output; T: High impedance.
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Fig. 8: ESP32-S3-DevKitM-1 Pin Layout (click to enlarge)

Pin Layout

Hardware Revision Details  This is the first revision of this board released.

Related Documents

- ESP32-S3 Datasheet (PDF)
- ESP32-S3-MINI-1 & ESP32-S3-MINI-1U Datasheet (PDF)
- ESP32-S3-DevKitM-1 Schematic (PDF)
- ESP32-S3-DevKitM-1 PCB layout (PDF)
- ESP32-S3-DevKitM-1 Dimensions (PDF)
- ESP32-S3-DevKitM-1 Dimensions source file (DXF) - You can view it with Autodesk Viewer online

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

1.2.2 Software

To start using ESP-IDF on ESP32-S3 you’ll need the following software installed:

- **Toolchain** to compile code for ESP32-S3
- **Build tools** - CMake and Ninja to build a full Application for ESP32-S3
- **ESP-IDF** that essentially contains API (software libraries and source code) for ESP32-S3 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.

Build and Flash with Eclipse IDE

ESP-IDF V4.0 has a new CMake-based build system as the default build system.

There is a new ESP-IDF Eclipse Plugin that works with the CMake-based build system. Please refer to Espressif IDF Eclipse Plugins IDF for further instructions.

Note: In Espressif IDF Eclipse Plugins, though screenshots are captured from macOS, installation instructions are applicable for Windows, Linux and macOS.

Getting Started with VS Code IDE

We have official support for VS Code and we aim to provide complete end to end support for all actions related to ESP-IDF namely build, flash, monitor, debug, tracing, core-dump, System Trace Viewer, etc.
Quick Install Guide  Recommended way to install ESP-IDF Visual Studio Code Extension is by downloading it from VS Code Marketplace or following Quick Installation Guide.


Supported Features

- Setup, will help you to quickly install ESP-IDF and its relevant toolchain with just few clicks.
- Build, with one click build and multi target build, you can easily build and deploy your applications.
- Flash, with both UART and JTAG flash out of the box.
- Monitoring comes with built-in terminal where you can trigger IDF Monitor Commands from within VS Code as you are used to in traditional terminals.
- Debugging <https://github.com/espressif/vscode-esp-idf-extension/blob/master/docs/tutorial/debugging.md>, with out of box hardware debugging and also support for postmortem debugging like core-dump, you can analyze the bugs with convenience.
- GUI Menu Config, provides with simplified UI for configuring your chip.
- App & Heap Tracing, provides support for collecting traces from your application and simplified UI for analyzing them.
- System View Tracing Viewer, aims to read and display the .svdat files into trace UI, we also support multiple core tracing views.
- IDF Size Analysis Overview presents an UI for binary size analysis.
- Rainmaker Cloud, we have inbuilt Rainmaker Cloud support where you can edit/read state of your connected IoT devices easily.
- Code Coverage, we have inbuilt code coverage support which shall highlight in color which line have been covered. We also render the existing HTML report directly inside the IDE.

Bugs & Feature Requests  If you face an issue with certain feature of VS Code or VS Code in general we recommend to ask your question in the forum, or open a github issue for our dev teams to review.

We also welcome new feature request, most of the features we have today is result of people asking it to implement, or improve certain aspect of the extension, raise your feature request on github.

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 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.

Windows Installer Download

What is the usecase 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:

Run ESP-IDF Command Prompt (cmd.exe):

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.
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Fig. 9: Completing the ESP-IDF Tools Setup Wizard with Run ESP-IDF PowerShell Environment

Fig. 10: ESP-IDF PowerShell
Fig. 11: Completing the ESP-IDF Tools Setup Wizard with Run ESP-IDF Command Prompt (cmd.exe)
Fig. 12: ESP-IDF Command Prompt
First Steps on ESP-IDF  Now you have all requirements 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-S3 and build, flash, and monitor the device output.

**Note:** If you haven’t yet installed the 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-S3. You can start with get-started/hello_world project from examples directory in 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:

**Windows**

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

**Linux/macOS**

```bash
 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-S3 board to the computer and check under what serial port the board is visible.

Serial ports have the following patterns in their names:

- **Windows:** names like COM1
- **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-S3 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-S3 chip as the target and run the project configuration utility menuconfig.

**Windows**

```bash
 cd %userprofile%\esp\hello_world
 idf.py set-target esp32s3
 idf.py menuconfig
```
Linux/macOS

```bash
cd ~/esp/hello_world
idf.py set-target esp32s3
idf.py menuconfig
```

Setting the target with `idf.py set-target esp32s3` should be done once after opening a new project. If the project contains some existing builds and configurations, they will be cleared and initialized. The target may be saved in the environment variable to skip this step at all. See Selecting the Target for additional information.

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

![Menu configuration](image)

Fig. 13: 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_word”. This example will run with default configuration.

**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.

**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_iot component due to configuration
-- Component names: ...
-- Component paths: ...
... (more lines of build system output)
```
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.
0x01000 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**  Flash the binaries that you just built (bootloader.bin, partition-table.bin and hello_world.bin) onto your ESP32-S3 board by running:
```
idf.py -p PORT [-b BAUD] flash
```

Replace PORT with your ESP32-S3 board’s serial port name.

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

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?**  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 manual reset described below, and if it does not help you can find more details about possible issues in [*Troubleshooting*](#).

`esptool.py` resets ESP32-S3 automatically by asserting DTR and RTS control lines of the USB to serial converter chip, i.e., FTDI or CP210x (for more information, see [*Establish Serial Connection with ESP32-S3*](#)). The DTR and RTS control lines are in turn connected to GPIO0 and CHIP_PU (EN) pins of ESP32-S3, thus changes in the voltage levels of DTR and RTS will boot ESP32-S3 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:

- 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-S3 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.

**Normal Operation**  When flashing, you will see the output log similar to the following:
... 
esptool.py esp32s3 -p /dev/ttyUSB0 -b 460800 --before=default_reset --after=hard_reset 
--reset write_flash --flash_mode dio --flash_freq 80m --flash_size 2MB 0x0
--bootloader/bootloader.bin 0x10000 hello_world.bin 0x8000 partition_table/
--partition-table.bin
esptool.py v3.2-dev
Serial port /dev/ttyUSB0
Connecting...
Chip is ESP32-S3
Features: WiFi, BLE
Crystal is 40MHz
MAC: 7c:df:a1:e0:00:64
Uploading stub...
Running stub...
Stub running...
Changing baud rate to 460800
Changed.
Configuring flash size...
Flash will be erased from 0x00000000 to 0x00004fff...
Flash will be erased from 0x00010000 to 0x00039fff...
Flash will be erased from 0x00008000 to 0x00008fff...
Compressed 18896 bytes to 11758...
Writing at 0x00000000... (100 %)
Wrote 18896 bytes (11758 compressed) at 0x00000000 in 0.5 seconds (effective 279.9...
→ kbit/s)... 
Hash of data verified.
Compressed 168208 bytes to 88178...
Writing at 0x00010000... (16 %)
Writing at 0x0001a80f... (33 %)
Writing at 0x000201f1... (50 %)
Writing at 0x00025dcf... (66 %)
Writing at 0x0002d0be... (83 %)
Writing at 0x00036c07... (100 %)
Wrote 168208 bytes (88178 compressed) at 0x00010000 in 2.4 seconds (effective 569.2 kbit/s)... 
Hash of data verified.
Compressed 3072 bytes to 103...
Writing at 0x00008000... (100 %)
Wrote 3072 bytes (103 compressed) at 0x00008000 in 0.1 seconds (effective 478.9...
→ 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 the Eclipse guide, VS Code guide.

**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 ---
```

(continues on next page)
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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 esp32s3 chip with 2 CPU core(s), This is esp32s3 chip with 2 CPU_
    core(s), WiFi/BLE, silicon revision 0, 2MB external flash
    Minimum free heap size: 390684 bytes
    Restarting in 9 seconds...
    Restarting in 8 seconds...
    Restarting in 7 seconds...
```

To exit IDF monitor use the shortcut Ctrl+].

**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-S3!

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-S3 because required hardware is not included in ESP32-S3 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-S3 target, or the table does not exist at all, the example will work on ESP32-S3.

**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-S3. *This can be solved by adding the current user to the dialout group.*

**Python compatibility** ESP-IDF supports Python 3.6 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.

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

**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-S3** This section provides guidance how to establish serial connection between ESP32-S3 and PC.

**Connect ESP32-S3 to PC** Connect the ESP32-S3 board to the PC using the USB cable. If device driver does not install automatically, identify USB to serial converter chip on your ESP32-S3 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-S3 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 serial converter 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.

**Check port on Windows** Check the list of identified COM ports in the Windows Device Manager. Disconnect ESP32-S3 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
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Fig. 14: USB to UART bridge of ESP32-DevKitC in Windows Device Manager
Fig. 15: Two USB Serial Ports of ESP-WROVER-KIT in Windows Device Manager
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Check port on Linux and macOS  To check the device name for the serial port of your ESP32-S3 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:

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 as shown in the Getting Started guide for your particular development board. 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 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-S3.

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 program and set communication parameters like below.

Run terminal, set identified serial port, baud rate = 115200, data bits = 8, stop bits = 1, and parity = N. Below are example screen shots 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-S3. The log contents will depend on application loaded to ESP32-S3, 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_USBtoUART
  ```
Fig. 16: Setting Serial Communication in PuTTY on Windows
Fig. 17: Setting Serial Communication in PuTTY on Linux
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- 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:

```
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-S3, 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 by ESP32-S3 is shown below. Reset the board if you do not see anything.

```
ets Jun 8 2016 00:22:57
rst:0x5 (DEEPSLEEP_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
ets Jun 8 2016 00:22:57
rst:0x7 (TG0WDT_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 of application to ESP32-S3.

**Note:** For some serial port wiring configurations, the serial RTS & DTR pins need to be disabled in the terminal program before the ESP32-S3 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-S3 development, then you can continue with *Step 5. First Steps on ESP-IDF*.

**IDF Monitor**  
The IDF monitor tool is mainly a serial terminal program which relays serial data to and from the target device’s serial port. It also provides some IDF-specific features.

This tool 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.
Keyboard Shortcut | Action | Description
--- | --- | ---
Ctrl+J | Exit the program | Press and follow it by one of the keys given below.
Ctrl+T | Menu escape key | Send the menu character itself to remote
• Ctrl+T | Send the menu character itself to remote | Press and follow it by one of the keys given below.
• Ctrl+J | Send the exit character itself to remote | 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.
• Ctrl+P | Reset target into bootloader to pause app via RTS line | Resets the target board and re-starts the application via the RTS line (if connected).
• Ctrl+R | Reset target board via RTS | Reset target board via RTS line (if connected).
• Ctrl+F | Build and flash the project | Build and flash the project. 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.
• Ctrl+A (or A) | Build and flash the app only | Build and flash the app only. 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.
• Ctrl+Y | Stop/resume log output printing on screen | Stop/resume log output printing on screen. Discards all incoming serial data while activated. Allows to quickly pause and examine log output without quitting the monitor.
• Ctrl+L | Stop/resume log output saved to file | Stop/resume log output saved to file. 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).
• Ctrl+I (or I) | Stop/resume printing timestamps | 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.
• Ctrl+H (or H) | Display all keyboard shortcuts | Display all keyboard shortcuts.
• Ctrl+X (or X) | Exit the program | Exit the program.
Ctrl+C | Interrupt running application | Pauses IDF monitor and run GDB project debugger to debug the application at runtime. This requires :ref:CONFIG_ESP_SYSTEM_GDBSTUB_RUNTIME option to be enabled.

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

**IDF-specific features**

**Automatic Address Decoding** Whenever ESP-IDF outputs a hexadecimal code address of the form 0x4_______, IDF Monitor uses addr2line to look up the location in the source code and find the function name.

If an ESP-IDF app crashes and panics, a register dump and backtrace is produced, such as the following:
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Guru Meditation Error of type StoreProhibited occurred on core 0. Exception was unhandled.
Register dump:
PC : 0x400f360d PS : 0x00060330 A0 : 0x800dbf56 A1 : ...
-0x3ffbe00
A2 : 0x3ffbd16c A3 : 0x00000005 A4 : 0x00000000 A5 : ...
-0x00000000
A6 : 0x00000000 A7 : 0x00000080 A8 : 0x00000000 A9 : ...
-0x3ffbe7dd0
A10 : 0x00000003 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
-0x3ffbe6d0
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:0x3ffbe90

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 : ...
-0x3ffbe00
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 : 0x3ffbd16c A3 : 0x00000005 A4 : 0x00000000 A5 : ...
-0x00000000
A6 : 0x00000000 A7 : 0x00000080 A8 : 0x00000000 A9 : ...
-0x3ffbe7dd0
A10 : 0x00000003 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
-0x3ffbe6d0
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:0x3ffbe90

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 : 0x3ffbd16c A3 : 0x00000005 A4 : 0x00000000 A5 : ...
-0x00000000
A6 : 0x00000000 A7 : 0x00000080 A8 : 0x00000000 A9 : ...
-0x3ffbe7dd0
A10 : 0x00000003 A11 : 0x00060f23 A12 : 0x00060f20 A13 : ...
-0x3ffbe6d0
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:0x3ffbe90

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

xtensa-esp32s3-elf-addr2line -pfiaC -e build/PROJECT.elf ADDRESS

Note: Set environment variable ESP_MONITOR_DECODE to 0 or call idf_monitor.py with specific command line
**Chapter 1. Get Started**

option: `idf_monitor.py --disable-address-decoding` to disable address decoding.

**Launching GDB with GDBStub**

By default, if esp-idf crashes, the panic handler prints relevant registers and the stack dump (similar to the ones above) over the serial port. Then it resets the board.

Furthermore, the application can be configured to run GDBStub in the background and handle the Ctrl+C event from the monitor.

Optionally, the panic handler can be configured to run GDBStub, the tool which can communicate with **GDB** project debugger. GDBStub allows to read memory, examine call stack frames and variables, etc. It is not as versatile as JTAG debugging, but this method does not require any special hardware.

To enable GDBStub on panic, open the project configuration menu (`idf.py menuconfig`) and set `CONFIG_ESP_SYSTEM_PANIC` to `GDBStub on panic` or set `CONFIG_ESP_SYSTEM_PANIC` to `GDBStub on runtime`.

In this case, if the panic handler or Ctrl+C command is triggered, as soon as IDF Monitor sees that GDBStub has loaded, it automatically pauses serial monitoring and runs GDB with necessary arguments. After GDB exits, the board is reset via the RTS serial line. If this line is not connected, please reset the board manually by pressing its Reset button.

In the background, IDF Monitor runs the following command:

```
x tenga-esp32s3-elf-gdb -ex "set serial baud BAUD" -ex "target remote PORT" -ex...
```

**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 `tag1` prints nothing. Using `*:V` 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:V"` 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.
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- 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: Pro 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
D (318) vfs: esp_vfs_register_fd_range is successful for range <54; 64) and VFS ID...
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-S3.

- **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-S3, 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-setuptools cmake ninja-build ccache libffi-dev libssl-dev dfu-util libusb1.0-0
```

• CentOS 7 & 8:

```
sudo yum -y update && sudo yum install git wget flex bison gperf python3-pip python3-setuptools cmake ninja-build ccache dfu-util libusb1
```

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-pip cmake ninja --ccache dfu-util libusb
```

Note:

• CMake version 3.5 or newer is required for use with ESP-IDF. Older Linux distributions may require updating, enabling of a “backports” repository, or installing of a “cmake3” package rather than “cmake”.
• 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 pip:

```
sudo easy_install pip
```

• 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.
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**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-S3, 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 --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.

```
cd ~/esp/esp-idf
./install.sh esp32s3
```

or with Fish shell

```
cd ~/esp/esp-idf
./install.fish esp32s3
```

**Note:** To install tools for multiple targets you can specify those targets at once. For example: `./install.sh esp32,esp32c3,esp32s3`. To install tools for all supported targets, run the script without specifying targets `./install.sh all`.

**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.
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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:

```
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:

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

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

```
. $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.)

   ```
   alias get_idf=' $HOME/esp/esp-idf/export.sh'
   ```

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 you have all requirements 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-S3 and build, flash, and monitor the device output.

Note: If you haven’t yet installed the 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-S3. You can start with `get-started/hello_world` project from `examples` directory in 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:

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

**Linux/macOS**
```
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-S3 board to the computer and check under what serial port the board is visible.

Serial ports have the following patterns in their names:

- **Windows:** names like COM1
- **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-S3* 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-S3 chip as the target and run the project configuration utility `menuconfig`.

**Windows**
```
cd %userprofile%\esp\hello_world
idf.py set-target esp32s3
idf.py menuconfig
```

**Linux/macOS**
```
cd ~/esp/hello_world
idf.py set-target esp32s3
idf.py menuconfig
```

Setting the target with `idf.py set-target esp32s3` should be done once after opening a new project. If the project contains some existing builds and configurations, they will be cleared and initialized. The target may be saved in the environment variable to skip this step at all. See *Selecting the Target* for additional information.

If the previous steps have been done correctly, the following menu appears:
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”. This example will run with default configuration.

**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.

### Build the Project

Build the project by running:

```
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: ...
-- 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 0x10000 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**   Flash the binaries that you just built (bootloader.bin, partition-table.bin and hello_world.bin) onto your ESP32-S3 board by running:

```
idf.py -p PORT [-b BAUD] flash
```

Replace PORT with your ESP32-S3 board’s serial port name.

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

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?**   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 manual reset described below, and if it does not help you can find more details about possible issues in Troubleshooting.

`esptool.py` resets ESP32-S3 automatically by asserting DTR and RTS control lines of the USB to serial converter chip, i.e., FTDI or CP210x (for more information, see *Establish Serial Connection with ESP32-S3*). The DTR and RTS control lines are in turn connected to GPIO0 and CHIP_PU (EN) pins of ESP32-S3, thus changes in the voltage levels of DTR and RTS will boot ESP32-S3 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:

- 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-S3 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.

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

```bash
... esptool.py esp32s3 -p /dev/ttyUSB0 -b 460800 --before=default_reset --after=hard_
  → reset write_flash --flash_mode dio --flash_freq 80m --flash_size 2MB 0x0_
  → bootloader/bootloader.bin 0x10000 hello_world.bin 0x8000 partition_table/
  → partition-table.bin
  esptool.py v3.2-dev
  Serial port /dev/ttyUSB0
  Connecting....
  Chip is ESP32-S3
  Features: WiFi, BLE
  Crystal is 40MHz
  MAC: 7c:df:a1:e0:00:64
  Uploading stub...
  Running stub...
  Stub running...
  Changing baud rate to 460800
  Changed.
```

(continues on next page)
Chapter 1. Get Started

Configuring flash size...
Flash will be erased from 0x00000000 to 0x00004fff...
Flash will be erased from 0x00010000 to 0x00039fff...
Flash will be erased from 0x00008000 to 0x00008fff...
Compressed 18896 bytes to 11758...
Writing at 0x00000000... (100 %)
Wrote 18896 bytes (11758 compressed) at 0x00000000 in 0.5 seconds (effective 279.9
→ kbit/s)...
Hash of data verified.
Compressed 168208 bytes to 88178...
Writing at 0x00010000... (16 %)
Writing at 0x0001a80f... (33 %)
Writing at 0x000201f1... (50 %)
Writing at 0x00025dcf... (66 %)
Writing at 0x0002d0be... (83 %)
Writing at 0x00036c07... (100 %)
Wrote 168208 bytes (88178 compressed) at 0x00010000 in 2.4 seconds (effective 569.
→2 kbit/s)...
Hash of data verified.
Compressed 3072 bytes to 103...
Writing at 0x00008000... (100 %)
Wrote 3072 bytes (103 compressed) at 0x00008000 in 0.1 seconds (effective 478.9
→ 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 the Eclipse guide, VS Code guide.

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 esp32s3 chip with 2 CPU core(s), This is esp32s3 chip with 2 CPU_
→core(s), WiFi/BLE, silicon revision 0, 2MB external flash
Minimum free heap size: 390684 bytes
  Restarting in 9 seconds...
```

(continues on next page)
Restarting in 8 seconds...
Restarting in 7 seconds...

To exit IDF monitor use the shortcut Ctrl+]..

**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-S3!

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-S3 because required hardware is not included in ESP32-S3 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-S3 target, or the table does not exist at all, the example will work on ESP32-S3.

**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-S3. *This can be solved by adding the current user to the dialout group.*

**Python compatibility** ESP-IDF supports Python 3.6 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*.

**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**
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 *Step 5. First Steps on ESP-IDF*. 
Chapter 2

API Reference

2.1 Bluetooth API

2.1.1 Controller && VHCI

Overview

Instructions

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 Re-set/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.

Return

- ESP_OK - success, other - failed

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)

```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.

Return

- >= 0 - Power level, < 0 - Invalid

Parameters

- power_type: The type of which tx power, could set Advertising/Connection/Default and etc

```c
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 range of minimum value and maximum value. The power level will effect the global BR/EDR TX power, such inquire, page, connection and so on.
Please call the function after `esp_bt_controller_enable` and before any function which cause RF do 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 inquire, you should call this function before inquire. Another word, If call this function when BR/EDR is in inquire(ING), please do inquire again after call this function. Default minimum power level is `ESP_PWR_LVL_N0`, and maximum power level is `ESP_PWR_LVL_P3`.

Return ESP_OK - success, other - failed

Parameters
  - min_power_level: The minimum power level
  - max_power_level: The maximum power level

`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.

Return ESP_OK - success, other - failed

Parameters
  - min_power_level: The minimum power level
  - max_power_level: The maximum power level

`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.

Return ESP_OK - success, other - failed

Parameters
  - data_path: SCO data path

`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.

Return ESP_OK - success, other - failed

Parameters
  - cfg: Initial configuration of BT controller. Different from previous version, there’s a mode and some connection configuration in “cfg” to configure controller work mode and allocate the resource which is needed.

`esp_err_t esp_bt_controller_deinit(void)`

De-initialize BT controller to free resource and delete task.

This function should be called only once, after any other BT functions are called.

Return 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.

Return ESP_OK - success, other - failed

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()`.

`esp_err_t esp_bt_controller_disable(void)`

Disable BT controller.

Return 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.

Return status value

`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.
**Return** true for ready to send, false means cannot send packet

```c
void esp_vhci_host_send_packet (uint8_t *data, uint16_t len)
```

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)
```

Register the vhci reference callback struct defined by vhci_host_callback structure.

**Return** ESP_OK - success, ESP_FAIL - failed

**Parameters**
- **callback**: esp_vhci_host_callback type variable

```c
esp_err_t esp_bt_controller_mem_release (esp_bt_mode_t mode)
```

Release the controller memory as per the 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_BTDM, then it may be useful to call API esp_bt_mem_release(ESP_BT_MODE_BTDM) instead, which internally calls esp_bt_controller_mem_release(ESP_BT_MODE_BTDM) 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.

**Return** ESP_OK - success, other - failed

**Parameters**
- **mode**: the mode want to release memory

```c
esp_err_t esp_bt_mem_release (esp.bt_mode_t mode)
```

Release controller memory and BSS and data section of the BT/BLE host stack as per the 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_BTDM, 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.

**Return**  ESP_OK - success, other - failed

**Parameters**

- `mode`: the mode whose memory is to be released

```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”.

**Return**

- 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.

**Return**

- 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.

**Return**

- ESP_OK : success
- other : failed

```c
void esp_wifi_bt_power_domain_on(void)
```

bt Wi-Fi power domain power on

```c
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

uint8_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

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:

ESP_BT_MODE_IDLE = 0x00
Bluetooth is not running

ESP_BT_MODE_BLE = 0x01
Run BLE mode

ESP_BT_MODE_CLASSIC_BT = 0x02
Run Classic BT mode

ESP_BT_MODE_BTDM = 0x03
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:

ESP_BLE_SCA_500PPM = 0
BLE SCA at 500ppm

ESP_BLE_SCA_250PPM
BLE SCA at 250ppm

ESP_BLE_SCA_150PPM
BLE SCA at 150ppm

ESP_BLE_SCA_100PPM
BLE SCA at 100ppm

ESP_BLE_SCA_75PPM
BLE SCA at 75ppm
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ESP_BLE_SCA_50PPM
BLE SCA at 50ppm

ESP_BLE_SCA_30PPM
BLE SCA at 30ppm

ESP_BLE_SCA_20PPM
BLE SCA at 20ppm

enum esp_bt_controller_status_t
Bluetooth controller enable/disable/initiated/de-initialised status.
Values:

ESP_BT_CONTROLLER_STATUS_IDLE = 0
ESP_BT_CONTROLLER_STATUS_INITED
ESP_BT_CONTROLLER_STATUS_ENABLED
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_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:

ESP_BLE_PWR_TYPE_CONN_HDL0 = 0
For connection handle 0
ESP_BLE_PWR_TYPE_CONN_HDL1 = 1
For connection handle 1
ESP_BLE_PWR_TYPE_CONN_HDL2 = 2
For connection handle 2
ESP_BLE_PWR_TYPE_CONN_HDL3 = 3
For connection handle 3
ESP_BLE_PWR_TYPE_CONN_HDL4 = 4
For connection handle 4
ESP_BLE_PWR_TYPE_CONN_HDL5 = 5
For connection handle 5
ESP_BLE_PWR_TYPE_CONN_HDL6 = 6
For connection handle 6
ESP_BLE_PWR_TYPE_CONN_HDL7 = 7
For connection handle 7
ESP_BLE_PWR_TYPE_CONN_HDL8 = 8
For connection handle 8
ESP_BLE_PWR_TYPE_ADV = 9
For advertising
ESP_BLE_PWR_TYPE_SCAN = 10
For scan
ESP_BLE_PWR_TYPE_DEFAULT = 11
For default, if not set other, it will use default value
ESP_BLE_PWR_TYPE_NUM = 12
TYPE numbers
enum esp_power_level_t

Bluetooth TX power level(index), it’s just a index corresponding to power(dbm).

Values:

ESP_PWR_LVL_N12 = 0
Corresponding to -12dbm

ESP_PWR_LVL_N9 = 1
Corresponding to -9dbm

ESP_PWR_LVL_N6 = 2
Corresponding to -6dbm

ESP_PWR_LVL_N3 = 3
Corresponding to -3dbm

ESP_PWR_LVL_N0 = 4
Corresponding to 0dbm

ESP_PWR_LVL_P3 = 5
Corresponding to +3dbm

ESP_PWR_LVL_P6 = 6
Corresponding to +6dbm

ESP_PWR_LVL_P9 = 7
Corresponding to +9dbm

ESP_PWR_LVL_N14 = ESP_PWR_LVL_N12
Backward compatibility! Setting to -14dbm will actually result to -12dbm

ESP_PWR_LVL_N11 = ESP_PWR_LVL_N9
Backward compatibility! Setting to -11dbm will actually result to -9dbm

ESP_PWR_LVL_N8 = ESP_PWR_LVL_N6
Backward compatibility! Setting to -8dbm will actually result to -6dbm

ESP_PWR_LVL_N5 = ESP_PWR_LVL_N3
Backward compatibility! Setting to -5dbm will actually result to -3dbm

ESP_PWR_LVL_N2 = ESP_PWR_LVL_N0
Backward compatibility! Setting to -2dbm will actually result to 0dbm

ESP_PWR_LVL_P1 = ESP_PWR_LVL_P3
Backward compatibility! Setting to +1dbm will actually result to +3dbm

ESP_PWR_LVL_P4 = ESP_PWR_LVL_P6
Backward compatibility! Setting to +4dbm will actually result to +6dbm

ESP_PWR_LVL_P7 = ESP_PWR_LVL_P9
Backward compatibility! Setting to +7dbm will actually result to +9dbm

enum esp_sco_data_path_t

Bluetooth audio data transport path.

Values:

ESP_SCO_DATA_PATH_HCI = 0
data over HCI transport

ESP_SCO_DATA_PATH_PCM = 1
data over PCM interface

2.1.2 BT COMMON
BT GENERIC DEFINES

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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

uint16_t uuid16

16bit UUID

uint32_t uuid32

32bit UUID

uint8_t uuid128[ESP_UUID_LEN_128]

128bit UUID

union esp_bt_uuid_t::[anonymous] uuid

UUID

Macros

ESP_BLUEDROID_STATUS_CHECK (status)

ESP_BT_OCTET16_LEN

ESP_BT_OCTET8_LEN

ESP_DEFAULT_GATT_IF

Default GATT interface id.

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_CONN_PARAM_UNDEF

ESP_BLE_SCAN_PARAM_UNDEF
ESP_BLE_IS_VALID_PARAM \((x, \text{min, max})\)  
Check the param is valid or not.

ESP_UUID_LEN_16  
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 \((\text{addr})\)  

**Type Definitions**  
\texttt{typedef} uint8_t \texttt{esp_bt_octet16_t}[\texttt{ESP_BT_OCTET16_LEN}]  
\texttt{typedef} uint8_t \texttt{esp_bt_octet8_t}[\texttt{ESP_BT_OCTET8_LEN}]  
\texttt{typedef} uint8_t \texttt{esp_link_key}[\texttt{ESP_BT_OCTET16_LEN}]  
\texttt{typedef} uint8_t \texttt{esp_bd_addr_t}[\texttt{ESP_BD_ADDR_LEN}]  
Bluetooth device address.

\texttt{typedef} uint8_t \texttt{esp_ble_key_mask_t}

**Enumerations**  
\texttt{enum esp_bt_status_t}  
Status Return Value.  
\texttt{Values:}\n
- \texttt{ESP_BT_STATUS_SUCCESS} = 0  
- \texttt{ESP_BT_STATUS_FAIL}  
- \texttt{ESP_BT_STATUS_NOT_READY}  
- \texttt{ESP_BT_STATUS_NOMEM}  
- \texttt{ESP_BT_STATUS_BUSY}  
- \texttt{ESP_BT_STATUS_DONE} = 5  
- \texttt{ESP_BT_STATUS_UNSUPPORTED}  
- \texttt{ESP_BT_STATUS_PARM_INVALID}  
- \texttt{ESP_BT_STATUS_UNHANDLED}
ESP_BT_STATUS_AUTH_FAILURE
ESP_BT_STATUS_RMT_DEV_DOWN = 10
ESP_BT_STATUS_AUTH_REJECTED
ESP_BT_STATUS_INVALID_STATIC RAND_ADDR
ESP_BT_STATUS_PENDING
ESP_BT_STATUS_UNACCEPT_CONN_INTERVAL
ESP_BT_STATUS_PARAM_OUT_OF_RANGE
ESP_BT_STATUS_TIMEOUT
ESP_BT_STATUS_PEER_LE_DATA_LEN_UNSUPPORTED
ESP_BT_STATUS_CONTROL_LE_DATA_LEN_UNSUPPORTED
ESP_BT_STATUS_ERR_ILLEGAL_PARAMETER_FMT
ESP_BT_STATUS_MEMORY_FULL = 20
ESP_BT_STATUS_EIR_TOO_LARGE

enum esp_bt_dev_type_t
  Bluetooth device type.
  
  Values:
  
  ESP_BT_DEVICE_TYPE_BREDR = 0x01
  ESP_BT_DEVICE_TYPE_BLE = 0x02
  ESP_BT_DEVICE_TYPE_DUMO = 0x03

enum esp_ble_addr_type_t
  BLE device address type.
  
  Values:
  
  BLE_ADDR_TYPE_PUBLIC = 0x00
  BLE_ADDR_TYPE_RANDOM = 0x01
  BLE_ADDR_TYPE_RPA_PUBLIC = 0x02
  BLE_ADDR_TYPE_RPA_RANDOM = 0x03

enum esp_ble_wl_addr_type_t
  white list address type
  
  Values:
  
  BLE_WL_ADDR_TYPE_PUBLIC = 0x00
  BLE_WL_ADDR_TYPE_RANDOM = 0x01

BT MAIN API

Overview  Instructions

Application Example  Instructions

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.

Return: Bluetooth stack status

`esp_err_t esp_bluedroid_enable (void)`
Enable bluetooth, must after esp_bluedroid_init().

Return:
- ESP_OK : Succeed
- Other : Failed

`esp_err_t esp_bluedroid_disable (void)`
Disable bluetooth, must prior to esp_bluedroid_deinit().

Return:
- ESP_OK : Succeed
- Other : Failed

`esp_err_t esp_bluedroid_init (void)`
Init and alloc the resource for bluetooth, must be prior to every bluetooth stuff.

Return:
- 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.

Return:
- ESP_OK : Succeed
- Other : Failed

Enumerations

`enum esp_bluedroid_status_t`
Bluetooth stack status type, to indicate whether the bluetooth stack is ready.

Values:

- `ESP_BLUEDROID_STATUS_UNINITIALIZED = 0`
  Bluetooth not initialized

- `ESP_BLUEDROID_STATUS_INITIALIZED`
  Bluetooth initialized but not enabled

- `ESP_BLUEDROID_STATUS_ENABLED`
  Bluetooth initialized and enabled

BT DEVICE APIs

Overview: Bluetooth device reference APIs.

Instructions

Application Example: Instructions

API Reference

Header File
- components/bt/host/bluedroid/api/include/api/esp_bt_device.h
Chapter 2. API Reference

Functions

const uint8_t* esp_bt_dev_get_address (void)
Get bluetooth device address. Must use after “esp_bluedroid_enable”.

Return 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.

Return

• ESP_OK : Succeed
• ESP_ERR_INVALID_ARG : if name is NULL pointer or empty, or string length out of limit
• ESP_ERR_INVALID_STATE : if bluetooth stack is not yet enabled
• ESP_FAIL : others

Parameters

• [in] name: device name to be set

2.1.3 BT LE

GAP API

Overview

Instructions

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.

Return

• ESP_OK : success
• other : failed

Parameters

• [in] callback: callback function

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.

Return

• ESP_OK : success
• other : failed
Parameters
  • [in] adv_data: Pointer to User defined ADV data structure. This memory space can not be freed until callback of config_adv_data is received.

  \texttt{esp_err_t esp_ble_gap_set_scan_params(esp_ble_scan_params_t \*scan_params)}

  This function is called to set scan parameters.

  Return
  • ESP_OK : success
  • other : failed

Parameters
  • [in] scan_params: Pointer to User defined scan_params data structure. This memory space can not be freed until callback of set_scan_params

  \texttt{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.

  Return
  • ESP_OK : success
  • other : failed

Parameters
  • [in] duration: Keeping the scanning time, the unit is second.

  \texttt{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.

  Return
  • ESP_OK : success
  • other : failed

  \texttt{esp_err_t esp_ble_gap_start_advertising(esp_ble_adv_params_t \*adv_params)}

  This function is called to start advertising.

  Return
  • ESP_OK : success
  • other : failed

Parameters
  • [in] adv_params: pointer to User defined adv_params data structure.

  \texttt{esp_err_t esp_ble_gap_stop_advertising(void)}

  This function is called to stop advertising.

  Return
  • ESP_OK : success
  • other : failed

  \texttt{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.

  Return
  • ESP_OK : success
  • other : failed

Parameters
  • [in] params: - connection update parameters

  \texttt{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.

  Return
  • ESP_OK : success
  • other : failed

  \texttt{esp_err_t esp_ble_gap_set_rand_addr(esp_bd_addr_t rand_addr)}

  This function sets the static Random Address and Non-Resolvable Private Address for the application.
Return
• ESP_OK : success
• other : failed

Parameters
• [in] rand_addr: the random address which should be setting

esp_err_t esp_ble_gap_clear_rand_addr (void)
This function clears the random address for the application.

Return
• ESP_OK : success
• other : failed

Parameters
• [in] privacy_enable: - enable/disable privacy on remote device.

esp_err_t esp_ble_gap_config_local_icon (uint16_t icon)
Set local gap appearance icon

Return
• ESP_OK : success
• other : failed

Parameters
• [in] icon: - External appearance value, these values are defined by the Bluetooth SIG, please refer to https://www.bluetooth.com/specifications/gatt/viewer?attributeXmlFile=org.bluetooth.characteristic.gap.appearance.xml

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.

Return
• ESP_OK : success
• other : failed

Parameters
• [in] add_remove: the value is true if added the ble device to the white list, and false remove to the white list.
• [in] remote_bda: the remote device address add/remove from the white list.
• [in] wl_addr_type: whitelisted device type

esp_err_t esp_ble_gap_clear_whitelist (void)
Clear all white list.

Return
• ESP_OK : success
• other : failed

esp_err_t esp_ble_gap_get_whitelist_size (uint16_t *length)
Get the white list size in the controller.

Return
• ESP_OK : success
• other : failed

Parameters
• [out] length: the white list length.
Chapter 2. API Reference

```c
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.

**Return**
- ESP_OK : success
- other : failed

**Parameters**
- [in] bd_addr: BD address of the peripheral
- [in] min_conn_int: minimum preferred connection interval
- [in] max_conn_int: maximum preferred connection interval
- [in] slave_latency: preferred slave latency
- [in] supervision_tout: preferred supervision timeout

```c
esp_err_t esp_ble_gap_set_device_name(const char *name)
```

Set device name to the local device.

**Return**
- ESP_OK : success
- other : failed

**Parameters**
- [in] name: device name.

```c
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.

**Return**
- ESP_OK : success
- other : failed

**Parameters**
- [in] local_used_addr: current local used ble address (six bytes)
- [in] addr_type: ble address type

```c
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.

**Return**
pointer of ADV data

**Parameters**
- [in] adv_data: pointer of ADV data which to be resolved
- [in] type: finding ADV data type
- [out] length: return the length of ADV data not including type

```c
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.

**Return**
- ESP_OK : success
- other : failed

**Parameters**
- [in] raw_data: raw advertising data
- [in] raw_data_len: raw advertising data length, less than 31 bytes

```c
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.

**Return**
- ESP_OK : success
- other : failed

**Parameters**
• [in] raw_data: raw scan response data
• [in] raw_data_len: raw scan response data length, less than 31 bytes

`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.

Return
• ESP_OK: success
• other: failed

Parameters
• [in] remote_addr: The remote connection device address.

`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.

Return
• ESP_OK: success
• other: failed

Parameters
• [in] type: 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.
• [in] device_info: the device information.

`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.

Return
• ESP_OK: success
• other: failed

Parameters
• [in] type: 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.
• [in] device_info: the device information.

`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.

Return
• ESP_OK: success
• other: failed

Parameters
• [in] list_type: duplicate scan exceptional list type, the value can be one or more of esp_duplicate_scan_exceptional_list_type_t.

`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'.

(continues on next page)
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').

Return:
- ESP_OK: success
- other: failed

Parameters:
- [in] param_type: the type of the param which to be set
- [in] value: the param value
- [in] len: the length of the param value

```c
esp_err_t esp_ble_gap_security_rsp(esp_bd_addr_t bd_addr, bool accept)
```

Grant security request access.

Return:
- ESP_OK: success
- other: failed

Parameters:
- [in] bd_addr: BD address of the peer
- [in] accept: accept the security request or not

```c
esp_err_t esp_ble_set_encryption(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.

Return:
- ESP_OK: success
- other: failed

Parameters:
- [in] bd_addr: the address of the peer device need to encryption
- [in] sec_act: This is the security action to indicate what kind of BLE security level is required for the BLE link if the BLE is supported

```c
esp_err_t esp_ble_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.

Return:
- ESP_OK: success
- other: failed

Parameters:
- [in] bd_addr: BD address of the peer
- [in] accept: passkey entry successful or declined.
- [in] passkey: passkey value, must be a 6 digit number, can be lead by 0.

```c
esp_err_t esp_ble_confirm_reply(esp_bd_addr_t bd_addr, bool accept)
```

Reply the confirm value to the peer device in the secure connection stage.

Return:
- ESP_OK: success
- other: failed

Parameters:
- [in] bd_addr: BD address of the peer device
- [in] accept: numbers to compare are the same or different.

```c
esp_err_t esp_ble_remove_bond_device(esp_bd_addr_t bd_addr)
```

Removes a device from the security database list of peer device. It manages unpairing event while connected.

Return:
- ESP_OK: success
- other: failed

Parameters
Chapter 2. API Reference

- [in] bd_addr: BD address of the peer device

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.

Return
- >= 0: bonded devices number.
- ESP_FAIL: failed

esp_err_t esp_ble_get_bond_device_list (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.

Return
- ESP_OK: success
- other: failed

Parameters
- [inout] dev_num: 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().
- [out] 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.

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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] bd_addr: BD address of the peer device.
- [in] TK: TK value, the TK value shall be a 128-bit random number
- [in] len: length of tk, should always be 128-bit

esp_err_t esp_ble_gap_disconnect (esp_bd_addr_t remote_device)
This function is to disconnect the physical connection of 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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] remote_device: BD address of the peer device

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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] bd_addr: BD address of the peer device.
- [out] conn_params: the connection parameters information

esp_err_t esp_gap_ble_set_channels (esp_gap_ble_channels channels)
BLE set channels.

Return
- ESP_OK: success
- ESP_ERR_INVALID_STATE: if bluetooth stack is not yet enabled
- other: failed

Parameters
- [in] channels: 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.
**Chapter 2. API Reference**

**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).

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] bd_addr: BD address of the peer device.
- [out] authorize: Authorized the link or not.

**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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] bd_addr: BD address of the peer device

**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 allow 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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] tx_phy_mask: : indicates the transmitter PHYs that the Host prefers the Controller to use
- [in] rx_phy_mask: : indicates the receiver PHYs that the Host prefers the Controller to use

**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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] bd_addr: : remote address
- [in] all_phys_mask: : a bit field that allows the Host to specify
- [in] tx_phy_mask: : a bit field that indicates the transmitter PHYs that the Host prefers the Controller to use
- [in] rx_phy_mask: : a bit field that indicates the receiver PHYs that the Host prefers the Controller to use
- [in] phy_options: : a bit field that allows the Host to specify options for PHYs

**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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] instance: : Used to identify an advertising set
- [in] rand_addr: : Random Device Address

**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.

**Return**
- ESP_OK: success
- other: failed
Parameters
• [in] instance: identifies the advertising set whose parameters are being configured.
• [in] params: advertising parameters

`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.

Return - ESP_OK : success
• other : failed

Parameters
• [in] instance: identifies the advertising set whose data are being configured
• [in] length: data length
• [in] data: data information

`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.

Return - ESP_OK : success
• other : failed

Parameters
• [in] instance: identifies the advertising set whose response data are being configured.
• [in] length: responsedata length
• [in] scan_rsp_data: response data information

`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.

Return - ESP_OK : success
• other : failed

Parameters
• [in] num_adv: Number of advertising sets to enable or disable
• [in] ext_adv: adv parameters

`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.

Return - ESP_OK : success
• other : failed

Parameters
• [in] num_adv: Number of advertising sets to enable or disable
• [in] ext_adv_inst: ext adv instance

`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.

Return - ESP_OK : success
• other : failed

Parameters
• [in] instance: Used to identify an advertising set

`esp_err_t esp_ble_gap_ext_adv_set_clear(void)`

This function is used to remove all existing advertising sets from the Controller.

Return - ESP_OK : success
• other : failed

`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.
Return  - ESP_OK : success  
  • other : failed  

Parameters  
  • [in] instance: : identifies the advertising set whose periodic advertising parameters are being configured.  
  • [in] params: : periodic adv parameters

`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.

Return  - ESP_OK : success  
  • other : failed  

Parameters  
  • [in] instance: : identifies the advertising set whose periodic advertising parameters are being configured.  
  • [in] length: : the length of periodic data  
  • [in] data:: periodic data information

`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.

Return  - ESP_OK : success  
  • other : failed  

Parameters  
  • [in] instance: : Used to identify an advertising set

`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.

Return  - ESP_OK : success  
  • other : failed  

Parameters  
  • [in] instance: : Used to identify an advertising set

`esp_err_t esp_ble_gap_set_ext_scan_params(const esp_ble_ext_scan_params_t *params)`  
This function is used to set the extended scan parameters to be used on the advertising channels.

Return  - ESP_OK : success  
  • other : failed  

Parameters  
  • [in] params:: scan parameters

`esp_err_t esp_ble_gap_start_ext_scan(uint32_t duration, uint16_t period)`  
This function is used to enable scanning.

Return  - ESP_OK : success  
  • other : failed  

Parameters  
  • [in] duration: : Scan duration  
  • [in] period: : Time interval from when the Controller started its last Scan Duration until it begins the subsequent Scan Duration.

`esp_err_t esp_ble_gap_stop_ext_scan(void)`  
This function is used to disable scanning.

Return  - ESP_OK : success  
  • other : failed

`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.

Return  - ESP_OK : success
• other : failed

**Parameters**

• [in] params: : sync parameters

```c
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.

**Return**

- ESP_OK : success
- other : failed

```c
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.

**Return**

- ESP_OK : success
- other : failed

**Parameters**

• [in] sync_handle: : identify the periodic advertiser

```c
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.

**Return**

- ESP_OK : success
- other : failed

**Parameters**

• [in] addr_type: : address type
• [in] addr:: Device Address
• [in] sid:: Advertising SID subfield in the ADI field used to identify the Periodic Advertising

```c
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.

**Return**

- ESP_OK : success
- other : failed

**Parameters**

• [in] addr_type: : address type
• [in] addr:: Device Address
• [in] sid:: Advertising SID subfield in the ADI field used to identify the Periodic Advertising

```c
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.

**Return**

- ESP_OK : success
- other : failed

```c
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.

**Return**

- ESP_OK : success
- other : failed

**Parameters**

• [in] addr:: device address
• [in] phy_mask:: 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.

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• [in] phy_1m_conn_params: Scan connectable advertisements on the LE 1M PHY. Connection parameters for the LE 1M PHY are provided.
• [in] phy_2m_conn_params: Connection parameters for the LE 2M PHY are provided.
• [in] phy_coded_conn_params: Scan connectable advertisements on the LE Coded PHY. Connection parameters for the LE Coded PHY are provided.

Unions

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_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

  struct esp_ble_gap_cb_param_t:ble_adv_data_cmpl_evt_param adv_data_cmpl
    Event parameter of ESP_GAP_BLE_ADV_DATA_CMPL_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_CMPL_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_CMPL_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 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_lenth_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_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_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
  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_PREFERED_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_PREFERED_PHY_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_cmpl_param 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_start_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_EXT_CONN_PARAMS_SET_COMPLETE_EVT

struct esp_ble_gap_cb_param_t::ble_adv_terminate_cmpl_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 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 operations 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_gap_ext_adv_report_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 sacn 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

```c
esp_bt_status_t status
```
Indicate advertising stop operation success status

```c
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

```c
esp_bt_status_t status
```
Indicate extend advertising parameters set status

```c
struct ble_ext_adv_set_rand_addr_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_SET_RAND_ADDR_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate extend advertising random address set status

```c
struct ble_ext_adv_set_remove_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_SET_REMOVE_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate advertising stop operation success status

```c
struct ble_ext_adv_start_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_START_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate advertising start operation success status

```c
struct ble_ext_adv_stop_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_EXT_ADV_STOP_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate advertising stop operation success status

```c
struct ble_ext_conn_params_set_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PREFER_EXT_CONN_PARAMS_SET_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate extend connection parameters set status

```c
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_local_privacy_cmpl_evt_param`
#include `<esp_gap_ble_api.h>` ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT.

Public Members

`esp_bt_status_t status`
Indicate the set local privacy operation success status

`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

`esp_bt_status_t status`
Indicate periodic advertising device list add status

`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

`esp_bt_status_t status`
Indicate periodic advertising device list clean status

`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

```c
struct ble_period_adv_sync_terminate_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SYNC_TERMINATE_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising sync terminate status

```c
struct ble_periodic_adv_data_set_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_DATA_SET_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising data set status

```c
struct ble_periodic_adv_report_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_REPORT_EVT.
```

Public Members

```c
esp_ble_gap_periodic_adv_report_t params
```
periodic advertising report parameters

```c
struct ble_periodic_adv_set_params_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_SET_PARAMS_COMPLETE_EVT.
```

Public Members

```c
esp_bt_status_t status
```
Indicate periodic advertising parameters set status

```c
struct ble_periodic_adv_start_cmpl_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_PERIODIC_ADV_START_COMPLETE_EVT.
```
Public Members

\texttt{esp\_bt\_status\_t \textit{status}}
Indicate periodic advertising start status

\texttt{struct ble\_periodic\_adv\_stop\_cmpl\_param}
\#include \texttt{<esp\_gap\_ble\_api\_h> \texttt{ESP\_GAP\_BLE\_PERIODIC\_ADV\_STOP\_COMPLETE\_EVT.}}

Public Members

\texttt{esp\_bt\_status\_t \textit{status}}
Indicate periodic advertising stop status

\texttt{struct ble\_periodic\_adv\_sync\_estab\_param}
\#include \texttt{<esp\_gap\_ble\_api\_h> \texttt{ESP\_GAP\_BLE\_PERIODIC\_ADV\_SYNC\_ESTAB\_EVT.}}

Public Members

\texttt{uint8\_t \textit{status}}
periodic advertising sync status

\texttt{uint16\_t \textit{sync\_handle}}
periodic advertising sync handle

\texttt{uint8\_t \textit{sid}}
periodic advertising sid

\texttt{esp\_ble\_addr\_type\_t \textit{adv\_addr\_type}}
periodic advertising address type

\texttt{esp\_bd\_addr\_t \textit{adv\_addr}}
periodic advertising address

\texttt{esp\_ble\_gap\_phy\_t \textit{adv\_phy}}
periodic advertising phy type

\texttt{uint16\_t \textit{period\_adv\_interval}}
periodic advertising interval

\texttt{uint8\_t \textit{adv\_clk\_accuracy}}
periodic advertising clock accuracy

\texttt{struct ble\_periodic\_adv\_sync\_lost\_param}
\#include \texttt{<esp\_gap\_ble\_api\_h> \texttt{ESP\_GAP\_BLE\_PERIODIC\_ADV\_SYNC\_LOST\_EVT.}}

Public Members

\texttt{uint16\_t \textit{sync\_handle}}
sync handle

\texttt{struct ble\_phy\_update\_cmpl\_param}
\#include \texttt{<esp\_gap\_ble\_api\_h> \texttt{ESP\_GAP\_BLE\_PHY\_UPDATE\_COMPLETE\_EVT.}}

Public Members

\texttt{esp\_bt\_status\_t \textit{status}}
phy update status

\texttt{esp\_bd\_addr\_t \textit{bda}}
address
**Chapter 2. API Reference**

```c
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_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT.
```

**Public Members**

```c
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_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_READ_PHY_COMPLETE_EVT.
```

**Public Members**

```c
esp_bt_status_t status
  read phy complete status

esp_bd_addr_t bda
  read phy address

esp_ble_gap_phy_t tx_phy
  tx phy type

esp_ble_gap_phy_t rx_phy
  rx phy type
```

```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

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.

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

esp_bd_addr_t bd_addr
  The device address which has been remove from the bond list
**struct ble_scan_param_cmpl_evt_param**

```c
#include <esp_gap_ble_api.h>  // ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT.
```

**Public Members**

- `esp_bt_status_t status`
  - Indicate the set scan param operation success status

**struct ble_scan_req_received_param**

```c
#include <esp_gap_ble_api.h>  // ESP_GAP_BLE_SCAN_REQ_RECEIVED_EVT.
```

**Public Members**

- `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

**struct ble_scan_result_evt_param**

```c
#include <esp_gap_ble_api.h>  // ESP_GAP_BLE_SCAN_RESULT_EVT.
```

**Public Members**

- `esp_gap_search_evt_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`
  - Ble 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

- `uint8_t scan_rsp_len`
  - Scan response length

- `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 stat
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_perf_def_phy_cmpl_evt_param
#include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PREFERED_DEFAULT_PHY_COMPLETE_EVT.
Chapter 2. API Reference

Public Members

```c
typedef enum esp_bt_status_t
{
    ESP_BT_SUCCESS = 0,
    ESP_BT_ERROR = 1
} esp_bt_status_t;
```

Indicate perf default phy set status

```c
struct ble_set_perf_phy_cmpl_evt_param
{
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_PREFERED_PHY_COMPLETE_EVT.
}
```

Public Members

```c
typedef enum esp_bt_status_t
{
    ESP_BT_SUCCESS = 0,
    ESP_BT_ERROR = 1
} esp_bt_status_t;
```

Indicate perf phy set status

```c
struct ble_set_rand_cmpl_evt_param
{
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT.
}
```

Public Members

```c
typedef enum esp_bt_status_t
{
    ESP_BT_SUCCESS = 0,
    ESP_BT_ERROR = 1
} esp_bt_status_t;
```

Indicate set static rand address operation success status

```c
struct ble_update_conn_params_evt_param
{
    #include <esp_gap_ble_api.h> ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT.
}
```

Public Members

```c
typedef enum esp_bt_status_t
{
    ESP_BT_SUCCESS = 0,
    ESP_BT_ERROR = 1
} esp_bt_status_t;
```

Indicate update connection parameters success status

```c
esp_bd_addr_t bda
```

Bluetooth device address

```c
uint16_t min_int
```

Min connection interval

```c
uint16_t max_int
```

Max connection interval

```c
uint16_t latency
```

Slave latency for the connection in number of connection events. Range: 0x0000 to 0x01F3

```c
uint16_t conn_int
```

Current connection interval

```c
uint16_t timeout
```

Supervision timeout for the LE Link. Range: 0x000A to 0x0C80. Mandatory Range: 0x000A to 0x0C80 Time = N * 10 msec

```c
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

```c
typedef enum esp_bt_status_t
{
    ESP_BT_SUCCESS = 0,
    ESP_BT_ERROR = 1
} esp_bt_status_t;
```

Indicate update duplicate scan exceptional list operation success status

```c
uint8_t subcode
```

Define in esp_bt_duplicate_exceptional_subcode_type_t
uint16_t length
The length of device_info

```c
esp_duplicate_info / device_info
```
device information, when subcode is ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_CLEAN, the value is invalid

```c
struct ble_update_whitelist_cmpl_evt_param
```
#include <esp_gap_ble_api.h> ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT.

**Public Members**

```c
esp_bt_status_t status
```
Indicate the add or remove whitelist operation success status

```c
esp_ble_wl_opration_t wl_opration
```
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

Advertising max interval

```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 0x0C80 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 following manner: connIntervalMax = Conn_Interval_Max * 1.25 ms Conn_Interval_Max range: 0x0006 to 0x0C80 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

exp_ble_scan_type_t scan_type
   Scan type

exp_ble_addr_type_t own_addr_type
   Owner address type

exp_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
  
  \[\text{Time} = N \times 10 \text{ msec} \]
  
  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
- `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
  
  \[\text{Time} = N \times 10 \text{ msec} \]
  
  Time Range: 100 msec to 32 seconds

**struct esp_ble_pkt_data_length_params_t**

BLE pkt data length keys.

**Public Members**

- `uint16_t rx_len`
  -(pkt rx data length value
- `uint16_t tx_len`
  -(pkt tx data length value

**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

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
BLE Encryption 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.
Chapter 2. API Reference

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_key_notif_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 witch 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_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_bit_dev_type_t dev_type
  Device type
- esp_ble_auth_req_t auth_mode
  authentication mode

struct esp_ble_gap_ext_adv_params_t
ext adv parameters
Public Members

\texttt{esp\_ble\_ext\_adv\_type\_mask\_t type}
\hspace{2em} ext adv type

\texttt{uint32\_t interval\_min}
\hspace{2em} ext adv minimum interval

\texttt{uint32\_t interval\_max}
\hspace{2em} ext adv maximum interval

\texttt{esp\_ble\_adv\_channel\_t channel\_map}
\hspace{2em} ext adv channel map

\texttt{esp\_ble\_addr\_type\_t own\_addr\_type}
\hspace{2em} ext adv own address type

\texttt{esp\_ble\_addr\_type\_t peer\_addr\_type}
\hspace{2em} ext adv peer address type

\texttt{esp\_bd\_addr\_t peer\_addr}
\hspace{2em} ext adv peer address

\texttt{esp\_ble\_adv\_filter\_t filter\_policy}
\hspace{2em} ext adv filter policy

\texttt{int8\_t tx\_power}
\hspace{2em} ext adv tx power

\texttt{esp\_ble\_gap\_pri\_phy\_t primary\_phy}
\hspace{2em} ext adv primary phy

\texttt{uint8\_t max\_skip}
\hspace{2em} ext adv maximum skip

\texttt{esp\_ble\_gap\_phy\_t secondary\_phy}
\hspace{2em} ext adv secondary phy

\texttt{uint8\_t sid}
\hspace{2em} ext adv sid

\texttt{bool scan\_req\_notif}
\hspace{2em} ext adv scan request event notify

\texttt{struct esp\_ble\_ext\_scan\_cfg\_t}
\hspace{2em} ext scan config

Public Members

\texttt{esp\_ble\_scan\_type\_t scan\_type}
\hspace{2em} ext scan type

\texttt{uint16\_t scan\_interval}
\hspace{2em} ext scan interval

\texttt{uint16\_t scan\_window}
\hspace{2em} ext scan window

\texttt{struct esp\_ble\_ext\_scan\_params\_t}
\hspace{2em} ext scan parameters

Public Members

\texttt{esp\_ble\_addr\_type\_t own\_addr\_type}
\hspace{2em} ext scan own address type
Chapter 2. API Reference

```c

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
```

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Public Members

```c
uint16_t interval_min
   periodic advertising minimum interval
uint16_t interval_max
   periodic advertising maximum interval
uint8_t properties
   periodic advertising properties
```

```c
struct esp_ble_gap_periodic_adv_sync_params_t
   periodic adv sync parameters
```

Public Members

```c
esp_ble_gap_sync_t filter_policy
   periodic advertising sync filter policy
uint8_t sid
   periodic advertising sid
esp_ble_addr_type_t addr_type
   periodic advertising address type
esp_bd_addr_t addr
   periodic advertising address
uint16_t skip
   the maximum number of periodic advertising events that can be skipped
uint16_t sync_timeout
   synchronization timeout
```

```c
struct esp_ble_gap_ext_adv_reprot_t
   extend adv report parameters
```

Public Members

```c
esp_ble_gap_adv_type_t event_type
   extend advertising type
uint8_t addr_type
   extend advertising address type
esp_bd_addr_t addr
   extend advertising address
esp_ble_gap_pri_phy_t primary_phy
   extend advertising primary phy
esp_ble_gap_phy_t secondly_phy
   extend advertising secondary phy
uint8_t sid
   extend advertising sid
uint8_t tx_power
   extend advertising tx power
int8_t rssi
   extend advertising rssi
uint16_t per_adv_interval
   periodic advertising interval
```
Chapter 2. API Reference

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
periodic adv sync establish parameters

Public Members

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
Macros

ESP_BLE_ADV_FLAG_LIMIT_DISC
  BLE_ADV_DATA_FLAG data 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
ESP_LE_KEY_PENC
ESP_LE_KEY_PID
ESP_LE_KEY_PCSRK
ESP_LE_KEY_PLK
ESP_LE_KEY_LLK
ESP_LE_KEY_LENC
ESP_LE_KEY_LID
ESP_LE_KEY_LCSRK
ESP_LE_AUTH_NO_BOND
ESP_LE_AUTH_BOND
ESP_LE_AUTH_REQ_MITM
ESP_LE_AUTH_REQ_BOND_MITM
ESP_LE_AUTH_REQ_SC_ONLY
ESP_LE_AUTH_REQ_SC_BOND
ESP_LE_AUTH_REQ_SC_MITM
ESP_LE_AUTH_REQ_SC_MITM_BOND
ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_DISABLE
ESP_BLE_ONLY_ACCEPT_SPECIFIED_AUTH_ENABLE
ESP_BLE_OOB_DISABLE
ESP_BLE_OOB_ENABLE
ESP_IO_CAP_OUT
ESP_IO_CAP_IO
ESP_IO_CAP_IN
ESP_IO_CAP_NONE
ESP_IO_CAP_KBDISP
ESP_BLE_APPEARANCE_UNKNOWN
ESP_BLE_APPEARANCE_GENERIC_PHONE
ESP_BLE_APPEARANCE_GENERIC_COMPUTER
ESP_BLE_APPEARANCE_GENERIC_WATCH
ESP_BLE_APPEARANCE_SPORTS_WATCH
ESP_BLE_APPEARANCE_GENERIC_CLOCK
ESP_BLE_APPEARANCE_GENERIC_DISPLAY
ESP_BLE_APPEARANCE_GENERIC_REMOTE
ESP_BLE_APPEARANCE_GENERIC_EYEGlasses
ESP_BLE_APPEARANCE_GENERIC_TAG
ESP_BLE_APPEARANCE_GENERIC_KEYRING
ESP_BLE_APPEARANCE_GENERIC_MEDIA_PLAYER
ESP_BLE_APPEARANCE_GENERIC_BARCODE.Scanner
ESP_BLE_APPEARANCE_GENERIC_THERMOMETER
ESP_BLE_APPEARANCE_THERMOMETER_EAR
ESP_BLE_APPEARANCE_GENERIC_HEART_RATE
ESP_BLE_APPEARANCE_HEART_RATE_BELT
ESP_BLE_APPEARANCE_GENERIC_BLOOD_PRESSURE
ESP_BLE_APPEARANCE_BLOOD_PRESSURE_ARM
ESP_BLE_APPEARANCE_BLOOD_PRESSURE_WRIST
ESP_BLE_APPEARANCE_GENERIC_HID
ESP_BLE_APPEARANCE_HID_KEYBOARD
ESP_BLE_APPEARANCE_HID_MOUSE
ESP_BLE_APPEARANCE_HID_JOYSTICK
ESP_BLE_APPEARANCE_HID_GAMEPAD
ESP_BLE_APPEARANCE_HID_DIGITIZER_TABLET
ESP_BLE_APPEARANCE_HID_CARD_READER
ESP_BLE_APPEARANCE_HID_DIGITAL_PEN
ESP_BLE_APPEARANCE_HID_BARCODE.Scanner
ESP_BLE_APPEARANCE_GENERIC_GLUCOSE
ESP_BLE_APPEARANCE_GENERIC_WALKING
ESP_BLE_APPEARANCE_WALKING_IN_SHOE
ESP_BLE_APPEARANCE_WALKING_ON_SHOE
ESP_BLE_APPEARANCE_WALKING_ON_HIP
ESP_BLE_APPEARANCE_GENERIC_CYCLING
ESP_BLE_APPEARANCE_CYCLING_COMPUTER
ESP_BLE_APPEARANCE_CYCLING_SPEED
ESP_BLE_APPEARANCE_CYCLING_CADENCE
ESP_BLE_APPEARANCE_CYCLING_POWER
ESP_BLE_APPEARANCE_CYCLING_SPEED_CADENCE
ESP_BLE_APPEARANCE_GENERIC_PULSE_OXIMETER
ESP_BLE_APPEARANCE_PULSE_OXIMETER_FINGERTIP
ESP_BLE_APPEARANCE_PULSE_OXIMETER_WRIST
ESP_BLE_APPEARANCE_GENERIC_WEIGHT
ESP_BLE_APPEARANCE_GENERIC_PERSONAL_MOBILITY_DEVICE
ESP_BLE_APPEARANCE_POWERED_WHEELCHAIR
ESP_BLE_APPEARANCE_MOBILITY_SCOOTER
ESP_BLE_APPEARANCE_GENERIC_CONTINUOUS_GLUCOSE_MONITOR
ESP_BLE_APPEARANCE_GENERIC_INSULIN_PUMP
ESP_BLE_APPEARANCE_INSULIN_PUMP_DURABLE_PUMP
ESP_BLE_APPEARANCE_INSULIN_PUMP_PATCH_PUMP
ESP_BLE_APPEARANCE_INSULIN_PEN
ESP_BLE_APPEARANCE_GENERIC_MEDICATION_DELIVERY
ESP_BLE_APPEARANCE_GENERIC_OUTDOOR_SPORTS
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_AND_NAV
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD
ESP_BLE_APPEARANCE_OUTDOOR_SPORTS_LOCATION_POD_AND_NAV
ESP_GAP_BLE_CHANNELS_LEN
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_BLE_SCAN_RSP_DATA_LEN_MAX
Scan response data maximum length.
BLE_BIT (n)
ESP_BLE_GAP_SET_EXT_ADV_PROP_NONCONN_NONSCANNABLE_UNDIRECTED
ESP_BLE_GAP_SET_EXT_ADV_PROP_CONNECTABLE
ESP_BLE_GAP_SET_EXT_ADV_PROP_SCANNABLE
ESP_BLE_GAP_SET_EXT_ADV_PROP_DIRECTED
ESP_BLE_GAP_SET_EXT_ADV_PROP_HD_DIRECTED
ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY
ESP_BLE_GAP_SET_EXT_ADV_PROP_ANON_ADV
ESP_BLE_GAP_SET_EXT_ADV_PROP_INCLUDE_TX_PWR
ESP_BLE_GAP_SET_EXT_ADV_PROP_MASK
ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_IND
ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_LD_DIR
ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_HD_DIR
ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_SCAN
ESP_BLE_GAP_SET_EXT_ADV_PROP_LEGACY_NONCONN
ESP_BLE_GAP_PHY_1M
ESP_BLE_GAP_PHY_2M
ESP_BLE_GAP_PHY_CODED
ESP_BLE_GAP_NO_PREFER_TRANSMIT_PHY
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ESP_BLE_GAP_NO_PREFER_RECEIVE_PHY
ESP_BLE_GAP_PRI_PHY_1M
ESP_BLE_GAP_PRI_PHY_CODED
ESP_BLE_GAP_PHY_1M_PREF_MASK
ESP_BLE_GAP_PHY_2M_PREF_MASK
ESP_BLE_GAP_PHY_CODED_PREF_MASK
ESP_BLE_GAP_PHY_OPTIONS_NO_PREF
ESP_BLE_GAP_PHY_OPTIONS_PREF_S2_CODING
ESP_BLE_GAP_PHY_OPTIONS_PREF_S8_CODING
ESP_BLE_GAP_EXT_SCAN_CFG_UNCODE_MASK
ESP_BLE_GAP_EXT_SCAN_CFG_CODE_MASK
ESP_BLE_GAP_EXT_ADV_DATA_COMPLETE
ESP_BLE_GAP_EXT_ADV_DATA_INCOMPLETE
ESP_BLE_GAP_EXT_ADV_DATA_TRUNCATED
ESP_BLE_GAP_SYNC_POLICY_BY_ADV_INFO
ESP_BLE_GAP_SYNC_POLICY_BY_PERIODIC_LIST
ESP_BLE_ADV_REPORT_EXT_ADV_IND
ESP_BLE_ADV_REPORT_EXT_SCAN_IND
ESP_BLE_ADV_REPORT_EXT_DIRECT_ADV
ESP_BLE_ADV_REPORT_EXT_SCAN_RSP
ESP_BLE_LEGACY_ADV_TYPE_IND
ESP_BLE_LEGACY_ADV_TYPE_DIRECT_IND
ESP_BLE_LEGACY_ADV_TYPE_SCAN_IND
ESP_BLE_LEGACY_ADV_TYPE_NONCON_IND
ESP_BLE_LEGACY_ADV_TYPE_SCAN_RSP_TO_ADV_IND
ESP_BLE_LEGACY_ADV_TYPE_SCAN_RSP_TO_ADV_SCAN_IND

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
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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 void (*esp_gap_ble_cb_t)(esp_gap_ble_cb_event_t event, esp_ble_gap_cb_param_t *param)

GAP callback function type.

Parameters
• event: Event type
• param: Point to callback parameter, currently is union type

Enumerations
enum esp_gap_ble_cb_event_t
GAP BLE callback event type.

Values:

ESP_GAP_BLE_ADV_DATA_SET_COMPLETE_EVT = 0
When advertising data set complete, the event comes

ESP_GAP_BLE_SCAN_RSP_DATA_SET_COMPLETE_EVT
When scan response data set complete, the event comes

ESP_GAP_BLE_SCAN_PARAM_SET_COMPLETE_EVT
When scan parameters set complete, the event comes

ESP_GAP_BLE_SCAN_RESULT_EVT
When one scan result ready, the event comes each time

ESP_GAP_BLE_ADV_DATA_RAW_SET_COMPLETE_EVT
When raw advertising data set complete, the event comes

ESP_GAP_BLE_SCAN_RSP_DATA_RAW_SET_COMPLETE_EVT
When raw advertising data set complete, the event comes

ESP_GAP_BLE_ADV_START_COMPLETE_EVT
When start advertising complete, the event comes

ESP_GAP_BLE_SCAN_START_COMPLETE_EVT
When start scan complete, the event comes

ESP_GAP_BLE_AUTH_CMPL_EVT = 8

ESP_GAP_BLE_KEY_EVT
ESP_GAP_BLE_SEC_REQ_EVT
ESP_GAP_BLE_PASSKEY_NOTIF_EVT
ESP_GAP_BLE_PASSKEY_REQ_EVT
ESP_GAP_BLE_OOB_REQ_EVT
ESP_GAP_BLE_LOCAL_IR_EVT
ESP_GAP_BLE_LOCAL_ER_EVT
ESP_GAP_BLE_NC_REQ_EVT
ESP_GAP_BLE_ADV_STOP_COMPLETE_EVT
When stop adv complete, the event comes

ESP_GAP_BLE_SCAN_STOP_COMPLETE_EVT
When stop scan complete, the event comes
ESP_GAP_BLE_SET_STATIC_RAND_ADDR_EVT = 19
When set the static rand address complete, the event comes

ESP_GAP_BLE_UPDATE_CONN_PARAMS_EVT
When update connection parameters complete, the event comes

ESP_GAP_BLE_SET_PKT_LENGTH_COMPLETE_EVT
When set pkt length complete, the event comes

ESP_GAP_BLE_SET_LOCAL_PRIVACY_COMPLETE_EVT
When Enable/disable privacy on the local device complete, the event comes

ESP_GAP_BLE_REMOVE_BOND_DEV_COMPLETE_EVT
When remove the bond device complete, the event comes

ESP_GAP_BLE_CLEAR_BOND_DEV_COMPLETE_EVT
When clear the bond device clear complete, the event comes

ESP_GAP_BLE_GET_BOND_DEV_COMPLETE_EVT
When get the bond device list complete, the event comes

ESP_GAP_BLE_READ_RSSI_COMPLETE_EVT
When read the rssi complete, the event comes

ESP_GAP_BLE_UPDATE_WHITELIST_COMPLETE_EVT
When add or remove whitelist complete, the event comes

ESP_GAP_BLE_UPDATE_DUPLICATE_EXCEPTIONAL_LIST_COMPLETE_EVT
When update duplicate exceptional list complete, the event comes

ESP_GAP_BLE_SET_CHANNELS_EVT = 29
When setting BLE channels complete, the event comes

ESP_GAP_BLE_READ_PHY_COMPLETE_EVT
ESP_GAP_BLE_SET_PREFERED_DEFAULT_PHY_COMPLETE_EVT
ESP_GAP_BLE_SET_PREFERED_PHY_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_SET_RAND_ADDR_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_SET_PARAMS_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_DATA_SET_COMPLETE_EVT
ESP_GAP_BLE_EXT_SCAN_RSP_DATA_SET_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_START_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_STOP_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_SET_REMOVE_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_SET_CLEAR_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_SET_PARAMS_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_DATA_SET_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_START_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_STOP_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_CREATE_SYNC_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_SYNC_CANCEL_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_SYNC_TERMINATE_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_ADD_DEV_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_REMOVE_DEV_COMPLETE_EVT
ESP_GAP_BLE_PERIODIC_ADV_CLEAR_DEV_COMPLETE_EVT
ESP_GAP_BLE_SET_EXT_SCAN_PARAMS_COMPLETE_EVT
ESP_GAP_BLE_EXT_SCAN_START_COMPLETE_EVT
ESP_GAP_BLE_EXT_SCAN_STOP_COMPLETE_EVT
ESP_GAP_BLE_PREFER_EXT_CONN_PARAMS_SET_COMPLETE_EVT
ESP_GAP_BLE_PHY_UPDATE_COMPLETE_EVT
ESP_GAP_BLE_EXT_ADV_REPORT_EVT
ESP_GAP_BLE_SCAN_TIMEOUT_EVT
ESP_GAP_BLE_ADV_TERMINATED_EVT
ESP_GAP_BLE_SCAN_REQ_RECEIVED_EVT
ESP_GAP_BLE_CHANNEL_SELECT_ALGORITHM_EVT
ESP_GAP_BLE_PERIODIC_ADV_REPORT_EVT
ESP_GAP_BLE_PERIODIC_ADV_SYNC_LOST_EVT
ESP_GAP_BLE_PERIODIC_ADV_SYNC_ESTAB_EVT
ESP_GAP_BLE_EVT_MAX

enum esp_ble_adv_data_type
The type of advertising data (not adv_type)

Values:
ESP_BLE_AD_TYPE_FLAG = 0x01
ESP_BLE_AD_TYPE_16SRV_PART = 0x02
ESP_BLE_AD_TYPE_16SRV_CMPL = 0x03
ESP_BLE_AD_TYPE_32SRV_PART = 0x04
ESP_BLE_AD_TYPE_32SRV_CMPL = 0x05
ESP_BLE_AD_TYPE_128SRV_PART = 0x06
ESP_BLE_AD_TYPE_128SRV_CMPL = 0x07
ESP_BLE_AD_TYPE_NAME_SHORT = 0x08
ESP_BLE_AD_TYPE_NAME_CMPL = 0x09
ESP_BLE_AD_TYPE_TX_PWR = 0x0A
ESP_BLE_AD_TYPE_DEV_CLASS = 0x0D
ESP_BLE_AD_TYPE_SM_TK = 0x10
ESP_BLE_AD_TYPE_SM_OOB_FLAG = 0x11
ESP_BLE_AD_TYPE_INT_RANGE = 0x12
ESP_BLE_AD_TYPE_SOL_SRV_UUID = 0x14
ESP_BLE_AD_TYPE_128SOL_SRV_UUID = 0x15
ESP_BLE_AD_TYPE_SERVICE_DATA = 0x16
ESP_BLE_AD_TYPE_PUBLIC_TARGET = 0x17
ESP_BLE_AD_TYPE_RANDOM_TARGET = 0x18
ESP_BLE_AD_TYPE_APPEARANCE = 0x19
ESP_BLE_AD_TYPE_ADV_INT = 0x1A
ESP_BLE_AD_TYPE_LE_DEV_ADDR = 0x1b
ESP_BLE_AD_TYPE_LE_ROLE = 0x1c
ESP_BLE_ADV_TYPE_SPAIR_C256 = 0x1d
ESP_BLE_ADV_TYPE_SPAIR_R256 = 0x1e
ESP_BLE_ADV_TYPE_32SOL_SRV_UUID = 0x1f
ESP_BLE_ADV_TYPE_32SERVICE_DATA = 0x20
ESP_BLE_ADV_TYPE_128SERVICE_DATA = 0x21
ESP_BLE_ADV_TYPE_LE_SECURE_CONFIRM = 0x22
ESP_BLE_ADV_TYPE_LE_SECURE_RANDOM = 0x23
ESP_BLE_ADV_TYPE_URI = 0x24
ESP_BLE_ADV_TYPE_INDOOR_POSITION = 0x25
ESP_BLE_ADV_TYPE_TRANS_DISC_DATA = 0x26
ESP_BLE_ADV_TYPE_LE_SUPPORT_FEATURE = 0x27
ESP_BLE_ADV_TYPE_CHAN_MAP_UPDATE = 0x28
ESP_BLE_ADV_MANUFACTURER_SPECIFIC_TYPE = 0xFF

enum esp_ble_adv_type_t
Advertising mode.
Values:
ADV_TYPE_IND = 0x00
ADV_TYPE_DIRECT_IND_HIGH = 0x01
ADV_TYPE_SCAN_IND = 0x02
ADV_TYPE_NONCONN_IND = 0x03
ADV_TYPE_DIRECT_IND_LOW = 0x04

enum esp_ble_adv_channel_t
Advertising channel mask.
Values:
ADV_CHNL_37 = 0x01
ADV_CHNL_38 = 0x02
ADV_CHNL_39 = 0x04
ADV_CHNL_ALL = 0x07

enum esp_ble_adv_filter_t
Values:
ADV_FILTER_ALLOW_SCAN_ANY_CON_ANY = 0x00
  Allow both scan and connection requests from anyone.
ADV_FILTER_ALLOW_SCAN_WLST_CON_ANY
  Allow both scan req from White List devices only and connection req from anyone.
ADV_FILTER_ALLOW_SCAN_ANY_CON_WLST
  Allow both scan req from anyone and connection req from White List devices only.
ADV_FILTER_ALLOW_SCAN_WLST_CON_WLST
  Allow scan and connection requests from White List devices only.

enum esp_ble_sec_act_t
Values:
ESP_BLE_SEC_ENCRYPT = 1
ESP_BLE_SEC_ENCRYPT_NO_MITM


```c
#define ESP_BLE_SEC_ENCRYPT_MITM

enum esp_ble_sm_param_t
{
    ESP_BLE_SM_PASSKEY = 0,
    ESP_BLE_SM_AUTHEN_REQ_MODE,
    ESP_BLE_SM_IOCAP_MODE,
    ESP_BLE_SM_SET_INIT_KEY,
    ESP_BLE_SM_SET_RSP_KEY,
    ESP_BLE_SM_MAX_KEY_SIZE,
    ESP_BLE_SM_MIN_KEY_SIZE,
    ESP_BLE_SM_SET_STATIC_PASSKEY,
    ESP_BLE_SM_CLEAR_STATIC_PASSKEY,
    ESP_BLE_SM_ONLY_ACCEPT_SPECIFIED_SEC_AUTH,
    ESP_BLE_SM_OOB_SUPPORT,
    ESP_BLE_APP_ENC_KEY_SIZE,
    ESP_BLE_SM_MAX_PARAM
};

enum esp_ble_scan_type_t
{
    BLE_SCAN_TYPE_PASSIVE = 0x0,
    BLE_SCAN_TYPE_ACTIVE = 0x1
};

enum esp_ble_scan_filter_t
{
    BLE_SCAN_FILTER_ALLOW_ALL = 0x0,
    BLE_SCAN_FILTER_ALLOW_ONLY_WLST = 0x1,
    BLE_SCAN_FILTER_ALLOW_UND_RPA_DIR = 0x2,
    BLE_SCAN_FILTER_ALLOW_WLIST_RPA_DIR = 0x3
};
```
enum esp_ble_scan_duplicate_t
Ble scan duplicate type.

Values:

BLE_SCAN_DUPLICATE_DISABLE = 0x0
the Link Layer should generate advertising reports to the host for each packet received

BLE_SCAN_DUPLICATE_ENABLE = 0x1
the Link Layer should filter out duplicate advertising reports to the Host

BLE_SCAN_DUPLICATE_MAX = 0x2
0x02 –0xFF, Reserved for future use

enum esp_gap_search_evt_t
Sub Event of ESP_GAP_BLE_SCAN_RESULT_EVT.

Values:

ESP_GAP_SEARCH_INQ_RES_EVT = 0
Inquiry result for a peer device.

ESP_GAP_SEARCH_INQ_CMPL_EVT = 1
Inquiry complete.

ESP_GAP_SEARCH_DISC_RES_EVT = 2
Discovery result for a peer device.

ESP_GAP_SEARCH_DISC_BLE_RES_EVT = 3
Discovery result for BLE GATT based service on a peer device.

ESP_GAP_SEARCH_DISC_CMPL_EVT = 4
Discovery complete.

ESP_GAP_SEARCH_DISC_CMPL_EVT = 5
Discovery complete.

ESP_GAP_SEARCH_SEARCH_CANCEL_CMPL_EVT = 6
Search cancelled

ESP_GAP_SEARCH_INQ_DISCARD_NUM_EVT = 7
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:

ESP_BLE_EVT_CONN_ADV = 0x00
Connectable undirected advertising (ADV_IND)

ESP_BLE_EVT_CONN_DIR_ADV = 0x01
Connectable directed advertising (ADV_DIRECT_IND)

ESP_BLE_EVT_DISC_ADV = 0x02
Scannable undirected advertising (ADV_SCAN_IND)

ESP_BLE_EVT_NON_CONN_ADV = 0x03
Non connectable undirected advertising (ADV_NONCONN_IND)

ESP_BLE_EVT_SCAN_RSP = 0x04
Scan Response (SCAN_RSP)

enum esp_ble_wl_opration_t

Values:

ESP_BLE_WHITELIST_REMOVE = 0X00
remove mac from whitelist
ESP_BLE_WHITELIST_ADD = 0x01
add address to whitelist

enum esp_bt_duplicate_exceptional_subcode_type_t
Values:
ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_ADD = 0
Add device info into duplicate scan exceptional list
ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_REMOVE
Remove device info from duplicate scan exceptional list
ESP_BLE_DUPLICATE_EXCEPTIONAL_LIST_CLEAN
Clean duplicate scan exceptional list

enum esp_ble_duplicate_exceptional_info_type_t
Values:
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_ADV_ADDR = 0
BLE advertising address, device info will be added into ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ADDR_LIST
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
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_MESH_BEACON_TYPE
BLE mesh beacon AD type, the format is \| Len \| 0x2B \| Beacon Type \| Beacon Data \|
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_INFO_MESH_PROV_SRV_ADV
BLE mesh provisioning service uuid, the format is \| 0x02 \| 0x01 \| flags \| 0x03 \| 0x03 \| 0x1827 \| … \|
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:
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ADDR_LIST = BLE_BIT(0)
duplicate scan exceptional addr list
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_LINK_ID_LIST = BLE_BIT(1)
duplicate scan exceptional mesh link ID list
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_BEACON_TYPE_LIST = BLE_BIT(2)
duplicate scan exceptional mesh beacon type list
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_PROV_SRV_ADV_LIST = BLE_BIT(3)
duplicate scan exceptional mesh adv with provisioning service uuid
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_MESH_PROXY_SRV_ADV_LIST = BLE_BIT(4)
duplicate scan exceptional mesh adv with provisioning service uuid
ESP_BLE_DUPLICATE_SCAN_EXCEPTIONAL_ALL_LIST = 0xFFFF
duplicate scan exceptional all list

GATT DEFINES

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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

    esp_gatt_value_t attr_value
    Gatt attribute structure

    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
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```c
uint8_t *value
Element value array

struct esp_attr_control_t
attribute auto response flag

Public Members

uint8_t auto_rsp
if autorsp set to ESP_GATT_RSP_BY_APP, means the response of Write/Read operation will be 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 includes service 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

uint16_t start_hdl
    Gatt start handle value of included 128 bit service

uint16_t end_hdl
    Gatt end handle value of included 128 bit service

struct esp_gatt_value_t
    Gatt attribute value.

Public Members

uint8_t value[ESP_GATT_MAX_ATTR_LEN]
    Gatt attribute value

uint16_t handle
    Gatt attribute handle

uint16_t offset
    Gatt attribute value offset

uint16_t len
    Gatt attribute value length

uint8_t auth_req
    Gatt authentication request

struct esp_gatt_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_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
Chapter 2. API Reference

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

`esp_bt_uuid_t` uuid
The uuid of the service

`struct esp_gattc_char_elem_t`
Characteristic element

Public Members

`uint16_t char_handle`
The characteristic handle

`esp_gatt_char_prop_t` properties
The characteristic properties

`esp_bt_uuid_t` uuid
The characteristic uuid

`struct esp_gattc_descr_elem_t`
Descriptor element

Public Members

`uint16_t handle`
The characteristic descriptor handle

`esp_bt_uuid_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

- `esp_bt_uuid_t uuid`
  The include service uuid

**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_ENVIRONMENTALSENSING_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_FW_STATUS
ESP_GATT_UUID_FW_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_UUID_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
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
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```c
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_CHAR_PROP_BIT_BROADCAST
ESP_GATT_CHAR_PROP_BIT_READ
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 gatte_if/gatts_if as this macro, means this event is not correspond to any app
```

Type Definitions
```c
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
```c
enum esp_gatt_prep_write_type
Attribute write data type from the client.
Values:
ESP_GATT_PREP_WRITE_CANCEL = 0x00
Prepare write cancel
ESP_GATT_PREP_WRITE_EXEC = 0x01
Prepare write execute
```
```c
enum esp_gatt_status_t
GATT success code and error codes.
Values:
ESP_GATT_OK = 0x0
ESP_GATT_INVALID_HANDLE = 0x01
ESP_GATT_READ_NOT_PERMIT = 0x02
```

GATT maximum attribute length.
ESP_GATT_WRITE_NOT_PERMIT = 0x03
ESP_GATT_INVALID_PDU = 0x04
ESP_GATT_INSUF_AUTHENTICATION = 0x05
ESP_GATT_REQ_NOT_SUPPORTED = 0x06
ESP_GATT_INVALID_OFFSET = 0x07
ESP_GATT_INSUF_AUTHORIZATION = 0x08
ESP_GATT_PREPARE_Q_FULL = 0x09
ESP_GATT_NOT_FOUND = 0x0a
ESP_GATT_NOT_LONG = 0x0b
ESP_GATT_INSUF_KEY_SIZE = 0x0c
ESP_GATT_INVALID_ATTR_LEN = 0x0d
ESP_GATT_ERR_UNLIKELY = 0x0e
ESP_GATT_INSUF_ENCRYPTION = 0x0f
ESP_GATT_UNSUPPORT_GRP_TYPE = 0x10
ESP_GATT_INSUFRESOURCE = 0x11
ESP_GATT_NO_RESOURCES = 0x80
ESP_GATT_INTERNAL_ERROR = 0x81
ESP_GATT_WRONG_STATE = 0x82
ESP_GATT_DB_FULL = 0x83
ESP_GATT_BUSY = 0x84
ESP_GATT_ERROR = 0x85
ESP_GATT_CMD_STARTED = 0x86
ESP_GATT_ILLEGAL_PARAMETER = 0x87
ESP_GATT_PENDING = 0x88
ESP_GATT_AUTH_FAIL = 0x89
ESP_GATT_MORE = 0x8a
ESP_GATT_INVALID_CFG = 0x8b
ESP_GATT_SERVICE_STARTED = 0x8c
ESP_GATT_ENCRYPTED_MITM = ESP_GATT_OK
ESP_GATT_ENCRYPTED_NO_MITM = 0x8d
ESP_GATT_NOT_ENCRYPTED = 0x8e
ESP_GATT_CONGESTED = 0x8f
ESP_GATT_DUP_REG = 0x90
ESP_GATT_ALREADY_OPEN = 0x91
ESP_GATT_CANCEL = 0x92
ESP_GATT_STACK_RSP = 0xe0
ESP_GATT_APP_RSP = 0xe1
ESP_GATT_UNKNOWN_ERROR = 0xef
ESP_GATT_CCC_CFG_ERR = 0xfd
**ESP_GATT_PRC_IN_PROGRESS** = 0xfe

**ESP_GATT_OUT_OF_RANGE** = 0xff

**enum esp_gatt_conn_reason_t**

Gatt Connection reason enum.

*Values:*

**ESP_GATT_CONN_UNKNOWN** = 0

Gatt connection unknown

**ESP_GATT_CONN_L2C_FAILURE** = 1

General L2cap failure

**ESP_GATT_CONN_TIMEOUT** = 0x08

Connection timeout

**ESP_GATT_CONN_TERMINATE_PEER_USER** = 0x13

Connection terminate by peer user

**ESP_GATT_CONN_TERMINATE_LOCAL_HOST** = 0x16

Connection terminated by local host

**ESP_GATT_CONN_FAIL_ESTABLISH** = 0x3e

Connection fail to establish

**ESP_GATT_CONN_LMP_TIMEOUT** = 0x22

Connection fail for LMP response tout

**ESP_GATT_CONN_CONN_CANCEL** = 0x0100

L2CAP connection cancelled

**ESP_GATT_CONN_NONE** = 0x0101

No connection to cancel

**enum esp_gatt_auth_req_t**

Gatt authentication request type.

*Values:*

**ESP_GATT_AUTH_REQ_NONE** = 0

**ESP_GATT_AUTH_REQ_NO_MITM** = 1

**ESP_GATT_AUTH_REQ_MITM** = 2

**ESP_GATT_AUTH_REQ_SIGNED_NO_MITM** = 3

**ESP_GATT_AUTH_REQ_SIGNED_MITM** = 4

**enum esp_service_source_t**

Values:

**ESP_GATT_SERVICE_FROM_REMOTE_DEVICE** = 0

**ESP_GATT_SERVICE_FROM_NVS_FLASH** = 1

**ESP_GATT_SERVICE_FROM_UNKNOWN** = 2

**enum esp_gatt_write_type_t**

Gatt write type.

*Values:*

**ESP_GATT_WRITE_TYPE_NO_RSP** = 1

Gatt write attribute need no response

**ESP_GATT_WRITE_TYPE_RSP**

Gatt write attribute need remote response
enum esp_gatt_db_attr_type_t
    the type of attribute element

Values:

ESP_GATT_DB_PRIMARY_SERVICE
    Gattc primary service attributetype in the cache

ESP_GATT_DB_SECONDARY_SERVICE
    Gattc secondary service attributetype in the cache

ESP_GATT_DB_CHARACTERISTIC
    Gattc characteristic attributetype in the cache

ESP_GATT_DB_DESCRIPTOR
    Gattc characteristic descriptor attributetype in the cache

ESP_GATT_DB_INCLUDED_SERVICE
    Gattc include service attributetype in the cache

ESP_GATT_DB_ALL
    Gattc all the attribute (primary service & secondary service & include service & char & descriptor) type
    in the cache

GATT SERVER API

Overview

Application Example
    Check bluetooth/bluedroid/ble folder in ESP-IDF examples, which contains the following demos and their tutorials:
    • This is a GATT sever 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.
      – bluetooth/bluedroid/ble/gatt_server_service_table
      – GATT Server Service Table Example Walkthrough
    • 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
      – GATT Server Example Walkthrough
    • 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.
      – bluetooth/bluedroid/ble/ble_spp_server

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.

    Return
        • 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.

    Return
Chapter 2. API Reference

- ESP_OK: success
- other: failed

`esp_err_t esp_ble_gatts_app_unregister (esp_gatt_if_t gatts_if)`

unregister with GATT Server.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gatts_if: GATT server access interface

`esp_err_t esp_ble_gatts_create_service (esp_gatt_if_t gatts_if, esp_gatt_svc_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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gatts_if: GATT server access interface
- [in] service_id: service ID.
- [in] num_handle: number of handle requested for this service.

`esp_err_t esp_ble_gatts_create_attr_tab (const esp_gatts_attr_db_t *gatts_attr_db, esp_gatt_if_t gatts_if, uint8_t max_nb_attr, uint8_t svc_inst_id)`

Create a service attribute tab.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gatts_attr_db: the pointer to the service attr tab
- [in] gatts_if: GATT server access interface
- [in] max_nb_attr: the number of attribute to be added to the service database.
- [in] svc_inst_id: the instance id of the service

`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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] service_handle: service handle to which this included service is to be added.
- [in] included_service_handle: the service ID to be included.

`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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] service_handle: service handle to which this included service is to be added.
- [in] char_uuid: Characteristic UUID.
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- [in] perm: Characteristic value declaration attribute permission.
- [in] property: Characteristic Properties
- [in] char_val: Characteristic value
- [in] control: attribute response control byte

**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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] service_handle: service handle to which this characteristic descriptor is to be added.
- [in] perm: descriptor access permission.
- [in] descr_uuid: descriptor UUID.
- [in] char_descr_val: Characteristic descriptor value
- [in] control: attribute response control byte

**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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] service_handle: service_handle to be deleted.

**esp_err_t esp_ble_gatts_start_service** (uint16_t service_handle)

This function is called to start a service.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] service_handle: the service handle to be started.

**esp_err_t esp_ble_gatts_stop_service** (uint16_t service_handle)

This function is called to stop a service.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] service_handle: - service to be topped.

**esp_err_t esp_ble_gatts_send_indicate** (esp_gatt_if_t gatts_if, uint16_t conn_id, uint16_t attr_handle, uint16_t value_len, uint8_t *value, bool need_confirm)

Send indicate or notify to GATT client. Set param need_confirm as false will send notification, otherwise indication.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gatts_if: GATT server access interface
- [in] conn_id: - connection id to indicate.
- [in] attr_handle: - attribute handle to indicate.
- [in] value_len: - indicate value length.
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- [in] value: value to indicate.
- [in] need_confirm: Whether a confirmation is required. false sends a GATT notification, true sends a GATT indication.

```c
esp_err_t esp_ble_gatts_send_response(esp_gatt_if_t gatts_if, uint16_t conn_id, uint32_t trans_id, esp_gatt_status_t status, esp_gatt_rsp_t *rsp)
```

This function is called to send a response to a request.

Return
- ESP_OK : success
- other : failed

Parameters
- [in] gatts_if: GATT server access interface
- [in] trans_id: transfer id
- [in] status: response status

```c
esp_err_t esp_ble_gatts_set_attr_value(uint16_t attr_handle, uint16_t length, const uint8_t *value)
```

This function is called to set the attribute value by the application.

Return
- ESP_OK : success
- other : failed

Parameters
- [in] attr_handle: the attribute handle which to be set
- [in] length: the value length
- [in] value: the pointer to the attribute value

```c
esp_gatt_status_t esp_ble_gatts_get_attr_value(uint16_t attr_handle, uint16_t *length, const uint8_t **value)
```

Retrieve attribute value.

Return
- ESP_GATT_OK : success
- other : failed

Parameters
- [in] attr_handle: Attribute handle.
- [out] length: pointer to the attribute value length
- [out] value: Pointer to attribute value payload, the value cannot be modified by user

```c
esp_err_t esp_ble_gatts_open(esp_gatt_if_t gatts_if, esp_bd_addr_t remote_bda, bool is_direct)
```

Open a direct open connection or add a background auto connection.

Return
- ESP_OK : success
- other : failed

Parameters
- [in] gatts_if: GATT server access interface
- [in] remote_bda: remote device bluetooth device address.
- [in] is_direct: direct connection or background auto connection

```c
esp_err_t esp_ble_gatts_close(esp_gatt_if_t gatts_if, uint16_t conn_id)
```

Close a connection a remote device.

Return
- ESP_OK : success
- other : failed

Parameters
- [in] gatts_if: GATT server access interface
- [in] conn_id: connection ID to be closed.
**`esp_err_t esp_ble_gatts_send_service_change_indication`**

Send service change indication.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- `[in] gatts_if`: GATT server access interface
- `[in] remote_bda`: 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

**Unions**

```c
union esp_ble_gatts_cb_param_t
    #include <esp_gatts_api.h> Gatt server callback parameters union.
```

**Public Members**

```c
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.
Chapter 2. API Reference

Public Members

```c
struct esp_gatt_status_t
{
    Operation status

    uint16_t attr_handle
    Characteristic attribute handle

    uint16_t service_handle
    Service attribute handle

    esp_bt_uuid_t char_uuid
    Characteristic uuid
};
```

```c
struct gatts_add_incl_srvc_evt_param
{
    #include <esp_gatts_api.h>
    ESP_GATTS_ADD_INCL_SRVC_EVT.
};
```

Public Members

```c
struct esp_gatt_status_t
{
    Operation status

    uint16_t attr_handle
    Included service attribute handle

    uint16_t service_handle
    Service attribute handle
};
```

```c
struct gatts_cancel_open_evt_param
{
    #include <esp_gatts_api.h>
    ESP_GATTS_CANCEL_OPEN_EVT.
};
```

Public Members

```c
struct esp_gatt_status_t
{
    Operation status

    uint16_t conn_id
    Connection id

    struct gatts_close_evt_param
    {
        #include <esp_gatts_api.h>
        ESP_GATTS_CLOSE_EVT.
    } handle
    attribute handle
};
```

Public Members

```c
struct esp_gatt_status_t
{
    Operation status

    uint16_t conn_id
    Connection id

    struct gatts_conf_evt_param
    {
        #include <esp_gatts_api.h>
        ESP_GATTS_CONF_EVT.
    } 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_LISTEN_EVT.
    ESP_GATTS_CONGEST_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

esp_gatt_conn_params_t conn_params
    current Connection parameters

struct gatts_create_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_UNREG_EVT.
    ESP_GATTS_CREATE_EVT

Public Members

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

struct gatts_delete_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_DELETE_EVT.

Public Members

esp_gatt_status_t status
    Operation status
Chapter 2. API Reference

```c
uint16_t service_handle
    Service attribute handle

struct gatts_disconnect_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_DISCONNECT_EVT.

Public Members

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**

```c
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
```

```c
struct gatts_reg_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_REG_EVT.
```

**Public Members**

```c
esp_gatt_status_t status
    Operation status

uint16_t app_id
    Application id which input in register API
```

```c
struct gatts_rsp_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_RESPONSE_EVT.
```

**Public Members**

```c
esp_gatt_status_t status
    Operation status

uint16_t handle
    Attribute handle which send response
```

```c
struct gatts_send_service_change_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_SEND_SERVICE_CHANGE_EVT.
```

**Public Members**

```c
esp_gatt_status_t status
    Operation status
```

```c
struct gatts_set_attr_val_evt_param
    #include <esp_gatts_api.h> ESP_GATTS_SET_ATTR_VAL_EVT.
```
Chapter 2. API Reference

Public Members

\texttt{uint16_t srvc\_handle}

The service handle

\texttt{uint16_t attr\_handle}

The attribute handle

\texttt{esp\_gatt\_status\_t status}

Operation status

\texttt{struct gatts\_start\_evt\_param}

\texttt{#include <esp\_gatts\_api.h> ESP\_GATTS\_START\_EVT.}

Public Members

\texttt{esp\_gatt\_status\_t status}

Operation status

\texttt{uint16_t service\_handle}

Service attribute handle

\texttt{struct gatts\_stop\_evt\_param}

\texttt{#include <esp\_gatts\_api.h> ESP\_GATTS\_STOP\_EVT.}

Public Members

\texttt{esp\_gatt\_status\_t status}

Operation status

\texttt{uint16_t service\_handle}

Service attribute handle

\texttt{struct gatts\_write\_evt\_param}

\texttt{#include <esp\_gatts\_api.h> ESP\_GATTS\_WRITE\_EVT.}

Public Members

\texttt{uint16_t conn\_id}

Connection id

\texttt{uint32_t trans\_id}

Transfer id

\texttt{esp\_bd\_addr t bda}

The bluetooth device address which been written

\texttt{uint16_t handle}

The attribute handle

\texttt{uint16_t offset}

Offset of the value, if the value is too long

\texttt{bool need\_rsp}

The write operation need to do response

\texttt{bool is\_prep}

This write operation is prepare write

\texttt{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.

Parameters
    • event:: Event type
    • gatts_if: : GATT server access interface, normally different gatts_if correspond to different profile
    • param: : Point to callback parameter, currently is union type

Enumerations
eenum esp_gatts_cb_event_t
    GATT Server callback function events.
Values:
ESP_GATTS_REG_EVT = 0
    When register application id, the event comes
ESP_GATTS_READ_EVT = 1
    When gatt client request read operation, the event comes
ESP_GATTS_WRITE_EVT = 2
    When gatt client request write operation, the event comes
ESP_GATTS_EXEC_WRITE_EVT = 3
    When gatt client request execute write, the event comes
ESP_GATTS_MTU_EVT = 4
    When set mtu complete, the event comes
ESP_GATTS_CONF_EVT = 5
    When receive confirm, the event comes
ESP_GATTS_UNREG_EVT = 6
    When unregister application id, the event comes
ESP_GATTS_CREATE_EVT = 7
    When create service complete, the event comes
ESP_GATTS_ADD_INCL_SRVC_EVT = 8
    When add included service complete, the event comes
ESP_GATTS_ADD_CHAR_EVT = 9
    When add characteristic complete, the event comes
ESP_GATTS_ADD_CHAR_DESCR_EVT = 10
    When add descriptor complete, the event comes
ESP_GATTS_DELETE_EVT = 11
    When delete service complete, the event comes
ESP_GATTS_START_EVT = 12
    When start service complete, the event comes
**Chapter 2. API Reference**

```c
ESP_GATTS_STOP_EVT = 13
    When stop service complete, the event comes

ESP_GATTS_CONNECT_EVT = 14
    When gatt client connect, the event comes

ESP_GATTS_DISCONNECT_EVT = 15
    When gatt client disconnect, the event comes

ESP_GATTS_OPEN_EVT = 16
    When connect to peer, the event comes

ESP_GATTS_CANCEL_OPEN_EVT = 17
    When disconnect from peer, the event comes

ESP_GATTS_CLOSE_EVT = 18
    When gatt server close, the event comes

ESP_GATTS_LISTEN_EVT = 19
    When gatt listen to be connected the event comes

ESP_GATTS_CONGEST_EVT = 20
    When congest happen, the event comes

ESP_GATTS_RESPONSE_EVT = 21
    When gatt send response complete, the event comes

ESP_GATTS_CREAT_ATTR_TAB_EVT = 22
    When gatt create table complete, the event comes

ESP_GATTS_SET_ATTR_VAL_EVT = 23
    When gatt set attr value complete, the event comes

ESP_GATTS_SEND_SERVICE_CHANGE_EVT = 24
    When gatt send service change indication complete, the event comes
```

**GATT CLIENT API**

**Overview**

**Instructions**

**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/gattc_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

**esp_err_t esp_ble_gattc_register_callback (esp_gattc_cb_t callback)**

This function is called to register application callbacks with GATTC module.

**Return**

- ESP_OK: success
- other: failed

**Parameters**

- [in] callback: pointer to the application callback function.

**esp_err_t esp_ble_gattc_app_register (uint16_t app_id)**

This function is called to register application callbacks with GATTC module.

**Return**

- ESP_OK: success
- other: failed

**Parameters**

- [in] app_id: Application Identify (UUID), for different application

**esp_err_t esp_ble_gattc_app_unregister (esp_gattc_if_t gattc_if)**

This function is called to un register an application from GATTC module.

**Return**

- ESP_OK: success
- other: failed

**Parameters**

- [in] gattc_if: Gatt client access interface.

**esp_err_t esp_ble_gattc_open (esp_gattc_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.

**Return**

- ESP_OK: success
- other: failed

**Parameters**

- [in] gattc_if: Gatt client access interface.
- [in] remote_bda: remote device bluetooth device address.
- [in] remote_addr_type: remote device bluetooth device the address type.
- [in] is_direct: direct connection or background auto connection(by now, background auto connection is not supported).

**esp_err_t esp_ble_gattc_aux_open (esp_gattc_if_t gattc_if, esp_bd_addr_t remote_bda, esp_ble_addr_type_t remote_addr_type, bool is_direct)**

**esp_err_t esp_ble_gattc_close (esp_gattc_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).

**Return**

- ESP_OK: success
- other: failed

**Parameters**

- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID to be closed.

**esp_err_t esp_ble_gattc_send_mtu_req (esp_gattc_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.

**Return**

- ESP_OK: success
- other: failed
Parameters
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.

`esp_err_t 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 reports service search result by a callback event, and followed by a service search complete event.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] filter_uuid: a UUID of the service application is interested in. If Null, discover for all services.

`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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] svc_uuid: the pointer to the service uuid.
- [inout] result: The pointer to the service which has been found in the gattc cache.
- [inout] count: 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.
- [in] offset: Offset of the service position to get.

`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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] start_handle: the attribute start handle.
- [in] end_handle: the attribute end handle
- [inout] result: The pointer to the characteristic in the service.
- [inout] count: 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.
- [in] offset: Offset of the characteristic position to get.

`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.
### Return
- ESP_OK: success
- other: failed

### Parameters
- **[in]** `gattc_if`: Gatt client access interface.
- **[in]** `conn_id`: connection ID which identify the server.
- **[in]** `char_handle`: the given characteristic handle
- **[out]** `result`: The pointer to the descriptor in the characteristic.
- **[inout]** `count`: 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.
- **[in]** `offset`: offset of the descriptor position to get.

```c
esp_gatt_status_t esp_ble_gattc_get_char_by_uuid(esp_gatt_if_t gattc_if, uint16_t conn_id, uint16_t conn_id, uint16_t start_handle, uint16_t end_handle, esp_bt_uuid_t char_uuid, esp_gattc_char_elem_t *result, uint16_t *count)
```

Find the characteristic with the given characteristic uuid in the gattc cache. Note: It just get characteristic from local cache, won’t get from remote devices.

### Return
- ESP_OK: success
- other: failed

### Parameters
- **[in]** `gattc_if`: Gatt client access interface.
- **[in]** `conn_id`: connection ID which identify the server.
- **[in]** `start_handle`: the attribute start handle
- **[in]** `end_handle`: the attribute end handle
- **[in]** `char_uuid`: the characteristic uuid
- **[out]** `result`: The pointer to the characteristic in the service.
- **[inout]** `count`: 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.

```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 gattc cache. Note: It just get descriptor from local cache, won’t get from remote devices.

### Return
- ESP_OK: success
- other: failed

### Parameters
- **[in]** `gattc_if`: Gatt client access interface.
- **[in]** `conn_id`: connection ID which identify the server.
- **[in]** `start_handle`: the attribute start handle
- **[in]** `end_handle`: the attribute end handle
- **[in]** `char_uuid`: the characteristic uuid.
- **[in]** `descr_uuid`: the descriptor uuid.
- **[out]** `result`: The pointer to the descriptor in the given characteristic.
- **[inout]** `count`: 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.

```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 gattc cache. Note: It just get descriptor from local cache, won’t get from remote devices.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] char_handle: the characteristic handle.
- [out] result: The pointer to the descriptor in the given characteristic.
- [inout] count: 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.

```c
esp_gatt_status_t esp_ble_gattc_get_include_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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] start_handle: the attribute start handle
- [in] end_handle: the attribute end handle
- [in] incl_uuid: the include service uuid
- [out] result: The pointer to the include service in the given service.
- [inout] count: 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.

```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, esp_gattc_dbElementType_t char_handle, uint16_t *count)
```

Find the attribute count with the given service or characteristic in the gattc cache.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID which identify the server.
- [in] type: the attribute type.
- [in] start_handle: the attribute start handle, if the type is ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore
- [in] end_handle: the attribute end handle, if the type is ESP_GATT_DB_DESCRIPTOR, this parameter should be ignore
- [in] char_handle: 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.
- [out] count: output the number of attribute has been found in the gattc cache with the given attribute type.

```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_dbElementType_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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] `gattc_if`: Gatt client access interface.
- [in] `start_handle`: the attribute start handle
- [in] `end_handle`: the attribute end handle
- [in] `conn_id`: connection ID which identify the server.
- [in] `db`: output parameter which will contain the GATT database copy. Caller is responsible for freeing it.
- [in] `count`: number of elements in database.

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] `gattc_if`: Gatt client access interface.
- [in] `conn_id`: connection ID.
- [in] `handle`: characteristic handle to read.
- [in] `auth_req`: authenticate request type

```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_bt_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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] `gattc_if`: Gatt client access interface.
- [in] `conn_id`: connection ID.
- [in] `start_handle`: the attribute start handle.
- [in] `end_handle`: the attribute end handle
- [in] `uuid`: The UUID of attribute which will be read.
- [in] `auth_req`: authenticate request type

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] `gattc_if`: Gatt client access interface.
- [in] `conn_id`: connection ID.
- [in] `auth_req`: authenticate request type

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] handle: descriptor handle to read.
- [in] auth_req: authenticate request type

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] handle: characteristic handle to write.
- [in] value_len: length of the value to be written.
- [in] value: the value to be written.
- [in] write_type: the type of attribute write operation.
- [in] auth_req: authentication request.

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] handle: characteristic handle to prepare write.
- [in] offset: offset of the write value.
- [in] value_len: length of the value to be written.
- [in] value: the value to be written.
- [in] auth_req: authentication request.

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] handle: characteristic handle to prepare write.


```c
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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] handle: characteristic descriptor handle to prepare write.
- [in] offset: offset of the write value.
- [in] value_len: length of the value to be written.
- [in] value: the value to be written.
- [in] auth_req: authentication request.

```c
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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] conn_id: connection ID.
- [in] is_execute: execute or cancel.

```c
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.

**Return**
- ESP_OK: registration succeeds
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] handle: GATT characteristic handle.

```c
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.

**Return**
- ESP_OK: unregister succeeds
- other: failed

**Parameters**
- [in] gattc_if: Gatt client access interface.
- [in] handle: GATT characteristic handle.

```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.

**Return**
- ESP_OK: success
- other: failed

**Parameters**
- [in] remote_bda: remote device BD address.
`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 main that device want to used the database has stored in the local cache. The source address main that device want to share the database to the associated address device.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.
- [in] src_addr: the source address which provide the attribute table.
- [in] assoc_addr: the associated device address which went to share the attribute table with the source address.
- [in] is_assoc: true add the associated device address, false remove the associated device address.

`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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] gattc_if: Gatt client access interface.

`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.

Return
- ESP_OK: success
- other: failed

Parameters
- [in] remote_bda: remote device BD address.

Unions

```
union esp_ble_gattc_cb_param_t
#include <esp_gattc_api.h> Gatt client callback parameters union.

Public Members
```

```
struct esp_ble_gattc_cb_param_t::gatte_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
```

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Submit Document Feedback
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_gatt_api.h> ESP_GATTC_CFG_MU_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_gatt_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

**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

```c
esp_gatt_conn_reason_t reason
    disconnection reason
uint16_t conn_id
    Connection id
esp_bd_addr_t 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
esp_gatt_status_t status
    Operation status
uint16_t conn_id
    Connection id
```

```c
struct gattc_get_addr_list_evt_param
    #include <esp_gattc_api.h> ESP_GATTC_GET_ADDR_LIST_EVT.
```

Public Members

```c
esp_gatt_status_t status
    Operation status
uint8_t num_addr
    The number of address in the gattc cache address list
esp_bd_addr_t *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
esp_bd_addr_t 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
```

```c
struct gattc_open_evt_param
    #include <esp_gattc_api.h> ESP_GATTC_OPEN_EVT.
```
Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t conn_id
Connection id
```

```c
esp_bd_addr_t remote_bda
Remote bluetooth device address
```

```c
uint16_t mtu
MTU size
```

```c
struct gattc_queue_full_evt_param
#include <esp_gattc_api.h> ESP_GATTC_QUEUE_FULL_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t conn_id
Connection id
```

```c
bool is_full
The gattc command queue is full or not
```

```c
struct gattc_read_char_evt_param
#include <esp_gattc_api.h> ESP_GATTC_READ_CHAR_EVT, ESP_GATTC_READ_DESCR_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t conn_id
Connection id
```

```c
uint16_t handle
Characteristic handle
```

```c
uint8_t* value
Characteristic value
```

```c
uint16_t value_len
Characteristic value length
```

```c
struct gattc_reg_evt_param
#include <esp_gattc_api.h> ESP_GATTC_REG_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```c
uint16_t app_id
Application id which input in register API
```

```c
struct gattc_reg_for_notify_evt_param
#include <esp_gattc_api.h> ESP_GATTC_REG_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_search_cmpl_evt_param
#include <esp_gattc_api.h> ESP_GATTC_SEARCH_CMPL_EVT.
```

Public Members

```c
esp_gatt_status_t status
Operation status
```

```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

```c
typedef void (*esp_gattc_cb_t)(esp_gattc_cb_event_t event, esp_gatt_if_t gatc_if, esp_ble_gattc_cb_param_t *param)
```
GATT Client callback function type.

Parameters

- **event**: Event type
- **gatc_if**: GATT client access interface, normally different gatc_if correspond to different profile
- **param**: Point to callback parameter, currently is union type

Enumerations

```c
enum esp_gattc_cb_event_t
```
GATT Client callback function events.

Values:

```c
ESP_GATTC_REG_EVT = 0
```
When GATT client is registered, the event comes

```c
ESP_GATTC_UNREG_EVT = 1
```
When GATT client is unregistered, the event comes

```c
ESP_GATTC_OPEN_EVT = 2
```
When GATT virtual connection is set up, the event comes

```c
ESP_GATTC_READ_CHAR_EVT = 3
```
When GATT characteristic is read, the event comes

```c
ESP_GATTC_WRITE_CHAR_EVT = 4
```
When GATT characteristic write operation completes, the event comes

```c
ESP_GATTC_CLOSE_EVT = 5
```
When GATT virtual connection is closed, the event comes

```c
ESP_GATTC_SEARCH_CMPL_EVT = 6
```
When GATT service discovery is completed, the event comes
<table>
<thead>
<tr>
<th>Event Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_GATTC_SEARCH_RES_EVT = 7</td>
<td>When GATT service discovery result is got, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_READ_DESCR_EVT = 8</td>
<td>When GATT characteristic descriptor read completes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_WRITE_DESCR_EVT = 9</td>
<td>When GATT characteristic descriptor write completes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_NOTIFY_EVT = 10</td>
<td>When GATT notification or indication arrives, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_PREP_WRITE_EVT = 11</td>
<td>When GATT prepare-write operation completes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_EXEC_EVT = 12</td>
<td>When write execution completes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_ACL_EVT = 13</td>
<td>When ACL connection is up, the event comes</td>
</tr>
<tr>
<td>ESP_GATTCCANCEL_OPEN_EVT = 14</td>
<td>When GATT client ongoing connection is cancelled, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_SRVC_CHG_EVT = 15</td>
<td>When “service changed” occurs, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_ENC_CMPL_CB_EVT = 17</td>
<td>When encryption procedure completes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_CFG_MTU_EVT = 18</td>
<td>When configuration of MTU completes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_ADV_DATA_EVT = 19</td>
<td>When advertising of data, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_MULT_ADV_ENB_EVT = 20</td>
<td>When multi-advertising is enabled, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_MULT_ADV_UPD_EVT = 21</td>
<td>When multi-advertising parameters are updated, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_MULT_ADV_DATA_EVT = 22</td>
<td>When multi-advertising data arrives, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_MULT_ADV_DIS_EVT = 23</td>
<td>When multi-advertising is disabled, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_CONGEST_EVT = 24</td>
<td>When GATT connection congestion comes, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_BTH_SCAN_ENB_EVT = 25</td>
<td>When batch scan is enabled, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_BTH_SCAN_CFG_EVT = 26</td>
<td>When batch scan storage is configured, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_BTH_SCAN_RD_EVT = 27</td>
<td>When Batch scan read event is reported, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_BTH_SCAN_THR_EVT = 28</td>
<td>When Batch scan threshold is set, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_BTH_SCAN_PARAM_EVT = 29</td>
<td>When Batch scan parameters are set, the event comes</td>
</tr>
<tr>
<td>ESP_GATTC_BTH_SCAN_DIS_EVT = 30</td>
<td>When Batch scan is disabled, the event comes</td>
</tr>
</tbody>
</table>
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ESP_GATTC_SCAN_FLT_CFG_EVT = 31
When Scan filter configuration completes, the event comes

ESP_GATTC_SCAN_FLT_PARAM_EVT = 32
When Scan filter parameters are set, the event comes

ESP_GATTC_SCAN_FLT_STATUS_EVT = 33
When Scan filter status is reported, the event comes

ESP_GATTC_ADV_VSC_EVT = 34
When advertising vendor spec content event is reported, the event comes

ESP_GATTC_REG_FOR_NOTIFY_EVT = 38
When register for notification of a service completes, the event comes

ESP_GATTC_UNREG_FOR_NOTIFY_EVT = 39
When unregister for notification of a service completes, the event comes

ESP_GATTC_CONNECT_EVT = 40
When the ble physical connection is set up, the event comes

ESP_GATTC_DISCONNECT_EVT = 41
When the ble physical connection disconnected, the event comes

ESP_GATTC_READ_MULTIPLE_EVT = 42
When the ble characteristic or descriptor multiple complete, the event comes

ESP_GATTC_QUEUE_FULL_EVT = 43
When the gattc command queue full, the event comes

ESP_GATTC_SET_ASSOC_EVT = 44
When the ble gattc set the associated address complete, the event comes

ESP_GATTC_GET_ADDR_LIST_EVT = 45
When the ble get gattc address list in cache finish, the event comes

ESP_GATTC_DIS_SRVĆ_CMPL_EVT = 46
When the ble discover service 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
Chapter 2. API Reference

Functions

```c
esp_err_t esp_blufi_register_callbacks(esp_blufi_callbacks_t *callbacks)
This function is called to receive blufi callback event.
```

**Parameters**

- **callbacks**: callback functions

```c
esp_err_t esp_blufi_profile_init()
This function is called to initialize blufi_profile.
```

**Parameters**

```c
esp_err_t esp_blufi_profile_deinit()
This function is called to de-initialize blufi_profile.
```

**Parameters**

- **extra_info**: extra information, such as sta_ssid, softap_ssid and etc.

```c
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.

```c
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

```c
uint16_t esp_blufi_get_version()
Get BLUFI profile version.
```

**Parameters**

- **state**: error state

```c
esp_err_t esp_blufi_send_custom_data(uint8_t* data, uint32_t data_len)
This function is called to send custom data.
```

**Parameters**

- **data**: custom data value
- **data_len**: the length of custom data

Unions

```c
union esp_blufi_cb_param_t
#include <esp_blufi_api.h> BLUFI callback parameters union.
```
Public Members

```c
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_sta_passwd_evt_param sta_passwd  
Blufi callback param of ESP_BLUFI_EVENT_RECV_STA_PASSWD

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_ca_evt_param ca  
Blufi callback param of ESP_BLUFI_EVENT_RECV_CA_CERT

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

```c
esp_bd_addr_t remote_bda
  Blufi Remote bluetooth device address
```

```c
uint8_t server_if
  server interface
```

```c
uint16_t conn_id
  Connection id
```

```c
struct blufi_deinit_finish_evt_param
  #include <esp_blufi_api.h> ESP_BLUFI_EVENT_DEINIT_FINISH.
```

Public Members

```c
esp_blufi_deinit_state_t state
  De-initial status
```

```c
struct blufi_disconnect_evt_param
  #include <esp_blufi_api.h> ESP_BLUFI_EVENT_DISCONNECT.
```

Public Members

```c
esp_bd_addr_t remote_bda
  Blufi Remote bluetooth device address
```

```c
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
```

```c
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
```

```c
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
```

```c
struct blufi_recv_client_cert_evt_param
  #include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_CLIENT_CERT
```
Public Members

uint8_t *cert
Client certificate point

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

uint8_t *pkey
Client Private Key point, if Client certificate not contain Key

int pkey_len
Client Private key length

struct blufi_recv_custom_data_evt_param
#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
#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
#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
#include <esp_blufi_api.h> ESP_BLUFI_EVENT_RECV_SOFTAP_AUTH_MODE.
Public Members

```c
wifi_auth_mode_t auth_mode
```
Authentication mode

```c
struct blufi_recv_softap_channel_evt_param
#include <esp_blufi_api.h>
```
ESP_BLUFI_EVENT_RECV_SOFTAP_CHANNEL.

Public Members

```c
uint8_t channel
```
Authentication mode

```c
struct blufi_recv_softap_max_conn_num_evt_param
#include <esp_blufi_api.h>
```
ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM.

Public Members

```c
int max_conn_num
```
SSID

```c
struct blufi_recv_softap_passwd_evt_param
#include <esp_blufi_api.h>
```
ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD.

Public Members

```c
uint8_t *passwd
```
Password

```c
int passwd_len
```
Password Length

```c
struct blufi_recv_softap_ssid_evt_param
#include <esp_blufi_api.h>
```
ESP_BLUFI_EVENT_RECV_SOFTAP_SSID.

Public Members

```c
uint8_t *ssid
```
SSID

```c
int ssid_len
```
SSID length

```c
struct blufi_recv_sta_bssid_evt_param
#include <esp_blufi_api.h>
```
ESP_BLUFI_EVENT_RECV_STA_BSSID.

Public Members

```c
uint8_t bssid[6]
```
BSSID

```c
struct blufi_recv_sta_passwd_evt_param
#include <esp_blufi_api.h>
```
ESP_BLUFI_EVENT_RECV_STA_PASSWD.
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Public Members

```c
uint8_t* passwd
Password

int passwd_len
Password Length
```

```c
#include <esp_blufi_api.h>
ESP_BLUFI_EVENT_RECV_STA_SSID.
```

Public Members

```c
uint8_t* ssid
SSID

int ssid_len
SSID length
```

```c
#include <esp_blufi_api.h>
ESP_BLUFI_EVENT_RECV_USERNAME.
```

Public Members

```c
uint8_t* name
Username point

int name_len
Username length
```

```c
#include <esp_blufi_api.h>
ESP_BLUFI_EVENT_SET_WIFI_MODE.
```

Public Members

```c
wifi_mode_t op_mode
Wifi operation mode
```

Structures

```c
struct esp_blufi_extra_info_t
BLUFI extra information structure.
```

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

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
BLUFU callback functions type.

Public Members

esp_blufi_event_cb_t event_cb
BLUFU event callback

esp_blufi_negotiate_data_handler_t negotiate_data_handler
BLUFU negotiate data function for negotiate share key

esp_blufi_encrypt_func_t encrypt_func
BLUFU encrypt data function with share key generated by negotiate_data_handler

esp_blufi_decrypt_func_t decrypt_func
BLUFU decrypt data function with share key generated by negotiate_data_handler

esp_blufi_checksum_func_t checksum_func
BLUFU check sum function (FCS)
Macros

ESP_BD_ADDR_LEN

Bluetooth address length.

Type Definitions

typedef uint8_t esp_bd_addr_t[ESP_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.

Parameters

• event:: Event type
• 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.

Parameters

• data:: data from phone
• len:: length of data from phone
• output_data:: data want to send to phone
• output_len:: length of data want to send to phone
• 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.

Return Nonnegative number is encrypted length, if error, return negative number;

Parameters

• iv8:: initial vector(8bit), normally, blufi core will input packet sequence number
• crypt_data:: plain text and encrypted data, the encrypt function must support autochthonous encrypt
• crypt_len:: length of plain text

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.

Return Nonnegative number is decrypted length, if error, return negative number;

Parameters

• iv8:: initial vector(8bit), normally, blufi core will input packet sequence number
• crypt_data:: encrypted data and plain text, the encrypt function must support autochthonous decrypt
• crypt_len:: length of encrypted text

typedef uint16_t(*esp_blufi_checksum_func_t)(uint8_t iv8, uint8_t *data, int len)

BLUFI checksum.

Parameters

• iv8:: initial vector(8bit), normally, blufi core will input packet sequence number
• data:: data need to checksum
• len:: length of data

Enumerations

enum esp_blufi_cb_event_t

Values:

ESP_BLUFI_EVENT_INIT_FINISH = 0
ESP_BLUFI_EVENT_DEINIT_FINISH
ESP_BLUFI_EVENT_SET_WIFI_OPMODE
ESP_BLUFI_EVENT_BLE_CONNECT
ESP_BLUFI_EVENT_BLE_DISCONNECT
ESP_BLUFI_EVENT_REQ_CONNECT_TO_AP
ESP_BLUFI_EVENT_REQ_DISCONNECT_FROM_AP
ESP_BLUFI_EVENT_GET_WIFI_STATUS
ESP_BLUFI_EVENT_DEAUTHENTICATE_STA
ESP_BLUFI_EVENT_RECV_STA_BSSID
ESP_BLUFI_EVENT_RECV_STA_SSID
ESP_BLUFI_EVENT_RECV_STA_PASSWD
ESP_BLUFI_EVENT_RECV_SOFTAP_SSID
ESP_BLUFI_EVENT_RECV_SOFTAP_PASSWD
ESP_BLUFI_EVENT_RECV_SOFTAP_MAX_CONN_NUM
ESP_BLUFI_EVENT_RECV_SOFTAP_AUTH_MODE
ESP_BLUFI_EVENT_RECV_SOFTAP_CHANNEL
ESP_BLUFI_EVENT_RECV_USERNAME
ESP_BLUFI_EVENT_RECV_CA_CERT
ESP_BLUFI_EVENT_RECV_CLIENT_CERT
ESP_BLUFI_EVENT_RECV_SERVER_CERT
ESP_BLUFI_EVENT_RECV_CLIENT_PRIV_KEY
ESP_BLUFI_EVENT_RECV_SERVER_PRIV_KEY
ESP_BLUFI_EVENT_RECV_SLAVE_DISCONNECT_BLE
ESP_BLUFI_EVENT_GET_WIFI_LIST
ESP_BLUFI_EVENT_RECV_CUSTOM_DATA

enum esp_blufi_sta_conn_state_t
BLUFI config status.

Values:
ESP_BLUFI_STA_CONN_SUCCESS = 0x00
ESP_BLUFI_STA_CONN_FAIL = 0x01

enum esp_blufi_init_state_t
BLUFI init status.

Values:
ESP_BLUFI_INIT_OK = 0
ESP_BLUFI_INIT_FAILED

enum esp_blufi_deinit_state_t
BLUFI deinit status.

Values:
ESP_BLUFI_DEINIT_OK = 0
ESP_BLUFI_DEINIT_FAILED
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```c
enum esp_blufi_error_state_t
{
    ESP_BLUFI_SEQUENCE_ERROR = 0,
    ESP_BLUFI_CHECKSUM_ERROR,
    ESP_BLUFI_DECRYPT_ERROR,
    ESP_BLUFI_ENCRYPT_ERROR,
    ESP_BLUFI_INIT_SECURITY_ERROR,
    ESP_BLUFI_DH_MALLOC_ERROR,
    ESP_BLUFI_DH_PARAM_ERROR,
    ESP_BLUFI_READ_PARAM_ERROR,
    ESP_BLUFI_MAKE_PUBLIC_ERROR,
    ESP_BLUFI_DATA_FORMAT_ERROR,
}
```

2.1.4 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 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. However, 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 requirements.

![ESP NimBLE Stack](image)

Fig. 1: ESP NimBLE Stack

Threading Model

The NimBLE host can run inside the application thread or can have its own independent thread. This flexibility is inherently provided by NimBLE design. By default, a thread is spawned by the porting function `nimble_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.
• Call `esp_nimble_hci_and_controller_init()` to initialize ESP controller as well as transport layer. This will also link the host and controller modules together. Alternatively, if ESP controller is already initialized, then `esp_nimble_hci_init()` can be called for the remaining initialization.
• Initialize the host stack using `nimble_port_init`.
• Initialize the required NimBLE host configuration parameters and callbacks
• Perform application specific tasks/initialization
• 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

`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.

Return

• 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_and_controller_init(void)`
Initialize ESP Bluetooth controller(link layer) and VHCI transport layer between NimBLE Host and ESP Bluetooth controller.

This function initializes ESP controller in BLE only mode and the transport buffers to be exchanged between NimBLE host and ESP controller. It also registers required host callbacks with the controller.

Below is the sequence of APIs to be called to init/enable NimBLE host and ESP controller:

```c
void ble_host_task(void *param)
{
    nimble_port_run(); //This function will return only when nimble_port->stop() is executed.
    nimble_port_freertos_deinit();
}

int ret = esp_nimble_hci_and_controller_init();
if (ret != ESP_OK) {
    ESP_LOGE(TAG, "esp_nimble_hci_and_controller_init() failed with error: %d", ret);
    return;
}

nimble_port_init();

//Initialize the NimBLE Host configuration
```

(continues on next page)
nimble_port_freertos_init(ble_host_task);

nimble_port_freertos_init() is an optional call that creates a new task in which the NimBLE host will run. The task function should have a call to nimble_port_run(). If a separate task is not required, calling nimble_port_run() will run the NimBLE host in the current task.

**Return**
- ESP_OK if the initialization is successful
- Appropriate error code from esp_err_t in case of an error

```c
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.

**Return**
- ESP_OK if the deinitialization is successful
- Appropriate error codes from esp_err_t in case of an error

```c
esp_err_t esp_nimble_hci_and_controller_deinit (void)
```
Deinitialize VHCI transport layer between NimBLE Host and ESP Bluetooth controller and disable and deinitialize the controller.

Below is the sequence of APIs to be called to disable/deinit NimBLE host and ESP controller:

**Note** This function should not be executed in the context of Bluetooth host task.

**Note** This function should be called after the NimBLE host is deinitialized.

```c
int ret = nimble_port_stop();
if (ret == 0) {
    nimble_port_deinit();
    ret = esp_nimble_hci_and_controller_deinit();
    if (ret != ESP_OK) {
        ESP_LOGE(TAG, "esp_nimble_hci_and_controller_deinit() failed with_:\n        " error: %d", ret);
    }
}
```

If nimble_port_freertos_init() is used during initialization, then nimble_port_freertos_deinit() should be called in the host task after nimble_port_run().

**Return**
- ESP_OK if the deinitialization is successful
- Appropriate error codes from esp_err_t in case of an error

**Macros**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BLE_HCI_UART_H4_NONE</td>
<td></td>
</tr>
<tr>
<td>BLE_HCI_UART_H4_CMD</td>
<td></td>
</tr>
<tr>
<td>BLE_HCI_UART_H4_ACL</td>
<td></td>
</tr>
<tr>
<td>BLE_HCI_UART_H4_SCO</td>
<td></td>
</tr>
<tr>
<td>BLE_HCI_UART_H4_EVT</td>
<td></td>
</tr>
</tbody>
</table>

### 2.1.5 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 a 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 a 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
    
Event parameter of ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME_COMP_EVT

struct esp_ble_mesh_prov_cb_param_t::ble_mesh_prov_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_prov_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_num_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_param 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_param 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_event_param provisioner_prov_read_oob_pub_key_event
Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB Púb_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_link_close_evt
Event parameter of ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT
struct esp_ble_mesh_prov_cb_param_t::ble_mesh_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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
Event parameter of ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_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_DRIECT_ERASE_SETTINGS_COMP_EVT.
Event parameters of ESP_BLE_MESH_PROVISIONER_DRIECT_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
Chapter 2. API Reference

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::{anonymous} 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::{anonymous} 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::{anonymous} ble_mesh_heartbeat_msg_recv
heartbeat_msg_recv
Event parameter of ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT

struct esp_ble_mesh_prov_cb_param_t::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} 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::{anonymous} ble_mesh_proxy_clientDisconnected_param
proxy_clientDisconnected
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT

struct esp_ble_mesh_prov_cb_param_t::{anonymous} ble_mesh_proxy_client_recv_filter_status_param
proxy_client_recv_filter
Event parameter of ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT
**Public Members**

```c
int err_code
```

Indicate the result of BLE Mesh deinitialization

**Public Types**

```c
enum [anonymous]
```

This enum value is the reason of friendship termination on the friend node side

**Values:**

```c
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

```c
ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_POLL_TIMEOUT
```

Friendship is established, PollTimeout timer expires and no Friend Poll/Sub Add/Sub Remove is received

```c
ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_RECV_FRND_REQ
```

Receive Friend Request from existing Low Power Node

```c
ESP_BLE_MESH_FRND_FRIENDSHIP_TERMINATE_RECV_FRND_CLEAR
```

Receive Friend Clear from other friend node
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

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

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

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

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

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

struct ble_mesh_link_close_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_LINK_CLOSE_EVT.
Public Members

```c
struct ble_mesh_link_open_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_LINK_OPEN_EVT.
```

Public Members

```c
struct ble_mesh_lpn_disable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_DISABLE_COMP_EVT.
```

Public Members

```c
struct ble_mesh_lpn_enable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_ENABLE_COMP_EVT.
```

Public Members

```c
struct ble_mesh_lpn_friendship_establish_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT.
```

Public Members

```c
struct ble_mesh_lpn_friendship_terminate_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT.
```

Public Members

```c
struct ble_mesh_lpn_poll_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_LPN_POLL_COMP_EVT.
```

Public Members

```c
struct ble_mesh_model_sub_group_addr_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT.
```
Chapter 2. API Reference

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

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_NODE_PROV_REGISTER_PKT_EVT.
Public Members

int **err_code**
Indicate the result of BLE Mesh initialization

```c
struct ble_mesh_provision_complete_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT.
```

Public Members

```c
uint16_t net_idx
NetKey Index
```
```c
uint8_t net_key[16]
NetKey
```
```c
uint16_t addr
Primary address
```
```c
uint8_t flags
Flags
```
```c
uint32_t iv_index
IV Index
```

```c
struct ble_mesh_provision_reset_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_NODE_PROV_RESET_EVT.
```

```c
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

```c
int **err_code**
Indicate the result of adding local AppKey by the Provisioner
```
```c
uint16_t net_idx
NetKey Index
```
```c
uint16_t app_idx
AppKey Index
```

```c
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

```c
int **err_code**
Indicate the result of adding local NetKey by the Provisioner
```
```c
uint16_t net_idx
NetKey Index
```

```c
struct ble_mesh_provisioner_add_unprov_dev_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_ADD_UNPROV_DEV_COMP_EVT.
```
Chapter 2. API Reference

Public Members

```c
int err_code
Indicate the result of adding device into queue by the Provisioner
```

```c
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

```c
int err_code
Indicate the result of binding AppKey with model by the Provisioner
```

```c
uint16_t element_addr
Element address
```

```c
uint16_t app_idx
AppKey Index
```

```c
uint16_t company_id
Company ID
```

```c
uint16_t model_id
Model ID
```

```c
struct ble_mesh_provisioner_delete_dev_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT.
```

Public Members

```c
int err_code
Indicate the result of deleting device by the Provisioner
```

```c
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

```c
int err_code
Indicate the result of deleting node with unicast address by the Provisioner
```

```c
uint16_t unicast_addr
Node unicast address
```

```c
struct ble_mesh_provisioner_delete_node_with_uuid_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UUID_COMP_EVT.
```

Public Members

```c
int err_code
Indicate the result of deleting node with uuid by the Provisioner
```

```c
uint8_t uuid[16]
Node device uuid
```

```c
struct ble_mesh_provisioner_link_close_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT.
```
Chapter 2. API Reference

Public Members

```c
esp_ble_mesh_prov_bearer_t bearer
```

Type of the bearer used when Provisioner link is closed

```c
uint8_t reason
```

Reason of the closed provisioning link

```c
struct ble_mesh_provisioner_link_open_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_LINK_OPEN_EVT.
```

Public Members

```c
esp_ble_mesh_prov_bearer_t bearer
```

Type of the bearer used when Provisioner link is opened

```c
struct ble_mesh_provisioner_prov_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT.
```

Public Members

```c
uint16_t node_idx
```

Index of the provisioned device

```c
esp_ble_mesh_octet16_t device_uuid
```

Device UUID of the provisioned device

```c
uint16_t unicast_addr
```

Primary address of the provisioned device

```c
uint8_t element_num
```

Element count of the provisioned device

```c
uint16_t netkey_idx
```

NetKey Index of the provisioned device

```c
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

```c
int err_code
```

Indicate the result of Provisioner starting to provision a device

```c
struct ble_mesh_provisioner_prov_disable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT.
```

Public Members

```c
int err_code
```

Indicate the result of disabling BLE Mesh Provisioner

```c
struct ble_mesh_provisioner_prov_enable_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT.
```
Public Members

```c
int err_code
```

Indicate the result of enabling BLE Mesh Provisioner

```c
struct ble_mesh_provisioner_prov_input_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT.
```

Public Members

```c
esp_ble_mesh_oob_method_t method
```

Method of device Output OOB Authentication

```c
esp_ble_mesh_output_action_t action
```

Action of device Output OOB Authentication

```c
uint8_t size
```

Size of device Output OOB Authentication

```c
uint8_t link_idx
```

Index of the provisioning link

```c
struct ble_mesh_provisioner_prov_input_num_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT.
```

Public Members

```c
int err_code
```

Indicate the result of inputting number by the Provisioner

```c
struct ble_mesh_provisioner_prov_input_str_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT.
```

Public Members

```c
int err_code
```

Indicate the result of inputting string by the Provisioner

```c
struct ble_mesh_provisioner_prov_output_evt_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT.
```

Public Members

```c
esp_ble_mesh_oob_method_t method
```

Method of device Input OOB Authentication

```c
esp_ble_mesh_input_action_t action
```

Action of device Input OOB Authentication

```c
uint8_t size
```

Size of device Input OOB Authentication

```c
uint8_t link_idx
```

Index of the provisioning link

```c
char string[8]
```

String output by the Provisioner

```c
uint32_t number
```

Number output by the Provisioner
union esp_ble_mesh_prov_cb_param_t::ble_mesh_provisioner_prov_output_evt_param::[anonymous] [anonymous]

struct ble_mesh_provisioner_prov_read_oob_pub_key_comp_param
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_COMP_EVT.

Public Members

int err_code
Indicate the result of setting OOB Public Key by the Provisioner

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

uint8_t link_idx
Index of the provisioning link

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

uint8_t dev_uuid[16]
Device UUID of the unprovisioned device

esp_ble_mesh_bd_addr_t addr
Device address of the unprovisioned device

esp_ble_mesh_addr_type_t addr_type
Device address type

uint16_t oob_info
OOB Info of the unprovisioned device

uint8_t adv_type
Advertising type of the unprovisioned device

esp_ble_mesh_prov_bearer_t bearer
Bearer of the unprovisioned device

int8_t rssi
RSSI of the received advertising packet

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

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

```c
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

```c
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

```c
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

```c
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

```c
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

**struct ble_mesh_proxy_client_connected_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT.
```

**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

**struct ble_mesh_proxy_client_disconnect_comp_param**

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT.
```

**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

`struct ble_mesh_proxy_client_disconnected_param`

```
#include <esp_ble_mesh_defs.h> ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT.
```

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

`uint8_t reason`
Proxy disconnect reason

`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

`esp_ble_mesh_bd_addr_t addr`
Device address

`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

`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

`uint8_t conn_handle`
Proxy connection handle

`uint16_t server_addr`
Proxy Server primary element address

`uint16_t net_idx`
Corresponding NetKey Index
Chapter 2. API Reference

```
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.

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
```


```c
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
```

```c
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 statusunicast
Indicate the result of setting unicast address range of fast provisioning
uint8_t statusnet_idx
Indicate the result of setting NetKey Index of fast provisioning
uint8_t statusmatch
Indicate the result of setting matching Device UUID of fast provisioning
```

```c
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
```

```c
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
```

```c
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
```

```c
struct esp_ble_mesh_server_state_value_t::[anonymous] gen_onoff
The Generic OnOff state
```

```c
int16_t level
The value of the Generic Level state
```

```c
struct esp_ble_mesh_server_state_value_t::[anonymous] gen_level
The Generic Level state
```

```c
uint8_t onpowerup
The value of the Generic OnPowerUp state
```
struct esp_ble_mesh_server_state_value_t::[anonymous] gen_onpowerup
    The Generic OnPowerUp state

uint16_t power
    The value of the Generic Power Actual state

struct esp_ble_mesh_server_state_value_t::[anonymous] gen_power_actual
    The Generic Power Actual state

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 esp_ble_mesh_server_state_value_t::[anonymous] light_lightness_actual
    The Light Lightness Actual state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_lightness_linear
    The Light Lightness Linear state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_ctl_lightness
    The Light CTL Lightness state

uint16_t temperature
    The value of the Light CTL Temperature state

int16_t delta_uv
    The value of the Light CTL Delta UV state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_ctl_temp_delta_uv
    The Light CTL Temperature & Delta UV states

uint16_t hue
    The value of the Light HSL Hue state

uint16_t saturation
    The value of the Light HSL Saturation state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_hsl
    The Light HSL composite state

struct esp_ble_mesh_server_state_value_t::[anonymous] light_hsl_lightness
    The Light HSL Lightness state

struct esp_ble_mesh_server_state_value_t::[anonymous] 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

```c
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
```

```c
struct ble_mesh_client_model_send_timeout_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_CLIENT_MODEL_SEND_TIMEOUT_EVT.
```

Public Members

```c
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
```

```c
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

```c
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 message

uint16_t length
    Length of the received message

uint8_t *msg
    Value of the received message
```

```c
struct ble_mesh_model_operation_evt_param
    #include <esp_ble_mesh_defs.h> ESP_BLE_MESH_MODEL_OPERATION_EVT.
```
Chapter 2. API Reference

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

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

```c
int err_code
```
Indicate the result of updating server model state

```c
esp_ble_mesh_model_t *model
```
Pointer to the server model which state value is updated

```c
esp_ble_mesh_server_state_type_t type
```
Type of the updated server state

Structures

```c
struct esp_ble_mesh_deinit_param_t
```
BLE Mesh deinit parameters

Public Members

```c
bool erase_flash
```
Indicate if erasing flash when deinit mesh stack

```c
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

```c
uint16_t element_addr
```
Element Address, assigned during provisioning.

```c
const uint16_t location
```
Location Descriptor (GATT Bluetooth Namespace Descriptors)

```c
const uint8_t sig_model_count
```
SIG Model count

```c
const uint8_t vnd_model_count
```
Vendor Model count

```c
esp_ble_mesh_model_t *sig_models
```
SIG Models

```c
esp_ble_mesh_model_t *vnd_models
```
Vendor Models

```c
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

```c
esp_ble_mesh_model_t *model
```
Pointer to the model to which the context belongs. Initialized by the stack.

```c
uint16_t publish_addr
```
Publish Address.

```c
uint16_t app_idx : 12
```
Publish AppKey Index.

```c
uint16_t cred : 1
```
Friendship Credentials Flag.
uint16_t send_rel : 1
    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 : 4
    Divisor for the Period.
uint8_t fast_period : 1
    Use FastPeriodDivisor
uint8_t count : 3
    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

cons uint16_t model_id
16-bit model identifier

c uint16_t company_id
16-bit company identifier

c uint16_t model_id
16-bit model identifier

struct esp_ble_mesh_model::[anonymous]:[anonymous]::[anonymous]
Structure encapsulating a model ID with a company ID

union esp_ble_mesh_model::[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 : 7
    Received TTL value. Not used for sending.

uint8_t send_rel : 1
    Force sending reliably by using segment acknowledgement

uint8_t send_ttl
    TTL, or ESP_BLE_MESH_TTL_DEFAULT for default TTL.

uint32_t recv_op
    Opcode of a received message. Not used for sending message.

esp_ble_mesh_model_t *model
    Model corresponding to the message, no need to be initialized before sending message

bool srv_send
    Indicate if the message is sent by a node server model, no need to be initialized before sending message

struct esp_ble_mesh_prov_t
    Provisioning properties & capabilities. This structure is associated with struct bt_mesh_prov in mesh_access.h

struct esp_ble_mesh_comp_t
    Node Composition data context. This structure is associated with struct bt_mesh_comp in mesh_access.h

**Public Members**

uint16_t cid
    16-bit SIG-assigned company identifier

uint16_t pid
    16-bit vendor-assigned product identifier

uint16_t vid
    16-bit vendor-assigned product version identifier

size_t element_count
    Element count

esp_ble_mesh_elem_t *elements
    A sequence of elements

struct esp_ble_mesh_unprov_dev_add_t
    Information of the device which is going to be added for provisioning.

**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

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
**struct esp_ble_mesh_prov_bearer_t**
Provisioning Bearer

**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_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

tuint32_t iv_index
    Node IV Index

tuint8_t dev_key[16]
    Node device key

tchar name[ESP_BLE_MESH_NODE_NAME_MAX_LEN + 1]
    Node name

tuint16_t comp_length
    Length of Composition Data

tuint8_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_tt
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**

uint8_t tid
Transaction number of the last message

uint16_t src
Source address of the last message

uint16_t dst
Destination address of the last message

int64_t timestamp
Time when the last message is received

**struct esp_ble_mesh_server_rsp_ctrl_t**
Parameters of the Server Model response control

**Public Members**

uint8_t get_auto_rsp : 1
BLE Mesh Server Response Option.

1. If get_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, then the response of Client Get messages need to be replied by the application;
2. If get_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, then the response of Client Get messages will be replied by the server models;
3. If set_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, then the response of Client Set messages need to be replied by the application;
4. If set_auto_rsp is set to ESP_BLE_MESH_SERVER_AUTO_RSP, then the response of Client Set messages will be replied by the server models;
5. If status_auto_rsp is set to ESP_BLE_MESH_SERVER_RSP_BY_APP, then the response of Server Status messages need to be replied by the application;
6. If status_auto_rsp is set to 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

```
uint8_t set_auto_rsp : 1
   Response control for Client Set messages

uint8_t status_auto_rsp : 1
   Response control for Server Status messages
```

**Macros**

**ESP_BLE_MESH_SDU_MAX_LEN**
< The maximum length of a BLE Mesh message, including Opcode, Payload and TransMIC Length of a short Mesh MIC.

**ESP_BLE_MESH_MIC_SHORT**
Length of a long Mesh MIC.

**ESP_BLE_MESH_MIC_LONG**
The maximum length of a BLE Mesh provisioned node name

**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**
Primary Network Key index

**ESP_BLE_MESH_KEY_ANY**
Relay state value
Chapter 2. API Reference

ESP_BLE_MESH_RELAY_DISABLED
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 30 ms which includes 10ms of advertising interval random de-
lay).
Return BLE Mesh transmit value that can be used e.g. for the default values of the Configuration Model data.
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.
ESP_BLE_MESH_GET_TRANSMIT_COUNT(transmit)
Decode transmit count from a transmit value.
Return Transmission count (actual transmissions equal to N + 1).
Parameters
• transmit: Encoded transmit count & interval value.
Chapter 2. API Reference

ESP_BLE_MESH_GET_TRANSMIT_INTERVAL (transmit)
Decodes transmit interval from a transmit value.

Return Transmission interval in milliseconds.

Parameters
• transmit: Encoded transmit count & interval value.

ESP_BLE_MESH_PUBLISH_TRANSMIT (count, int_ms)
Encode Publish Retransmit count & interval steps.

Return BLE Mesh transmit value that can be used e.g. for the default values of the Configuration Model data.

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.

ESP_BLE_MESH_GET_PUBLISH_TRANSMIT_COUNT (transmit)
Decode Publish Retransmit count from a given value.

Return Retransmission count (actual transmissions equal to N + 1).

Parameters
• transmit: Encoded Publish Retransmit count & interval value.

ESP_BLE_MESH_GET_PUBLISH_TRANSMIT_INTERVAL (transmit)
Decode Publish Retransmit interval from a given value.

Callbacks which are not needed to be initialized by users (set with 0 and will be initialized internally)

Return Transmission interval in milliseconds.

Parameters
• transmit: Encoded Publish Retransmit count & interval value.

ESP_BLE_MESH_PROV_STATIC_OOB_MAX_LEN
Maximum length of string used by Output OOB authentication

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
Chapter 2. API Reference

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.

ESP_BLE_MESH_MODEL_ID_CONFIG_CLI

< Foundation Models

ESP_BLE_MESH_MODEL_ID_CONFIG_CLI
ESP_BLE_MESH_MODEL_ID_HEALTH_SRV
ESP_BLE_MESH_MODEL_ID_HEALTH_CLI
Models from the Mesh Model Specification

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
Chapter 2. API Reference

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
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_ID_LIGHT_XYL_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
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
Chapter 2. API Reference

- `ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_GET`
  - Config Key Refresh Phase Get

- `ESP_BLE_MESH_MODEL_OP_LPN_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_PUBLICATION_SET`
  - Config Model Publication Set

- `ESP_BLE_MESH_MODEL_OP_MODEL_SUBSCRIPTION_ADD`
  - Config Model Subscription Add

- `ESP_BLE_MESH_MODEL_OP_MODEL_SUBSCRIPTION_VIRTUAL_ADDR_ADD`
  - Config Model Subscription Virtual Address Add

- `ESP_BLE_MESH_MODEL_OP_MODEL_SUBSCRIPTION_DELETE`
  - Config Model Subscription Delete

- `ESP_BLE_MESH_MODEL_OP_MODEL_SUBSCRIPTION_VIRTUAL_ADDR_DELETE`
  - Config Model Subscription Virtual Address Delete

- `ESP_BLE_MESH_MODEL_OP_MODEL_SUBSCRIPTION_OVERWRITE`
  - Config Model Subscription Overwrite

- `ESP_BLE_MESH_MODEL_OP_NETWORK_KEY_ADD`
  - Config NetKey Add

- `ESP_BLE_MESH_MODEL_OP_APP_KEY_ADD`
  - Config AppKey Add

- `ESP_BLE_MESH_MODEL_OP_APP_BINDING`
  - 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_PUBLICATION_SET`
  - Config Heartbeat Publication Set

- `ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUBSCRIPTION_SET`
  - Config Heartbeat Subscription Set

- `ESP_BLE_MESH_MODEL_OP_NETWORK_KEY_UPDATE`
  - Config NetKey Update

- `ESP_BLE_MESH_MODEL_OP_NETWORK_KEY_DELETE`
  - Config NetKey Delete
Chapter 2. API Reference

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

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_LPN_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
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_HEALTH_PERIOD_SET_UNACK
  Health Period Set Unacknowledged
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_HEALTH_CURRENT_STATUS
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_STATUS
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_STATUS
ESP_BLE_MESH_MODEL_OP_ATTENTION_STATUS
ESP_BLE_MESH_MODEL_OP_GEN_ONOFF_GET
Chapter 2. API Reference

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
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
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
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
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
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_SCHEDULER_GET
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_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_SET_UNACK
    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_DEFAULT_GET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_STATUS
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_DEFAULT_SET_UNACK
Chapter 2. API Reference

ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET
ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_SET_UNACK
    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
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 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 xyL Setup Message Opcode
Chapter 2. API Reference

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_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 u\_8_t esp\_ble\_mesh\_octet16\_t[ESP\_BLE\_MESH\_OCTET16\_LEN]
Define the BLE Mesh octet 8 bytes size
typedef u\_8_t esp\_ble\_mesh\_octet8\_t[ESP\_BLE\_MESH\_OCTET8\_LEN]
Invalid Company ID
typedef u\_32_t esp\_ble\_mesh\_cb\_t
typedef u\_8_t \_UIN\_T8
typedef u\_16_t \_UIN\_T16
typedef u\_32_t \_UIN\_T32
typedef u\_64_t \_UIN\_T64
typedef \_UIN\_T8 BT\_OCTET32[BT\_OCTET32\_LEN]
typedef u\_8_t BD\_ADDR[BD\_ADDR\_LEN]
typedef u\_8_t esp\_ble\_mesh\_bd\_addr\_t[BD\_ADDR\_LEN]
typedef u\_8_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 esp_ble_mesh_config_client_get_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_client_get_t
This typedef is only used to indicate the status code contained in some of the Configuration Server Model status message.

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
This typedef is only used to indicate the status code contained in some of the server models (e.g. Generic Server Model) status message.

typedef uint32_t esp_ble_mesh_generic_message_opcode_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.

typedef uint32_t esp_ble_mesh_sensor_message_opcode_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.

typedef uint32_t esp_ble_mesh_time_scene_message_opcode_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.

typedef uint32_t esp_ble_mesh_light_message_opcode_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:

- ESP_BLE_MESH_TYPE_PROV_CB
- ESP_BLE_MESH_TYPE_OUTPUT_NUM_CB
- ESP_BLE_MESH_TYPE_OUTPUT_STR_CB
- ESP_BLE_MESH_TYPE_INPUT_CB
- ESP_BLE_MESH_TYPE_LINK_OPEN_CB
- ESP_BLE_MESH_TYPE_LINK_CLOSE_CB
- ESP_BLE_MESH_TYPE_COMPLETE_CB
- ESP_BLE_MESH_TYPE_RESET_CB

enum esp_ble_mesh_oob_method_t

Values:

- ESP_BLE_MESH_NO_OOB
- ESP_BLE_MESH_STATIC_OOB
- ESP_BLE_MESH_OUTPUT_OOB
- ESP_BLE_MESH_INPUT_OOB

enum esp_ble_mesh_output_action_t

Values:

- ESP_BLE_MESH_NO_OUTPUT = 0
- ESP_BLE_MESH_BLINK = BIT(0)
- ESP_BLE_MESH_BEEP = BIT(1)
- ESP_BLE_MESH_VIBRATE = BIT(2)
- ESP_BLE_MESH_DISPLAY_NUMBER = BIT(3)
- ESP_BLE_MESH_DISPLAY_STRING = BIT(4)

enum esp_ble_mesh_input_action_t

Values:

- ESP_BLE_MESH_NO_INPUT = 0
- ESP_BLE_MESH_PUSH = BIT(0)
- ESP_BLE_MESH_TWIST = BIT(1)
- ESP_BLE_MESH_ENTER_NUMBER = BIT(2)
- ESP_BLE_MESH_ENTER_STRING = BIT(3)

enum esp_ble_mesh_prov_bearer_t

Values:

- ESP_BLE_MESH_PROV_ADV = BIT(0)
- ESP_BLE_MESH_PROV_GATT = BIT(1)

enum esp_ble_mesh_prov_oob_info_t

Values:

- ESP_BLE_MESH_PROV_OOB_OTHER = BIT(0)
- ESP_BLE_MESH_PROV_OOB_URI = BIT(1)
- ESP_BLE_MESH_PROV_OOB_2D_CODE = BIT(2)
- ESP_BLE_MESH_PROV_OOB_BAR_CODE = BIT(3)
ESP_BLE_MESH_PROV_OOB_NFC = BIT(4)
ESP_BLE_MESH_PROV_OOB_NUMBER = BIT(5)
ESP_BLE_MESH_PROV_OOB_STRING = BIT(6)
ESP_BLE_MESH_PROV_OOB_ON_BOX = BIT(11)
ESP_BLE_MESH_PROV_OOB_IN_BOX = BIT(12)
ESP_BLE_MESH_PROV_OOB_ON_PAPER = BIT(13)
ESP_BLE_MESH_PROV_OOB_IN_MANUAL = BIT(14)
ESP_BLE_MESH_PROV_OOB_ON_DEV = BIT(15)

enum esp_ble_mesh_dev_role_t
Values:
ROLE_NODE = 0
ROLE_PROVISIONER
ROLE_FAST_PROV

enum esp_ble_mesh_fast_prov_action_t
Values:
FAST_PROV_ACT_NONE
FAST_PROV_ACT_ENTER
FAST_PROV_ACT_SUSPEND
FAST_PROV_ACT_EXIT
FAST_PROV_ACT_MAX

enum esp_ble_mesh_proxy_filter_type_t
Values:
PROXY_FILTER_WHITELIST
PROXY_FILTER_BLACKLIST

enum esp_ble_mesh_prov_cb_event_t
Values:
ESP_BLE_MESH_PROV.Register.COMP.EVT
  Initialize BLE Mesh provisioning capabilities and internal data information completion event
ESP_BLE_MESH_NODE_SET_UNPROV_DEV_NAME.COMP.EVT
  Set the unprovisioned device name completion event
ESP_BLE_MESH_NODE_PROV_ENABLE.COMP.EVT
  Enable node provisioning functionality completion event
ESP_BLE_MESH_NODE_PROV_DISABLE.COMP.EVT
  Disable node provisioning functionality completion event
ESP_BLE_MESH_NODE_PROV_LINK.OPEN.EVT
  Establish a BLE Mesh link event
ESP_BLE_MESH_NODE_PROV_LINK.CLOSE.EVT
  Close a BLE Mesh link event
ESP_BLE_MESH_NODE_PROV_OOB_PUB_KEY.EVT
  Generate Node input OOB public key event
ESP_BLE_MESH_NODE_PROV_OUTPUT.NUMBER.EVT
  Generate Node Output Number event
Chapter 2. API Reference

ESP_BLE_MESH_NODE_PROV_OUTPUT_STRING_EVT
Generate Node Output String event

ESP_BLE_MESH_NODE_PROV_INPUT_EVT
Event requiring the user to input a number or string

ESP_BLE_MESH_NODE_PROV_COMPLETE_EVT
Provisioning done event

ESP_BLE_MESH_NODE_PROV_RESET_EVT
Provisioning reset event

ESP_BLE_MESH_NODE_PROV_SET_OOB_PUB_KEY_COMP_EVT
Node set oob public key completion event

ESP_BLE_MESH_NODE_PROV_INPUT_NUMBER_COMP_EVT
Node input number completion event

ESP_BLE_MESH_NODE_PROV_INPUT_STRING_COMP_EVT
Node input string completion event

ESP_BLE_MESH_NODE_PROXY_IDENTITY_ENABLE_COMP_EVT
Enable BLE Mesh Proxy Identity advertising completion event

ESP_BLE_MESH_NODE_PROXY_GATT_ENABLE_COMP_EVT
Enable BLE Mesh GATT Proxy Service completion event

ESP_BLE_MESH_NODE_PROXY_GATT_DISABLE_COMP_EVT
Disable BLE Mesh GATT Proxy Service completion event

ESP_BLE_MESH_NODE_ADD_LOCAL_NET_KEY_COMP_EVT
Node add NetKey locally completion event

ESP_BLE_MESH_NODE_ADD_LOCAL_APP_KEY_COMP_EVT
Node add AppKey locally completion event

ESP_BLE_MESH_NODE_BIND_APP_KEY_TO_MODEL_COMP_EVT
Node bind AppKey to model locally completion event

ESP_BLE_MESH_PROVISIONER_PROV_ENABLE_COMP_EVT
Provisioner enable provisioning functionality completion event

ESP_BLE_MESH_PROVISIONER_PROV_DISABLE_COMP_EVT
Provisioner disable provisioning functionality completion event

ESP_BLE_MESH_PROVISIONER_PROV_RECV_UNPROV_ADV_PKT_EVT
Provisioner receives unprovisioned device beacon event

ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_EVT
Provisioner read unprovisioned device OOB public key event

ESP_BLE_MESH_PROVISIONER_PROV_INPUT_EVT
Provisioner input value for provisioning procedure event

ESP_BLE_MESH_PROVISIONER_PROV_OUTPUT_EVT
Provisioner output value for provisioning procedure event

ESP_BLE_MESH_PROVISIONER_PROV_LINK_OPEN_EVT
Provisioner establish a BLE Mesh link event

ESP_BLE_MESH_PROVISIONER_PROV_LINK_CLOSE_EVT
Provisioner close a BLE Mesh link event

ESP_BLE_MESH_PROVISIONER_PROV_COMPLETE_EVT
Provisioner provisioning done event

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
**Chapter 2. API Reference**

- **ESP_BLE_MESH_PROVISIONER_PROV_DEV_WITH_ADDR_COMP_EVT**
  Provisioner start to provision an unprovisioned device completion event

- **ESP_BLE_MESH_PROVISIONER_DELETE_DEV_COMP_EVT**
  Provisioner delete a device from the list, close provisioning link with the device completion event

- **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

- **ESP_BLE_MESH_PROVISIONER_SET_PROV_DATA_INFO_COMP_EVT**
  Provisioner set net_idx(flags)/iv_index used for provisioning completion event

- **ESP_BLE_MESH_PROVISIONER_SET_STATIC_OOB_VALUE_COMP_EVT**
  Provisioner set static oob value used for provisioning completion event

- **ESP_BLE_MESH_PROVISIONER_SET_PRIMARY_ELEM_ADDR_COMP_EVT**
  Provisioner set unicast address of primary element completion event

- **ESP_BLE_MESH_PROVISIONER_PROV_READ_OOB_PUB_KEY_COMP_EVT**
  Provisioner read unprovisioned device OOB public key completion event

- **ESP_BLE_MESH_PROVISIONER_PROV_INPUT_NUMBER_COMP_EVT**
  Provisioner input number completion event

- **ESP_BLE_MESH_PROVISIONER_PROV_INPUT_STRING_COMP_EVT**
  Provisioner input string completion event

- **ESP_BLE_MESH_PROVISIONER_SET_NODE_NAME_COMP_EVT**
  Provisioner set node name completion event

- **ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_APP_KEY_COMP_EVT**
  Provisioner add local app key completion event

- **ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_APP_KEY_COMP_EVT**
  Provisioner update local app key completion event

- **ESP_BLE_MESH_PROVISIONER_BIND_APP_KEY_TO_MODEL_COMP_EVT**
  Provisioner bind local model with local app key completion event

- **ESP_BLE_MESH_PROVISIONER_ADD_LOCAL_NET_KEY_COMP_EVT**
  Provisioner add local network key completion event

- **ESP_BLE_MESH_PROVISIONER_UPDATE_LOCAL_NET_KEY_COMP_EVT**
  Provisioner update local network key completion event

- **ESP_BLE_MESH_PROVISIONER_STORE_NODE_COMP_DATA_COMP_EVT**
  Provisioner store node composition data completion event

- **ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_UUID_COMP_EVT**
  Provisioner delete node with uuid completion event

- **ESP_BLE_MESH_PROVISIONER_DELETE_NODE_WITH_ADDR_COMP_EVT**
  Provisioner delete node with unicast address completion event

- **ESP_BLE_MESH_PROVISIONER_ENABLE_HEARTBEAT_RECV_COMP_EVT**
  Provisioner start to receive heartbeat message completion event

- **ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_TYPE_COMP_EVT**
  Provisioner set the heartbeat filter type completion event

- **ESP_BLE_MESH_PROVISIONER_SET_HEARTBEAT_FILTER_INFO_COMP_EVT**
  Provisioner set the heartbeat filter information completion event

- **ESP_BLE_MESH_PROVISIONER_RECV_HEARTBEAT_MESSAGE_EVT**
  Provisioner receive heartbeat message event

- **ESP_BLE_MESH_PROVISIONER_DRIECT_ERASE_SETTINGS_COMP_EVT**
  Provisioner directly erase settings completion event
ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_INDEX_COMP_EVT
Provisioner open settings with index completion event

ESP_BLE_MESH_PROVISIONER_OPEN_SETTINGS_WITH_UID_COMP_EVT
Provisioner open settings with user id completion event

ESP_BLE_MESH_PROVISIONER_CLOSESETTINGS_WITH_INDEX_COMP_EVT
Provisioner close settings with index completion event

ESP_BLE_MESH_PROVISIONER_CLOSE_SETTINGS_WITH_UID_COMP_EVT
Provisioner close settings with user id completion event

ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_INDEX_COMP_EVT
Provisioner delete settings with index completion event

ESP_BLE_MESH_PROVISIONER_DELETE_SETTINGS_WITH_UID_COMP_EVT
Provisioner delete settings with user id completion event

ESP_BLE_MESH_SET_FAST_PROV_INFO_COMP_EVT
Set fast provisioning information (e.g. unicast address range, net_idx, etc.) completion event

ESP_BLE_MESH_SET_FAST_PROV_ACTION_COMP_EVT
Set fast provisioning action completion event

ESP_BLE_MESH_HEARTBEAT_MESSAGE_RECV_EVT
Receive Heartbeat message event

ESP_BLE_MESH_LPN_ENABLE_COMP_EVT
Enable Low Power Node completion event

ESP_BLE_MESH_LPN_DISABLE_COMP_EVT
Disable Low Power Node completion event

ESP_BLE_MESH_LPN_POLL_COMP_EVT
Low Power Node send Friend Poll completion event

ESP_BLE_MESH_LPN_FRIENDSHIP_ESTABLISH_EVT
Low Power Node establishes friendship event

ESP_BLE_MESH_LPN_FRIENDSHIP_TERMINATE_EVT
Low Power Node terminates friendship event

ESP_BLE_MESH_FRIEND_FRIENDSHIP_ESTABLISH_EVT
Friend Node establishes friendship event

ESP_BLE_MESH_FRIEND_FRIENDSHIP_TERMINATE_EVT
Friend Node terminates friendship event

ESP_BLE_MESH_PROXY_CLIENT_RECV_ADV_PKT_EVT
Proxy Client receives Network ID advertising packet event

ESP_BLE_MESH_PROXY_CLIENT_CONNECTED_EVT
Proxy Client establishes connection successfully event

ESP_BLE_MESH_PROXY_CLIENT_DISCONNECTED_EVT
Proxy Client terminates connection successfully event

ESP_BLE_MESH_PROXY_CLIENT_RECV_FILTER_STATUS_EVT
Proxy Client receives Proxy Filter Status event

ESP_BLE_MESH_PROXY_CLIENT_CONNECT_COMP_EVT
Proxy Client connect completion event

ESP_BLE_MESH_PROXY_CLIENT_DISCONNECT_COMP_EVT
Proxy Client disconnect completion event

ESP_BLE_MESH_PROXY_CLIENT_SET_FILTER_TYPE_COMP_EVT
Proxy Client set filter type completion event
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**ESP_BLE_MESH_PROXY_CLIENT_ADD_FILTER_ADDR_COMP_EVT**
Proxy Client add filter address completion event

**ESP_BLE_MESH_PROXY_CLIENT_REMOVE_FILTER_ADDR_COMP_EVT**
Proxy Client remove filter address completion event

**ESP_BLE_MESH_MODEL_SUBSCRIBE_GROUP_ADDR_COMP_EVT**
Local model subscribes group address completion event

**ESP_BLE_MESH_MODEL_UNSUBSCRIBE_GROUP_ADDR_COMP_EVT**
Local model unsubscribes group address completion event

**ESP_BLE_MESH_DEINIT_MESH_COMP_EVT**
De-initialize BLE Mesh stack completion event

**ESP_BLE_MESH_PROV_EVT_MAX**

```c
enum [anonymous]
BLE Mesh server models related definitions.

This enum value is the flag of transition timer operation

*Values:*

ESP_BLE_MESH_SERVER_TRANS_TIMER_START
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:*

ESP_BLE_MESH_GENERIC_ONOFF_STATE
ESP_BLE_MESH_GENERIC_LEVEL_STATE
ESP_BLE_MESH_GENERIC_ONPOWERUP_STATE
ESP_BLE_MESH_GENERIC_POWER_ACTUAL_STATE
ESP_BLE_MESH_LIGHT_LIGHTNESS_ACTUAL_STATE
ESP_BLE_MESH_LIGHT_LIGHTNESS_LINEAR_STATE
ESP_BLE_MESH_LIGHT_CTL_LIGHTNESS_STATE
ESP_BLE_MESH_LIGHT_CTL_TEMP_DELTA_UV_STATE
ESP_BLE_MESH_LIGHT_HSL_STATE
ESP_BLE_MESH_LIGHT_HSL_LIGHTNESS_STATE
ESP_BLE_MESH_LIGHT_HSL_HUE_STATE
ESP_BLE_MESH_LIGHT_HSL_SATURATION_STATE
ESP_BLE_MESH_LIGHT_XYL_LIGHTNESS_STATE
ESP_BLE_MESH_LIGHT_LC_LIGHT_ONOFF_STATE
ESP_BLE_MESH_SERVER_MODEL_STATE_MAX

**enum esp_ble_mesh_model_cb_event_t**

*Values:*

ESP_BLE_MESH_MODEL_OPERATION_EVT
User-defined models receive messages from peer devices (e.g. get, set, status, etc) event

ESP_BLE_MESH_MODEL_SEND_COMP_EVT
User-defined models send messages completion event

ESP_BLE_MESH_MODEL_PUBLISH_COMP_EVT
User-defined models publish messages completion event
ESP_BLE_MESH_CLIENT_MODEL_RECV_PUBLISH_MSG_EVT
User-defined client models receive publish messages event

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

ESP_BLE_MESH_MODEL_PUBLISH_UPDATE_EVT
When a model is configured to publish messages periodically, this event will occur during every publish period

ESP_BLE_MESH_SERVER_MODEL_UPDATE_STATE_COMP_EVT
Server models update state value completion event

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.

Return ESP_OK on success or error code otherwise.

Parameters

• [in] prov: Pointer to the device provisioning capabilities. This pointer must remain valid during the lifetime of the BLE Mesh device.
• [in] comp: Pointer to the device composition data information. This pointer must remain valid during the lifetime of the BLE Mesh device.

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().

Return ESP_OK on success or error code otherwise.

Parameters

• [in] param: Pointer to the structure of BLE Mesh deinit parameters.

Reading of Local Data Information
**Header File**

- components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_local_data_operation_api.h

**Functions**

```c
int32_t esp_ble_mesh_get_model_publish_period (esp_ble_mesh_model_t *model)
```

Get the model publish period, the unit is ms.

**Return**
Publish period value on success, 0 or (negative) error code from errno.h on failure.

**Parameters**

```c
uint16_t esp_ble_mesh_get_primary_element_address (void)
```

Get the address of the primary element.

**Return**
Address of the primary element on success, or ESP_BLE_MESH_ADDR_UNASSIGNED on failure which means the device has not been provisioned.

```c
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.

**Return**
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.

**Parameters**
- [in] model: Pointer to the model.
- [in] group_addr: Group address.

```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.

**Return**
Pointer to the element on success, or NULL on failure.

**Parameters**
- [in] element_addr: Element address.

```c
uint8_t esp_ble_mesh_get_element_count (void)
```

Get the number of elements that have been registered.

**Return**
Number of elements.

```c
esp_ble_mesh_model_t* esp_ble_mesh_find_vendor_model (const esp_ble_mesh_elem_t *
                                                       element,
                                                       esp_ble_mesh_model_t *model,
                                                       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.

**Return**
Pointer to the Vendor Model on success, or NULL on failure which means the Vendor Model is not found.

**Parameters**
- [in] element: Element to which the model belongs.
- [in] company_id: A 16-bit company identifier assigned by the Bluetooth SIG.

```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.

**Return**
Pointer to the SIG Model on success, or NULL on failure which means the SIG Model is not found.

**Parameters**
- [in] element: Element to which the model belongs.
```c
const esp_ble_mesh_comp_t* esp_ble_mesh_get_composition_data (void)
Get the Composition data which has been registered.
Return 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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] element_addr: Unicast address of the element to which the model belongs.
• [in] group_addr: The group address to be subscribed.
```

```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)
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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] element_addr: Unicast address of the element to which the model belongs.
• [in] group_addr: The subscribed group address.
```

```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.
Return NetKey on success, or NULL on failure.
Parameters
• [in] net_idx: NetKey index.
```

```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.
Return AppKey on success, or NULL on failure.
Parameters
• [in] app_idx: AppKey index.
```

```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.
Note This function can only be called after the device is provisioned.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] net_key: NetKey to be added.
• [in] net_idx: NetKey Index.
```

```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.
Note The net_idx must be an existing one. This function can only be called after the device is provisioned.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] app_key: AppKey to be added.
• [in] net_idx: NetKey Index.
```
Chapter 2. API Reference

* [in] **app_idx**: AppKey Index.

```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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

* [in] **element_addr**: Node local element address
* [in] **company_id**: Node local company id
* [in] **model_id**: Node local model id
* [in] **app_idx**: Node local appkey index

### Low Power Operation (Updating)

**Header File**

* components/bt/esp_ble_mesh/api/core/include/esp_ble_mesh_low_power_api.h

**Functions**

* **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.

  **Return** ESP_OK on success or error code otherwise.

* **esp_err_t esp_ble_mesh_lpn_disable**(bool force)
  
  Disable BLE Mesh device LPN functionality.

  **Return** ESP_OK on success or error code otherwise.

  **Parameters**

  * [in] **force**: 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.

* **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.

  **Return** 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**
**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:

- 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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **in** callback: Pointer to the callback function.

**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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **in** data: Pointer to the message data.
- **in** opcode: The message opcode.

**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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **in** model: BLE Mesh Client model to which the message belongs.

**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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **in** model: Pointer of the Client model.

**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).

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **in** model: BLE Mesh Server Model to which the message belongs.
- **in** ctx: Message context, includes keys, TTL, etc.
- **in** opcode: Message opcode.
- **in** length: Message length (exclude the message opcode).
- **in** data: Parameters of Access Payload (exclude the message opcode) to be sent.
Send client model message (such as model get, set, etc).

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- [in] `model`: BLE Mesh Client Model to which the message belongs.
- [in] `ctx`: Message context, includes keys, TTL, etc.
- [in] `length`: Message length (include the message opcode).
- [in] `data`: Parameters of the Access Payload (exclude the message opcode) to be sent.
- [in] `msg_timeout`: Time to get response to the message (in milliseconds).
- [in] `need_rsp`: TRUE if the opcode requires the peer device to reply, FALSE otherwise.
- [in] `device_role`: Role of the device (Node/Provisioner) that sends the message.

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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- [in] `length`: Message length (include the message opcode).
- [in] `data`: Parameters of the Access Payload (exclude the message opcode) to be sent.
- [in] `device_role`: Role of the device (node/provisioner) publishing the message of the type `esp_ble_mesh_dev_role_t`.

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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- [in] `model`: Server model which is going to update the state.
- [in] `value`: Server model state value.

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 re-provisioned. The API function `esp_ble_mesh_node_prov_enable()` needs to be called to start a new provisioning procedure.

**Return** ESP_OK on success or error code otherwise.

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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
• [in] index: Index of the node in the node queue.
• [in] name: Name (end by ‘\0’) to be set for the node.

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.
Return Node name on success, or NULL on failure.
Parameters
• [in] index: Index of the node in the node queue.

uint16_t esp_ble_mesh_provisioner_get_node_index(const char *name)
This function is called to get the node (provisioned device) index.

Return Node index on success, or an invalid value (0xFFFF) on failure.
Parameters
• [in] name: Name of the node (end by ‘\0’).

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.

Return ESP_OK on success or error code otherwise.
Parameters
• [in] unicast_addr: Element address of the node
• [in] data: Pointer of Composition Data
• [in] length: Length of Composition Data

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.

Return Pointer of the node info struct or NULL on failure.
Parameters
• [in] uuid: Device UUID of the node

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.

Return Pointer of the node info struct or NULL on failure.
Parameters
• [in] unicast_addr: Unicast address of the node

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.

Return Pointer of the node info struct or NULL on failure.
Parameters
• [in] name: Name of the node (end by ‘\0’).

uint16_t esp_ble_mesh_provisioner_get_prov_node_count(void)
This function is called by Provisioner to get provisioned node count.

Return 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: ``` 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) { ⋯ } } 

Return 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.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] uuid: Device UUID of the node

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.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] unicast_addr: Unicast address of the node

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.

Note app_key: If set to NULL, app_key will be generated internally. net_idx: Should be an existing one. app_idx: If it is going to be generated internally, it should be set to 0xFFFF, and the new app_idx will be reported via an event.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] app_key: The app key to be set for the local BLE Mesh stack.
• [in] net_idx: The network key index.
• [in] app_idx: The app key index.

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.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] app_key: Value of the AppKey.
• [in] net_idx: Corresponding NetKey Index.
• [in] app_idx: The AppKey Index

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.

Return App key on success, or NULL on failure.

Parameters
• [in] app_idx: Application key index.

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.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] element_addr: Provisioner local element address
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- [in] app_idx: Provisioner local app key index
- [in] model_id: Provisioner local model id
- [in] company_id: Provisioner local company id

`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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- [in] net_key: The network key to be added to the Provisioner local BLE Mesh stack.

`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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- [in] net_key: Value of the NetKey.

`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.

**Return** Network key on success, or NULL on failure.

**Parameters**

`esp_err_t esp_ble_mesh_provisioner_recv_heartbeat(bool enable)`

This function is called by Provisioner to enable or disable receiving heartbeat messages.

**Note** If enabling receiving heartbeat message successfully, the filter will be an empty rejectlist by default, which means all heartbeat messages received by the Provisioner will be reported to the application layer.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- [in] enable: Enable or disable receiving heartbeat messages.

`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.
   1. 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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- [in] type: Heartbeat filter type (acceptlist or rejectlist).

`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.

1. 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.

Return: ESP_OK on success or error code otherwise.
Parameters:
- [in] op: Add or REMOVE
- [in] info: Heartbeat filter entry information, including: hb_src - Heartbeat source address; hb_dst - Heartbeat destination address;

**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.
Return: 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.
Return: ESP_OK on success or error code otherwise.
Parameters:
- [in] index: Settings index.

**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.
Return: ESP_OK on success or error code otherwise.
Parameters:
- [in] uid: Settings user id.

**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.
   1. 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.
   2. 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.
   3. 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) ……

Return: ESP_OK on success or error code otherwise.
Parameters:
- [in] index: Settings index.
- [in] erase: Indicate if erasing mesh information.

**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.
   1. 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.

2. 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.

3. 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) ……

Return ESP_OK on success or error code otherwise.

Parameters

- [in] uid: Settings user id.
- [in] erase: Indicate if erasing mesh information.

```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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] index: Settings index.

```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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] uid: Settings user id.

```c
const char* esp_ble_mesh_provisioner_get_settings_uid(uint8_t index)
```

This function is called by Provisioner to get settings user id.

Return Setting user id on success or NULL on failure.

Parameters

- [in] index: Settings index.

```c
uint8_t esp_ble_mesh_provisioner_get_settings_index(const char* uid)
```

This function is called by Provisioner to get settings index.

Return Settings index.

Parameters

- [in] uid: Settings user id.

```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.

Return 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.

Return Application key on success, or NULL on failure.

Parameters

- [in] app_idx: Application key index.

**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)

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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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] callback: Pointer to the callback function.

**bool esp_ble_mesh_node_is_provisioned (void)**

Check if a device has been provisioned.

Return 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.

Note PB-ADV: send unprovisioned device beacon. PB-GATT: send connectable advertising packets.

Return ESP_OK on success or error code otherwise.

Parameters


**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.

Return ESP_OK on success or error code otherwise.

Parameters


**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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] pub_key_x: Unprovisioned device’s Public Key X
- [in] pub_key_y: Unprovisioned device’s Public Key Y
- [in] private_key: Unprovisioned device’s Private Key

**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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] number: Number input by device.

**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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] string: String input by device.
### 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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in]** `name`: Unprovisioned device name

### 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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in]** `link_idx`: The provisioning link index
- **[in]** `pub_key_x`: Unprovisioned device’s Public Key X
- **[in]** `pub_key_y`: Unprovisioned device’s Public Key Y

### esp_err_t esp_ble_mesh_provisioner_input_string (const char *string, uint8_t link_idx)

Provide provisioning input OOB string.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in]** `string`: String input by Provisioner.
- **[in]** `link_idx`: The provisioning link index.

### esp_err_t esp_ble_mesh_provisioner_input_number (uint32_t number, uint8_t link_idx)

Provide provisioning input OOB number.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in]** `number`: Number input by Provisioner.
- **[in]** `link_idx`: The provisioning link index.

### 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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in]** `bearers`: Bit-wise OR of provisioning bearers.

### 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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in]** `bearers`: Bit-wise OR of provisioning bearers.
**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.

**Return** ESP_OK on success or error code otherwise.

**Note**:
1. Currently address type only supports public address and static random address.
2. 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.
3. 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**
- [in] add_dev: Pointer to a struct containing the device information
- [in] flags: 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)

**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.

**Return** Zero on success or (negative) error code otherwise.

**Note**:
1. Currently address type only supports public address and static random address.
2. 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.
2. 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.

3. 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**

- **[in] uuid**: Device UUID of the unprovisioned device
- **[in] addr**: Device address of the unprovisioned device
- **[in] addr_type**: Device address type of the unprovisioned device
- **[in] bearer**: Provisioning bearer going to be used by Provisioner
- **[in] oob_info**: OOB info of the unprovisioned device
- **[in] unicast_addr**: Unicast address going to be allocated for the unprovisioned device

```c
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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in] del_dev**: Pointer to a struct containing the device information.

```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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in] match_val**: Value to be compared with the part of the device UUID.
- **[in] match_len**: Length of the compared match value.
- **[in] offset**: Offset of the device UUID to be compared (based on zero).
- **[in] prov_after_match**: Flag used to indicate whether provisioner should start to provision the device immediately if the part of the UUID matches.

```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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in] prov_data_info**: Pointer to a struct containing net_idx or flags or iv_index.

```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).

**Return** ESP_OK on success or error code otherwise.

**Parameters**

- **[in] value**: Pointer to the static oob value.
- **[in] length**: Length of the static oob value.
**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 provunicast_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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- **[in]** addr: Unicast address of the Primary element of Provisioner.

**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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- **[in]** fast_prov_info: Pointer to a struct containing unicast address range, net_idx, etc.

**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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**
- **[in]** action: Fast provisioning action (i.e. enter, suspend, exit).

**Type Definitions**

```c
typedef void(*esp_ble_mesh_prov_cb_t)(esp_ble_mesh_prov_cb_event_t event, esp_ble_mesh_prov_cb_param_t *param)

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.

**Parameters**
- **[in]** addr: Pointer to the unprovisioned device address.
- **[in]** addr_type: Unprovisioned device address type.
- **[in]** adv_type: Adv packet type(ADV_IND or ADV_NONCONN_IND).
- **[in]** dev_uuid: Unprovisioned device UUID pointer.
- **[in]** oob_info: OOB information of the unprovisioned device.
- **[in]** bearer: 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**

```c
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.

Return ESP_OK on success or error code otherwise.

```c
esp_err_t esp_ble_mesh_proxy_gatt_enable (void)
Enable BLE Mesh GATT Proxy Service.
Return ESP_OK on success or error code otherwise.
```

```c
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.
Return ESP_OK on success or error code otherwise.
```

```c
esp_err_t esp_ble_mesh_proxy_gatt_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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] addr: Device address of the Proxy Server.
• [in] addr_type: Device address type (public or static random).
• [in] net_idx: NetKey Index relates with Network ID in the Mesh Proxy advertising packet.
```

```c
esp_err_t esp_ble_mesh_proxy_gatt_client_disconnect (uint8_t conn_handle)
Proxy Client terminates a connection with the Proxy Server.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] conn_handle: Proxy connection handle.
```

```c
esp_err_t esp_ble_mesh_proxy_gatt_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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] conn_handle: Proxy connection handle.
• [in] net_idx: Corresponding NetKey Index.
• [in] filter_type: whitelist or blacklist.
```

```c
esp_err_t esp_ble_mesh_proxy_gatt_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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] conn_handle: Proxy connection handle.
• [in] net_idx: Corresponding NetKey Index.
• [in] addr: Pointer to the filter address.
• [in] addr_num: Number of the filter address.
```

```c
esp_err_t esp_ble_mesh_proxy_gatt_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.
Return ESP_OK on success or error code otherwise.
Parameters
```
• [in] conn_handle: Proxy connection handle.
• [in] net_idx: Corresponding NetKey Index.
• [in] addr: Pointer to the filter address.
• [in] addr_num: Number of the filter address.

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.

Return ESP_OK on success or error code otherwise.

Parameters

• [in] callback: Pointer to the callback function.

```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.

Return ESP_OK on success or error code otherwise.

Parameters

• [in] callback: Pointer to the callback function.

```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.

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

Return ESP_OK on success or error code otherwise.

Parameters

• [in] params: Pointer to BLE Mesh common client parameters.
• [in] get_state: Pointer to a union, each kind of opcode corresponds to one structure inside.
  Shall not be set to NULL.

```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_set.h in esp_ble_mesh_defs.h

Return ESP_OK on success or error code otherwise.

Parameters

- [in] set_state: Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.

Unions

union esp_ble_mesh_cfg_client_get_state_t
#include <esp_ble_mesh_config_model_api.h> For ESP_BLE_MESH_MODEL_OP_BEACON_GET
ESP_BLE_MESH_MODEL_OP_COMPOSITION_DATA_GETESP_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 PubliGET ESP_BLE_MESH_MODEL_OP_FRIEND_GET
ESP_BLE_MESH_MODEL_OP_HEARTBEAT PubliGET 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(LP_POLLTIMEOUT_GET

union esp_ble_mesh_cfg_client_set_state_t
#include <esp_ble_mesh_config_model_api.h> For ESP_BLE_MESH_MODEL_OP_BEACON_SET
ESP_BLE_MESH_MODEL_OP_DEFAULT_TTL_SETESP_BLE_MESH_MODEL_OP_GATT_PROXY_SET
ESP_BLE_MESH_MODEL_OP_RELAY_SET ESP_BLE_MESH_MODEL_OP_MODEL_PUB_SET
ESP_BLE_MESH_MODEL_OP_MODEL SUB_ADD ESP_BLE_MESH_MODEL_OP MODEL SUB VIRTUAL ADDR
ESP_BLE_MESH_MODEL_OP_SUB_OVERWRITEESP_BLE_MESH_MODEL_OP_SUB_VIRTUAL_ADDR
ESP_BLE_MESH_MODEL_OP_NET KEY_ADD ESP_BLE_MESH_MODEL_OP_APP KEY ADD
ESP_BLE_MESH_MODEL_OP_MODEL_APP BIND ESP_BLE_MESH_MODEL_OP_NODE_RESET
ESP_BLE_MESH_MODEL_OP_FRIEND_SET ESP_BLE_MESH_MODEL_OP_HEARTBEAT PUBL GET
ESP_BLE_MESH MODEL_OP HEARTBEAT SUB_SET the set state parameter in 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

`esp_ble_mesh_cfg_model_sub_va_delete_t` **model_sub_va_delete**
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_DELETE

`esp_ble_mesh_cfg_model_sub_va_overwrite_t` **model_sub_va_overwrite**
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_VIRTUAL_ADDR_OVERWRITE

`esp_ble_mesh_cfg_heartbeat_pub_set_t` **heartbeat_pub_set**
For ESP_BLE_MESH_MODEL_OP_HEARTBEAT_PUB_SET

`esp_ble_mesh_cfg_heartbeat_sub_set_t` **heartbeat_sub_set**
For ESP_BLE_MESH_MODEL_OP_HEARTBEAT_SUB_SET

`esp_ble_mesh_cfg_model_pub_va_set_t` **model_pub_va_set**
For ESP_BLE_MESH_MODEL_OP_MODEL_PUB_VIRTUAL_ADDR_SET

`esp_ble_mesh_cfg_model_sub_delete_all_t` **model_sub_delete_all**
For ESP_BLE_MESH_MODEL_OP_MODEL_SUB_DELETE_ALL

`esp_ble_mesh_cfg_net_key_update_t` **net_key_update**
For ESP_BLE_MESH_MODEL_OP_NET_KEY_UPDATE

`esp_ble_mesh_cfg_net_key_delete_t` **net_key_delete**
For ESP_BLE_MESH_MODEL_OP_NET_KEY_DELETE

`esp_ble_mesh_cfg_app_key_update_t` **app_key_update**
For ESP_BLE_MESH_MODEL_OP_APP_KEY_UPDATE
esp_ble_mesh_cfg_app_key_delete_t app_key_delete
   For ESP_BLE_MESH_MODEL_OP_APP_KEY_DELETE

esp_ble_mesh_cfg_node_identity_set_t node_identity_set
   For ESP_BLE_MESH_MODEL_OP_NODE_IDENTITY_SET

esp_ble_mesh_cfg_model_app_unbind_t model_app_unbind
   For ESP_BLE_MESH_MODEL_OP_MODEL_APP_UNBIND

esp_ble_mesh_cfg_kr_phase_set_t kr_phase_set
   For ESP_BLE_MESH_MODEL_OP_KEY_REFRESH_PHASE_SET

esp_ble_mesh_cfg_net_transmit_set_t net_transmit_set
   For ESP_BLE_MESH_MODEL_OP_NETWORK_TRANSMIT_SET

union esp_ble_mesh_cfg_client_common_cb_param_t
#include <esp_ble_mesh_config_model_api.h>
Configuration Client Model received message union.

Public Members

esp_ble_mesh_cfg_beacon_status_cb_t beacon_status
   The beacon status value

esp_ble_mesh_cfg_comp_data_status_cb_t comp_data_status
   The composition data status value

esp_ble_mesh_cfg_default_ttl_status_cb_t default_ttl_status
   The default_ttl status value

esp_ble_mesh_cfg_gatt_proxy_status_cb_t gatt_proxy_status
   The gatt_proxy status value

esp_ble_mesh_cfg_relay_status_cb_t relay_status
   The relay status value

esp_ble_mesh_cfg_model_pub_status_cb_t model_pub_status
   The model publication status value

esp_ble_mesh_cfg_model_sub_status_cb_t model_sub_status
   The model subscription status value

esp_ble_mesh_cfg_net_key_status_cb_t netkey_status
   The netkey status value

esp_ble_mesh_cfg_app_key_status_cb_t appkey_status
   The appkey status value

esp_ble_mesh_cfg_mod_app_status_cb_t/model_app_status
   The model app status value

esp_ble_mesh_cfg_friend_status_cb_t friend_status
   The friend status value

esp_ble_mesh_cfg_hb_pub_status_cb_t heartbeat_pub_status
   The heartbeat publication status value

esp_ble_mesh_cfg_hb_sub_status_cb_t heartbeat_sub_status
   The heartbeat subscription status value

esp_ble_mesh_cfg_net_trans_status_cb_t net_transmit_status
   The network transmit status value

esp_ble_mesh_cfg_model_sub_list_cb_t/model_sub_list
   The model subscription list value

esp_ble_mesh_cfg_net_key_list_cb_t netkey_list
   The network key index list value
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#### 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 power node poll timeout status value

#### union esp_ble_mesh_cfg_server_state_change_t

```c
#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_model_sub_add_t mod_sub_add**
  
  Config Model Subscription Add

- **esp_ble_mesh_state_change_cfg_model_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

- **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_state_change_t

```c
#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

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

```

```c
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_cfgSig_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

`uint16_t company_id`
The company id, if not a vendor model, shall set to 0xFFFF

`struct esp_ble_mesh_cfg_vnd_model_app_get_t`
Parameters of Config Vendor Model App Get.

Public Members

`uint16_t net_idx`
The network key index

`struct esp_ble_mesh_cfg_kr_phase_get_t`
Parameters of Config Key Refresh Phase Get.

Public Members

`uint16_t lpn_addr`
The unicast address of the Low Power node

`struct esp_ble_mesh_cfg_lpn_polltimeout_get_t`
Parameters of Config Low Power Node PollTimeout Get.

Public Members
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

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.

Public Members

uint16_t net_idx
    The network key index

uint8_t net_key[16]
    The network key value

struct esp_ble_mesh_cfg_net_key_delete_t
Parameters of Config NetKey Delete.

Public Members

uint16_t net_idx
    The network key index

struct esp_ble_mesh_cfg_app_key_update_t
Parameters of Config AppKey Update.

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_app_key_delete_t
Parameters of Config AppKey Delete.
Chapter 2. API Reference

**Public Members**

```c
uint16_t net_idx  // The network key index
```

```c
uint16_t app_idx  // The app key index
```

**struct esp_ble_mesh_cfg_node_identity_set_t**

Parameters of Config Node Identity Set.

**Public Members**

```c
uint16_t net_idx  // The network key index
```

```c
uint8_t identity  // New Node Identity state
```

**struct esp_ble_mesh_cfg_model_app_unbind_t**

Parameters of Config Model App Unbind.

**Public Members**

```c
uint16_t element_addr  // The element address
```

```c
uint16_t model_app_idx  // Index of the app key to bind with the model
```

```c
uint16_t model_id  // The model id
```

```c
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**

```c
uint16_t net_idx  // The network key index
```

```c
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**

```c
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

**Public Members**

`uint8_t page`
Page number of the Composition Data

`struct net_buf_simple *composition_data`
Pointer to Composition Data for the identified page

`struct esp_ble_mesh_cfg_default_ttl_status_cb_t`
Parameter of Config Default TTL Status

**Public Members**

`uint8_t default_ttl`
Default TTL state value
struct esp_ble_mesh_cfg_gatt_proxy_status_cb_t
Parameter of Config GATT Proxy Status

Public Members

uint8_t gatt_proxy
GATT Proxy state value

struct esp_ble_mesh_cfg_relay_status_cb_t
Parameters of Config Relay Status

Public Members

uint8_t relay
Relay state value

uint8_t retransmit
Relay retransmit value (number of retransmissions and number of 10-millisecond steps between retransmissions)

struct esp_ble_mesh_cfg_model_pub_status_cb_t
Parameters of Config Model Publication Status

Public Members

uint8_t status
Status Code for the request message

uint16_t 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
Chapter 2. API Reference

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

Public Members

uint8_t status
Status Code for the request message

uint16_t net_idx
Index of the NetKey

struct esp_ble_mesh_cfg_app_key_status_cb_t
Parameters of Config AppKey Status

Public Members

uint8_t status
Status Code for the request message

uint16_t net_idx
Index of the NetKey

uint16_t app_idx
Index of the application key

struct esp_ble_mesh_cfg_mod_app_status_cb_t
Parameters of Config Model App Status

Public Members

uint8_t status
Status Code for the request message

uint16_t element_addr
Address of the element

uint16_t app_idx
Index of the application key

uint16_t company_id
Company ID

uint16_t model_id
Model ID
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

```c
uint8_t net_trans_count : 3
    Number of transmissions for each Network PDU originating from the node
```

```c
uint8_t net_trans_step : 5
    Maximum hops when receiving Heartbeat messages
```

```c
struct esp_ble_mesh_cfg_model_sub_list_cb_t
    Parameters of Config SIG/Vendor Subscription List
```

Public Members

```c
uint8_t status
    Status Code for the request message
```

```c
uint16_t element_addr
    Address of the element
```

```c
uint16_t company_id
    Company ID
```

```c
uint16_t model_id
    Model ID
```

```c
struct net_buf_simple *sub_addr
    A block of all addresses from the Subscription List
```

```c
struct esp_ble_mesh_cfg_net_key_list_cb_t
    Parameter of Config NetKey List
```

Public Members

```c
struct net_buf_simple *net_idx
    A list of NetKey Indexes known to the node
```

```c
struct esp_ble_mesh_cfg_app_key_list_cb_t
    Parameters of Config AppKey List
```

Public Members

```c
uint8_t status
    Status Code for the request message
```

```c
uint16_t net_idx
    NetKey Index of the NetKey that the AppKeys are bound to
```

```c
struct net_buf_simple *app_idx
    A list of AppKey indexes that are bound to the NetKey identified by NetKeyId
```

```c
struct esp_ble_mesh_cfg_node_id_status_cb_t
    Parameters of Config Node Identity Status
```

Public Members

```c
uint8_t status
    Status Code for the request message
```

```c
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

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

struct esp_ble_mesh_state_change_cfg_model_sub_add_t
Parameters of Config Model Subscription Add

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_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


```c
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

   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
```

Chapter 2. API Reference
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

uint16_t company_id
Company ID

uint16_t model_id
Model ID

struct esp_ble_mesh_state_change_cfg_model_app_unbind_t
Parameters of Config Model App Unbind

Public Members

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 esp_ble_mesh_state_change_cfg_kr_phase_set_t
Parameters of Config Key Refresh Phase Set

Public Members

uint16_t net_idx
NetKey Index

uint8_t kr_phase
New Key Refresh Phase Transition

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

Macros

```c
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.

**Return** New Config Server Model instance.

**Parameters**
- `srv_data`: Pointer to a unique Config Server Model user_data.

```c
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.

**Return** New Config Client Model instance.

**Parameters**
- `cli_data`: Pointer to a unique struct `esp_ble_mesh_client_t`.

Type Definitions

```c
typedef struct esp_ble_mesh_cfg_srv esp_ble_mesh_cfg_srv_t
```
Configuration Server Model context

```c
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**

**Parameters**
- `event`: Event type
- `param`: Pointer to callback parameter

```c
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.

**Parameters**
- `event`: Event type
- `param`: Pointer to callback parameter

Enumerations

```c
enum esp_ble_mesh_cfg_client_cb_event_t
```
This enum value is the event of Configuration Client Model

**Values:**

- `ESP_BLE_MESH_CFG_CLIENT_GET_STATE_EVT`
- `ESP_BLE_MESH_CFG_CLIENT_SET_STATE_EVT`
- `ESP_BLE_MESH_CFG_CLIENT_PUBLISH_EVT`
- `ESP_BLE_MESH_CFG_CLIENT_TIMEOUT_EVT`
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:
ESP_BLE_MESH_CFG_SERVER_STATE_CHANGE_EVT
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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] callback: Pointer to the callback function.

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.
Return ESP_OK on success or error code otherwise.
Parameters
• [in] callback: Pointer to the callback function.

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
Return ESP_OK on success or error code otherwise.
Parameters
• [in] params: Pointer to BLE Mesh common client parameters.
• [in] get_state: Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.

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.
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
Return ESP_OK on success or error code otherwise.
Parameters
• [in] params: Pointer to BLE Mesh common client parameters.
• [in] set_state: Pointer to a union, each kind of opcode corresponds to one structure inside. Shall not be set to NULL.

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.
Return ESP_OK on success or error code otherwise.
Parameters
Unions

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

esp_ble_mesh_health_fault_get_t fault_get
For ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_GET.

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 tested
ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_TEST_UNACK ESP_BLE_MESH_MODEL_OP_HEALTH_FAULT_PERIOD
ESP_BLE_MESH_MODEL_OP_HEALTH_PERIOD_SET_UNACK ESP_BLE_MESH_MODEL_OP_ATTENTION_SET
ESP_BLE_MESH_MODEL_OP_ATTENTION_SET_UNACK the set_state parameter in the
esp_ble_mesh_health_client_set_state function should not be set to NULL.

Public Members

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.

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.

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.

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
Chapter 2. API Reference

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

`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

```c
uint16_t company_id
    Bluetooth assigned 16-bit Company ID
```

```c
struct esp_ble_mesh_health_current_status_cb_t
    Parameters of Health Current Status
```

Public Members

```c
uint8_t test_id
    ID of a most recently performed test
```

```c
uint16_t company_id
    Bluetooth assigned 16-bit Company ID
```

```c
struct net_buf_simple *fault_array
    FaultArray field contains a sequence of 1-octet fault values
```

```c
struct esp_ble_mesh_health_fault_status_cb_t
    Parameters of Health Fault Status
```

Public Members

```c
uint8_t test_id
    ID of a most recently performed test
```

```c
uint16_t company_id
    Bluetooth assigned 16-bit Company ID
```

```c
struct net_buf_simple *fault_array
    FaultArray field contains a sequence of 1-octet fault values
```

```c
struct esp_ble_mesh_health_period_status_cb_t
    Parameter of Health Period Status
```

Public Members

```c
uint8_t fast_period_divisor
    Divider for the Publish Period
```

```c
struct esp_ble_mesh_health_attention_status_cb_t
    Parameter of Health Attention Status
```

Public Members

```c
uint8_t attention
    Value of the Attention Timer state
```

```c
struct esp_ble_mesh_health_client_cb_param_t
    Health 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.
```
The health message status callback values

The parameter of publishing Health Current Status completion event.

*Public Members*

- `error_code`: The result of publishing Health Current Status
- `element`: Pointer to the element which contains the Health Server Model

Parameters of Health Fault Clear event

*Public Members*

- `model`: Pointer to the Health Server Model
- `company_id`: Bluetooth assigned 16-bit Company ID

Parameters of Health Fault Test event

*Public Members*

- `model`: Pointer to the Health Server Model
- `test_id`: ID of a specific test to be performed
- `company_id`: Bluetooth assigned 16-bit Company ID

Parameters of Health Attention On event

*Public Members*

- `model`: Pointer to the Health Server Model
- `time`: Duration of attention timer on (in seconds)

Parameters of Health Attention Off event

*Public Members*

- `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.

*Return* New Health Server Model instance.

*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`.

**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.

*Return* New Health Client Model instance.

*Parameters*
- `cli_data`: Pointer to the unique struct `esp_ble_mesh_client_t`.

**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.

**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. 0x01~0xFF: 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**

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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_MESHDEVICE_MOVED_WARNING
ESP_BLE_MESHDEVICE_MOVED_ERROR
ESP_BLE_MESHDEVICE_DROPPED_WARNING
ESP_BLE_MESHDEVICE_DROPPED_ERROR
ESP_BLE_MESH_OVERFLOW_WARNING
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

Parameters
• event: Event type
• **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.

**Parameters**

• **event**: Event type
• **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:

ESP_BLE_MESH_HEALTH_CLIENT_GET_STATE_EVT
ESP_BLE_MESH_HEALTH_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_HEALTH_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_HEALTH_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_HEALTH_CLIENT_EVT_MAX

enum esp_ble_mesh_health_server_cb_event_t

This enum value is the event of Health Server Model

Values:

ESP_BLE_MESH_HEALTH_SERVER_FAULT_UPDATE_COMP_EVT
ESP_BLE_MESH_HEALTH_SERVER_FAULT_CLEAR_EVT
ESP_BLE_MESH_HEALTH_SERVER_FAULT_TEST_EVT
ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_ON_EVT
ESP_BLE_MESH_HEALTH_SERVER_ATTENTION_OFF_EVT
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.

**Return** ESP_OK on success or error code otherwise.

**Parameters**

• **[in]** callback: Pointer to the callback function.

`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
Return ESP_OK on success or error code otherwise.

Parameters
- [in] get_state: Pointer to generic get message value. Shall not be set to NULL.

```c
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.

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

Return ESP_OK on success or error code otherwise.

Parameters
- [in] set_state: Pointer to generic set message value. Shall not be set to NULL.

```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.

Return ESP_OK on success or error code otherwise.

Parameters
- [in] callback: Pointer to the callback function.

Unions

```c
union esp_ble_mesh_generic_client_get_state_t
#include <esp_ble_mesh_generic_model_api.h> Generic Client Model get message union.

Public Members

```c
esp_ble_mesh_gen_user_property_get_t user_property_get
For ESP_BLE_MESH_MODEL_OP_GEN_USER_PROPERTY_GET
```

```c
esp_ble_mesh_gen_admin_property_get_t admin_property_get
For ESP_BLE_MESH_MODEL_OP_GEN_ADMIN_PROPERTY_GET
```

```c
esp_ble_mesh_gen_admin_property_get_t manufacturer_property_get
For ESP_BLE_MESH_MODEL_OP_GEN_MANUFACTURER_PROPERTY_SET
```

```c
esp_ble_mesh_gen_client_properties_get_t client_properties_get
For ESP_BLE_MESH_MODEL_OP_GEN_CLIENT_PROPERTIES_GET
```

```c
union esp_ble_mesh_generic_client_set_state_t
#include <esp_ble_mesh_generic_model_api.h> Generic Client Model set message union.

Public Members

```c
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
```

```c
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
```

```c
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
```

```c
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
```
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- `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`

- `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`

- `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`

- `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`

- `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`

- `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`

- `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`

- `esp_ble_mesh_gen_user_property_set_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`

- `esp_ble_mesh_gen_admin_property_set_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`

- `esp_ble_mesh_gen_manufacturer_property_set_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 esp_ble_mesh_gen_client_status_cb_t
#include <esp_ble_mesh_generic_model_api.h> Generic Client Model received message union.

Public Members

- `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`
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```c
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

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

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
```

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```c
union esp_ble_mesh_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
    Generic User Property Get

esp_ble_mesh_server_recv_gen_admin_property_get_t
    Generic Admin Property Get

esp_ble_mesh_server_recv_gen_manufacturer_property_get_t
    Generic Manufacturer Property Get

esp_ble_mesh_server_recv_gen_client_properties_get_t
    Generic Client Properties Get

union esp_ble_mesh_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
    Generic OnOff Set/Generic OnOff Set Unack

esp_ble_mesh_server_recv_gen_level_set_t
    Generic Level Set/Generic Level Set Unack

esp_ble_mesh_server_recv_gen_delta_set_t
    Generic Delta Set/Generic Delta Set Unack

esp_ble_mesh_server_recv_gen_move_set_t
    Generic Move Set/Generic Move Set Unack

esp_ble_mesh_server_recv_gen_def_trans_time_set_t
    Generic Default Transition Time Set/Generic Default Transition Time Set Unack

esp_ble_mesh_server_recv_gen_onpowerup_set_t
    Generic OnPowerUp Set/Generic OnPowerUp Set Unack

esp_ble_mesh_server_recv_gen_power_level_set_t
    Generic Power Level Set/Generic Power Level Set Unack

esp_BLE_MESH_SERVER_RECV_GEN_POWER_DEFAULT_SET
    Generic Power Default Set/Generic Power Default Set Unack

esp_BLE_MESH_SERVER_RECV_GEN_POWER_RANGE_SET
    Generic Power Range Set/Generic Power Range Set Unack

esp_BLE_MESH_SERVER_RECV_GEN_LOC_GLOBAL_SET
    Generic Location Global Set/Generic Location Global Set Unack

esp_BLE_MESH_SERVER_RECV_GEN_LOC_LOCAL_SET
    Generic Location Local Set/Generic Location Local Set Unack
```
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```c
union esp_ble_mesh_server_recv_gen_user_property_set_t
    esp_ble_mesh_server_recv_gen_user_property_set_t user_property
    Generic User Property Set/Generic User Property Set Unack

union esp_ble_mesh_server_recv_gen_admin_property_set_t
    esp_ble_mesh_server_recv_gen_admin_property_set_t admin_property
    Generic Admin Property Set/Generic Admin Property Set Unack

union esp_ble_mesh_server_recv_gen_manufacturer_property_set_t
    esp_ble_mesh_server_recv_gen_manufacturer_property_set_t manu_property
    Generic Manufacturer Property Set/Generic Manufacturer Property Set Unack

union esp_ble_mesh_generic_server_cb_value_t
    #include <esp_ble_mesh_generic_model_api.h> Generic Server Model callback value union.
```

Public Members

```c
struct esp_ble_mesh_gen_onoff_set_t
    Bluetooth Mesh Generic Client Model Get and Set parameters structure.
    Parameters of Generic OnOff Set.
```

Public Members

```c
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)
```

Structures

```c
struct esp_ble_mesh_gen_level_set_t
    Parameters of Generic Level Set.
```

Public Members

```c
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)
```
```c
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.
```
Chapter 2. API Reference

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

```c
struct esp_ble_mesh_gen_user_property_get_t
Parameter of Generic User Property Get.
```

**Public Members**

```c
uint16_t property_id
Property ID identifying a Generic User Property
```

```c
struct esp_ble_mesh_gen_user_property_set_t
Parameters of Generic User Property Set.
```

**Public Members**

```c
uint16_t property_id
Property ID identifying a Generic User Property
```

```c
struct net_buf_simple *property_value
Raw value for the User Property
```

```c
struct esp_ble_mesh_gen_admin_property_get_t
Parameter of Generic Admin Property Get.
```

**Public Members**

```c
uint16_t property_id
Property ID identifying a Generic Admin Property
```

```c
struct esp_ble_mesh_gen_admin_property_set_t
Parameters of Generic Admin Property Set.
```

**Public Members**

```c
uint16_t property_id
Property ID identifying a Generic Admin Property
```

```c
uint8_t user_access
Enumeration indicating user access
```

```c
struct net_buf_simple *property_value
Raw value for the Admin Property
```

```c
struct esp_ble_mesh_gen_manufacturer_property_get_t
Parameter of Generic Manufacturer Property Get.
```

**Public Members**

```c
uint16_t property_id
Property ID identifying a Generic Manufacturer Property
```

```c
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 \texttt{battery_level} : 8
Value of Generic Battery Level state

uint32_t \texttt{time_to_discharge} : 24
Value of Generic Battery Time to Discharge state

uint32_t \texttt{time_to_charge} : 24
Value of Generic Battery Time to Charge state

uint32_t \texttt{flags} : 8
Value of Generic Battery Flags state

\texttt{struct esp_ble_mesh_gen_loc_global_status_cb_t}
Parameters of Generic Location Global Status.

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

\texttt{struct esp_ble_mesh_gen_loc_local_status_cb_t}
Parameters of Generic Location Local Status.

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

\texttt{struct esp_ble_mesh_gen_user_properties_status_cb_t}
Parameter of Generic User Properties Status.

Public Members

\texttt{struct net_buf_simple *property_ids}
Buffer contains a sequence of N User Property IDs

\texttt{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_admin_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.

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**

uint8_t onoff
    The present value of the Generic OnOff state

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**

esp_ble_mesh_model_t *model
    Pointer to the Generic OnOff 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_onoff_state_t state
    Parameters of the Generic OnOff 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_gen_level_state_t
    Parameters of Generic Level state
Public Members

int16_t level
The present value of the Generic Level state

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

esp_ble_mesh_model_t *model
Pointer to the Generic Default Transition Time Server Model. Initialized internally.
### Chapter 2. API Reference

#### esp_ble_mesh_server_rsp_ctrl_t
Response control of the server model received messages

#### esp_ble_mesh_gen_def_trans_time_state_t
Parameters of the Generic Default Transition Time state

#### struct esp_ble_mesh_gen_onpowerup_state_t
Parameter of Generic OnPowerUp state

**Public Members**

- `uint8_t onpowerup`
  The value of the Generic OnPowerUp state

#### struct esp_ble_mesh_gen_power_onoff_srv_t
User data of Generic Power OnOff Server Model

**Public Members**

- `esp_ble_mesh_model_t *model`
  Pointer to the Generic Power OnOff 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_onpowerup_state_t *state`
  Parameters of the Generic OnPowerUp state

#### struct esp_ble_mesh_gen_power_onoff_setup_srv_t
User data of Generic Power OnOff Setup Server Model

**Public Members**

- `esp_ble_mesh_model_t *model`
  Pointer to the Generic Power OnOff 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_onpowerup_state_t *state`
  Parameters of the Generic OnPowerUp state

#### 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
Chapter 2. API Reference

```c
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

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 : 8
The value of the Generic Battery Level state

uint32_t time_to_discharge : 24
The value of the Generic Battery Time to Discharge state

uint32_t time_to_charge : 24
The value of the Generic Battery Time to Charge state

uint32_t battery_flags : 8
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

*esp_ble_mesh_gen_battery_state_t* state
Parameters of the Generic Battery state

struct esp_ble_mesh_gen_location_state_t
Parameters of Generic Location state

Public Members

int32_t global_latitude
The value of the Global Latitude field

int32_t global_longitude
The value of the Global Longitude field

int16_t global_altitude
The value of the Global Altitude field

int16_t local_north
The value of the Local North field

int16_t local_east
The value of the Local East field

int16_t local_altitude
The value of the Local Altitude field

uint8_t floor_number
The value of the Floor Number field

uint16_t uncertainty
The value of the Uncertainty field

struct esp_ble_mesh_gen_location_srv_t
User data of Generic Location Server Model

Public Members

*esp_ble_mesh_model_t* model
Pointer to the Generic Location 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_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.
Chapter 2. API Reference

```c
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_generic_property_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_user_prop_srv_t
    User data of Generic User 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_admin_prop_srv_t
    User data of Generic Admin 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_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
Chapter 2. API Reference

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 altitude
    The Global Altitude value of Generic Location state

struct esp_ble_mesh_state_change_gen_loc_local_set_t
Parameters of Generic Location Local Set state change event

Public Members

int16_t north
    The Local North value of Generic Location state

int16_t east
    The Local East value of Generic Location state

int16_t altitude
    The Local Altitude value of Generic Location state

uint8_t floor_number
    The Floor Number value of Generic Location state

uint16_t uncertainty
    The Uncertainty value of Generic Location state

struct esp_ble_mesh_state_change_gen_user_property_set_t
Parameters of Generic User Property Set state change event

Public Members

uint16_t id
    The property id of Generic User Property state

struct net_buf_simple *value
    The property value of Generic User Property state

struct esp_ble_mesh_state_change_gen_admin_property_set_t
Parameters of Generic Admin Property Set state change event

Public Members

uint16_t id
    The property id of Generic Admin Property state

uint8_t access
    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
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

Public Members

`uint8_t onpowerup`  
The value of the Generic OnPowerUp state

`struct esp_ble_mesh_server_recv_gen_power_level_set_t`  
Context of the received Generic Power Level Set message

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_server_recv_gen_power_default_set_t`  
Context of the received Generic Power Default Set message

Public Members

`uint16_t power`  
The value of the Generic Power Default state

`struct esp_ble_mesh_server_recv_gen_power_range_set_t`  
Context of the received Generic Power Range Set message

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_server_recv_gen_loc_global_set_t`  
Context of the received Generic Location Global Set message
Public Members

```c
int32_t global_latitude
Global Coordinates (Latitude)

int32_t global_longitude
Global Coordinates (Longitude)

int16_t global_altitude
Global Altitude
```

```c
struct esp_ble_mesh_server_recv_gen_loc_local_set_t
Context of the received Generic Location Local Set message
```

Public Members

```c
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
```

```c
struct esp_ble_mesh_server_recv_gen_user_property_set_t
Context of the received Generic User Property Set message
```

Public Members

```c
uint16_t property_id
Property ID identifying a Generic User Property

struct net_buf_simple *property_value
Raw value for the User Property
```

```c
struct esp_ble_mesh_server_recv_gen_admin_property_set_t
Context of the received Generic Admin Property Set message
```

Public Members

```c
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
```

```c
struct esp_ble_mesh_server_recv_gen_manufacturer_property_set_t
Context of the received Generic Manufacturer Property Set message
```
Public Members

\texttt{uint16_t\ property_id}
Property ID identifying a Generic Manufacturer Property

\texttt{uint8_t\ user_access}
Enumeration indicating user access

\texttt{struct\ esp\_ble\_mesh\_generic\_server\_cb\_param\_t}
Generic Server Model callback parameters

Public Members

\texttt{esp\_ble\_mesh\_model\_t\ *model}
Pointer to Generic Server Models

\texttt{esp\_ble\_mesh\_msg\_ctx\_t\ ctx}
Context of the received messages

\texttt{esp\_ble\_mesh\_generic\_server\_cb\_value\_t\ value}
Value of the received Generic Messages

Macros

\texttt{ESP\_BLE\_MESH\_MODEL\_GEN\_ONOFF\_CLI (cli_pub, cli_data)}
Define a new Generic OnOff Client Model.

\textbf{Note} This API needs to be called for each element on which the application needs to have a Generic OnOff Client Model.

\textbf{Return} New Generic OnOff Client Model instance.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{cli_pub}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_model\_pub\_t}.
  \item \texttt{cli_data}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_client\_t}.
\end{itemize}

\texttt{ESP\_BLE\_MESH\_MODEL\_GEN\_LEVEL\_CLI (cli_pub, cli_data)}
Define a new Generic Level Client Model.

\textbf{Note} This API needs to be called for each element on which the application needs to have a Generic Level Client Model.

\textbf{Return} New Generic Level Client Model instance.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{cli_pub}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_model\_pub\_t}.
  \item \texttt{cli_data}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_client\_t}.
\end{itemize}

\texttt{ESP\_BLE\_MESH\_MODEL\_GEN\_DEF\_TRANS\_TIME\_CLI (cli_pub, cli_data)}
Define a new Generic Default Transition Time Client Model.

\textbf{Note} This API needs to be called for each element on which the application needs to have a Generic Default Transition Time Client Model.

\textbf{Return} New Generic Default Transition Time Client Model instance.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{cli_pub}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_model\_pub\_t}.
  \item \texttt{cli_data}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_client\_t}.
\end{itemize}

\texttt{ESP\_BLE\_MESH\_MODEL\_GEN\_POWER\_ONOFF\_CLI (cli_pub, cli_data)}
Define a new Generic Power OnOff Client Model.

\textbf{Note} This API needs to be called for each element on which the application needs to have a Generic Power OnOff Client Model.

\textbf{Return} New Generic Power OnOff Client Model instance.

\textbf{Parameters}

\begin{itemize}
  \item \texttt{cli_pub}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_model\_pub\_t}.
  \item \texttt{cli_data}: Pointer to the unique struct \texttt{esp\_ble\_mesh\_client\_t}.
\end{itemize}
**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.

**Return** New Generic Power Level Client Model instance.

**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`.

**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.

**Return** New Generic Battery Client Model instance.

**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`.

**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.

**Return** New Generic Location Client Model instance.

**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`.

**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.

**Return** New Generic Location Client Model instance.

**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`.

**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. 1. This model shall support model publication and model subscription.

**Return** New Generic OnOff Server Model instance.

**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`.

**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. 1. This model shall support model publication and model subscription.

**Return** New Generic Level Server Model instance.

**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_level_srv_t`.

**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.
2. This model shall support model publication and model subscription.

Return New Generic Default Transition Time Server Model instance.

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.

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.
2. 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.


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.

ESP_BLE_MESH_MODEL_GEN_POWER_ONOFF_SETUP_SRV (srv_pub, srv_data)
Define a new Generic Power OnOff Setup Server Model.

2. 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_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.
2. This model shall support model publication and model subscription.

Return New Generic Power Level Server Model instance.

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.

ESP_BLE_MESH_MODEL_GEN_POWER_LEVEL_SETUP_SRV (srv_pub, srv_data)
Define a new Generic Power Level Setup Server Model.

2. This model shall support model subscription.

Return New Generic Power Level Setup Server Model instance.

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.

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.
2. The model may be used to represent an element that is powered by a battery.

Return New Generic Battery Server Model instance.

Parameters
Chapter 2. API Reference

• `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`.

**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.
2. This model shall support model publication and model subscription.
3. The model may be used to represent an element that knows its location (global or local).

**Return**
New Generic Location Server Model instance.

**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`.

**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.
2. This model shall support model subscription.

**Return**
New Generic Location Setup Server Model instance.

**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`.

**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.
2. This model shall support model publication and model subscription.

**Return**
New Generic User Property Server Model instance.

**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`.

**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.
2. This model shall support model publication and model subscription.

**Return**
New Generic Admin Property Server Model instance.

**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`.

**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.
2. This model shall support model publication and model subscription.

**Return**
New Generic Manufacturer Property Server Model instance.

**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`.

**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.
2. This model shall support model publication and model subscription.

**Return**
New Generic Client Property Server Model instance.

**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`.
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

Parameters

• event: Event type
• 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

Parameters

• event: Event type
• param: Pointer to callback parameter

Enumerations

enum esp_ble_mesh_generic_client_cb_event_t

This enum value is the event of Generic Client Model

Values:

ESP_BLE_MESH_GENERIC_CLIENT_GET_STATE_EVT
ESP_BLE_MESH_GENERIC_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_GENERIC_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_GENERIC_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_GENERIC_CLIENT_EVT_MAX

enum esp_ble_mesh_gen_user_prop_access_t

This enum value is the access value of Generic User Property

Values:

ESP_BLE_MESH_GEN_USER_ACCESS_PROHIBIT
ESP_BLE_MESH_GEN_USER_ACCESS_READ
ESP_BLE_MESH_GEN_USER_ACCESS_WRITE
ESP_BLE_MESH_GEN_USER_ACCESS_READ_WRITE

enum esp_ble_mesh_gen_admin_prop_access_t

This enum value is the access value of Generic Admin Property

Values:

ESP_BLE_MESH_GEN_ADMIN_NOT_USER_PROP
ESP_BLE_MESH_GEN_ADMIN_ACCESS_READ
ESP_BLE_MESH_GEN_ADMIN_ACCESS_WRITE
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:
Chapter 2. API Reference

ESP_BLE_MESH_GEN_MANU_NOT_USER_PROP
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:

ESP_BLE_MESH_GENERIC_SERVER_STATE_CHANGE_EVT
1. 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.
2. 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.

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.

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.

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.

Return ESP_OK on success or error code otherwise.

Parameters

- [in] callback: Pointer to the callback function.

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_t in esp_ble_mesh_defs.h

Return ESP_OK on success or error code otherwise.

Parameters

- [in] get_state: Pointer to sensor get message value. Shall not be set to NULL.

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_t in esp_ble_mesh_defs.h

Return ESP_OK on success or error code otherwise.

Parameters

- [in] set_state: Pointer to sensor set message value. Shall not be set to NULL.
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.

Return ESP_OK on success or error code otherwise.

Parameters

• [in] callback: Pointer to the callback function.

Unions

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

esp_ble_mesh_sensor_descriptor_get_t descriptor_get

For ESP_BLE_MESH_MODEL_OP_SENSOR_DESCRIPTOR_GET

esp_ble_mesh_sensor_cadence_get_t cadence_get

For ESP_BLE_MESH_MODEL_OP_SENSOR_CADENCE_GET

esp_ble_mesh_sensor_settings_get_t settings_get

For ESP_BLE_MESH_MODEL_OP_SENSOR_SETTINGS_GET

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
Chapter 2. API Reference

```c
#include <esp_ble_mesh_sensor_model_api.h>
```

### Public Members

```c
esp_ble_mesh_state_change_sensor_cadence_set_t sensor_cadence_set
    The recv_op in ctx can be used to decide which state is changed. Sensor Cadence Set
```

```c
esp_ble_mesh_state_change_sensor_setting_set_t sensor_setting_set
    Sensor Setting Set
```

```c
union esp_ble_mesh_sensor_server_state_change_t
```
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: 7
  Divisor for the publish period

`uint8_t` status_trigger_type: 1
  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

**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)
```

**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
```

**struct esp_ble_mesh_sensor_series_get_t**
Parameters of Sensor Series Get

**Public Members**

```
uint16_t property_id
Property identifying a sensor
```

```
struct net_buf_simple* raw_value_x
Raw value identifying a column
```
Chapter 2. API Reference

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 if 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
**Public Members**

```c
void sensor_setting_access
```

Read/Write access rights for the setting (optional)

```c
struct net_buf_simple *sensor_setting_raw
```

Raw value for the setting

```c
struct esp_ble_mesh_sensor_status_cb_t
```

Parameter of Sensor Status

**Public Members**

```c
struct net_buf_simple *marshalled_sensor_data
```

Value of sensor data state (optional)

```c
struct esp_ble_mesh_sensor_column_status_cb_t
```

Parameters of Sensor Column Status

**Public Members**

```c
uint16_t property_id
```

Property identifying a sensor and the Y axis

```c
struct net_buf_simple *sensor_column_value
```

Left values of sensor column status

```c
struct esp_ble_mesh_sensor_series_status_cb_t
```

Parameters of Sensor Series Status

**Public Members**

```c
uint16_t property_id
```

Property identifying a sensor and the Y axis

```c
struct net_buf_simple *sensor_series_value
```

Left values of sensor series status

```c
struct esp_ble_mesh_sensor_client_cb_param_t
```

Sensor Client Model callback parameters

**Public Members**

```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
esp_ble_mesh_client_common_param_t *params
```

The client common parameters.

```c
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
uint32_t positive_tolerance : 12
```

The value of Sensor Positive Tolerance field
uint32_t negative_tolerance : 12
The value of Sensor Negative Tolerance field

uint32_t sampling_function : 8
The value of Sensor Sampling Function field

uint8_t measure_period
The value of Sensor Measurement Period field

uint8_t update_interval
The value of Sensor Update Interval field

struct esp_ble_mesh_sensor_setting_t
Parameters of Sensor Setting state

Public Members

uint16_t property_id
The value of Sensor Setting Property ID field

uint8_t access
The value of Sensor Setting Access field

struct net_buf_simple *raw
The value of Sensor Setting Raw field

struct esp_ble_mesh_sensor_cadence_t
Parameters of Sensor Cadence state

Public Members

uint8_t period_divisor : 7
The value of Fast Cadence Period Divisor field

uint8_t trigger_type : 1
The value of Status Trigger Type field

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

struct net_buf_simple *trigger_delta_up
The value of Status Trigger Delta Up field

uint8_t min_interval
The value of Status Min Interval field

struct net_buf_simple *fast_cadence_low
The value of Fast Cadence Low field

struct net_buf_simple *fast_cadence_high
The value of Fast Cadence High field

struct esp_ble_mesh_sensor_data_t
Parameters of Sensor Data state

Public Members

uint8_t format : 1
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 : 7
    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**

```c
struct net_buf_simple *raw_value_x
    The value of Sensor Raw Value X field
```

```c
struct net_buf_simple *column_width
    The value of Sensor Column Width field
```

```c
struct net_buf_simple *raw_value_y
    The value of Sensor Raw Value Y field
```

```c
struct esp_ble_mesh_sensor_state_t
    Parameters of Sensor states
```

**Public Members**

```c
uint16_t sensor_property_id
    The value of Sensor Property ID field
```

```c
esp_ble_mesh_sensor_descriptor_t descriptor
    Parameters of the Sensor Descriptor state
```

```c
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.
```

```c
esp_ble_mesh_sensor_setting_t *settings
    Parameters of the Sensor Setting state
```

```c
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
```

```c
esp_ble_mesh_sensor_data_t sensor_data
    Parameters of the Sensor Data state
```

```c
esp_ble_mesh_sensor_series_column_t *series_column
    Parameters of the Sensor Series Column state
```

```c
struct esp_ble_mesh_sensor_srv_t
    User data of Sensor Server Model
```

**Public Members**

```c
esp_ble_mesh_model_t *model
    Pointer to the Sensor Server Model. Initialized internally.
```

```c
esp_ble_mesh_server_rsp_ctrl_t *rsp_ctrl
    Response control of the server model received messages
```
**Chapter 2. API Reference**

```c
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 : 7
  The value of Fast Cadence Period Divisor state

uint8_t trigger_type : 1
  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

uint16_t setting_property_id
    Setting ID identifying a setting within a sensor

struct esp_ble_mesh_server_recv_sensor_setting_get_t
    Context of the received Sensor Setting Get message

Public Members

bool op_en
    Indicate if optional parameters are included

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

uint16_t property_id
    Property ID of a sensor (optional)
Chapter 2. API Reference

**Public Members**

*uint16_t property_id*
Property identifying a sensor

*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**

*bool op_en*
Indicate if optional parameters are included

*uint16_t property_id*
Property identifying a sensor

*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
Chapter 2. API Reference

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.

Return New Sensor Client Model instance.

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.

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.
   1. This model shall support model publication and model subscription.

Return New Sensor Server Model instance.

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.

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.
   1. This model shall support model publication and model subscription.

Return New Sensor Setup Server Model instance.

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.

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
Chapter 2. API Reference

**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_MESHSENSOR_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.

**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.

**Return** Format of the sensor data.

**Parameters**
- _data: Pointer to the start 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.

**Return** Length (zero-based) of the sensor data.

**Parameters**
- _data: Pointer to the start of the sensor data.
- _fmt: Format 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.

**Return** Sensor Property ID of the sensor data.

**Parameters**
- _data: Pointer to the start of the sensor data.
- _fmt: Format of the sensor data.
Chapter 2. API Reference

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.
2. The Length field is a 1-based uint4 value (valid range 0x0–0xF, representing range of 1–16).
3. The Property ID is an 11-bit bit field representing 11 LSB of a Property ID.
4. This format may be used for Property Values that are not longer than 16 octets and for Property IDs less than 0x0800.

Return 2-octet MPID value for sensor data with Format A.

Parameters
• len: Length of Sensor Raw value.
• id: Sensor Property ID.

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.
2. 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.
3. The Property ID is a 16-bit bit field representing a Property ID.
4. This format may be used for Property Values not longer than 128 octets and for any Property IDs.
5. Property values longer than 128 octets are not supported by the Sensor Status message.
6. Exclude the generated 1-octet value, the 2-octet Sensor Property ID.

Return 3-octet MPID value for sensor data with Format B.

Parameters
• len: Length of Sensor Raw value.
• id: Sensor Property ID.

Type Definitions
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.
Sensor Client Model callback function type

Parameters
• event: Event type
• param: Pointer to callback parameter

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.
Sensor Server Model callback function type

Parameters
• event: Event type
• param: Pointer to callback parameter

Enumerations
enum esp_ble_mesh_sensor_client_cb_event_t
This enum value is the event of Sensor Client Model

Values:
ESP_BLE_MESH_SENSOR_CLIENT_GET_STATE_EVT
ESP_BLE_MESH_SENSOR_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_SENSOR_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_SENSOR_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_SENSOR_CLIENT_EVT_MAX

enum esp_ble_mesh_sensor_sample_func
This enum value is value of Sensor Sampling Function

Values:
ESP_BLE_MESH_SAMPLE_FUNC_UNSPECIFIED
ESP_BLE_MESH_SAMPLE_FUNC_INSTANTANEOUS
ESP_BLE_MESH_SAMPLE_FUNC_ARITHMETIC_MEAN
ESP_BLE_MESH_SAMPLE_FUNC_RMS
ESP_BLE_MESH_SAMPLE_FUNC_MAXIMUM
ESP_BLE_MESH_SAMPLE_FUNC_MINIMUM
ESP_BLE_MESH_SAMPLE_FUNC_ACCUMULATED
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:
ESP_BLE_MESH_SENSOR_SERVER_STATE_CHANGE_EVT
1. 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.
2. 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.

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.

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.

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.

Return ESP_OK on success or error code otherwise.

Parameters
- [in] callback: Pointer to the callback function.

esp_err_t esp_ble_mesh_time_scene_client_get_state(esp_ble_mesh_client_common_param_t *params,
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
Return ESP_OK on success or error code otherwise.

Parameters
• [in] params: Pointer to BLE Mesh common client parameters.
• [in] get_state: Pointer to time scene get message value. Shall not be set to NULL.

```c
esp_err_t esp_ble_mesh_time_scene_client_set_state(esp_ble_mesh_client_common_param_t *params,
                                                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

Return ESP_OK on success or error code otherwise.

Parameters
• [in] params: Pointer to BLE Mesh common client parameters.
• [in] set_state: Pointer to time scene set message value. Shall not be set to NULL.

```c
esp_err_t esp_ble_mesh_register_time_scene_server_callback(esp_ble_mesh_time_scene_server_cb_t callback)
```

Register BLE Mesh Time and Scenes Server Model callback.

Return ESP_OK on success or error code otherwise.

Parameters
• [in] callback: Pointer to the callback function.

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
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
```
```c
 esp_ble_mesh_time_set_t time_set
For ESP_BLE_MESH_MODEL_OP_TIME_SET
esp_ble_mesh_time_zone_set_t time_zone_set
For ESP_BLE_MESH_MODEL_OP_TIME_ZONE_SET
esp_ble_mesh_tai_utc_delta_set_t tai_utc_delta_set
For ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_SET
esp_ble_mesh_time_role_set_t time_role_set
For ESP_BLE_MESH_MODEL_OP_TIME_ROLE_SET
esp_ble_mesh_scene_store_t scene_store
For ESP_BLE_MESH_MODEL_OP_SCENE_STORE & ESP_BLE_MESH_MODEL_OP_SCENE_STORE_UNACK
esp_ble_mesh_scene_recall_t scene_recall
For ESP_BLE_MESH_MODEL_OP_SCENE_RECALL & ESP_BLE_MESH_MODEL_OP_SCENE_RECALL_UNACK
esp_ble_mesh_scene_delete_t scene_delete
For ESP_BLE_MESH_MODEL_OP_SCENE_DELETE & ESP_BLE_MESH_MODEL_OP_SCENE_DELETE_UNACK
```
Chapter 2. API Reference

```c
union 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 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

esp_ble_mesh_time_status_cb_t time_status
    
    For ESP_BLE_MESH_MODEL_OP_TIME_STATUS

esp_ble_mesh_time_zone_status_cb_t time_zone_status
    
    For ESP_BLE_MESH_MODEL_OP_TIME_ZONE_STATUS

esp_ble_mesh_tai_utc_delta_status_cb_t tai_utc_delta_status
    
    For ESP_BLE_MESH_MODEL_OP_TAI_UTC_DELTA_STATUS

esp_ble_mesh_time_role_status_cb_t time_role_status
    
    For ESP_BLE_MESH_MODEL_OP_TIME_ROLE_STATUS

esp_ble_mesh_scene_status_cb_t scene_status
    
    For ESP_BLE_MESH_MODEL_OP_SCENE_STATUS

esp_ble_mesh_scene_register_status_cb_t scene_register_status
    
    For ESP_BLE_MESH_MODEL_OP_SCENE_REGISTER_STATUS

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

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

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

esp_ble_mesh_server_recv_time_set_t time
Time Set

esp_ble_mesh_server_recv_time_zone_set_t time_zone
Time Zone Set

esp_ble_mesh_server_recv_tai_utc_delta_set_t tai_utc_delta
TAI-UTC Delta Set

esp_ble_mesh_server_recv_time_role_set_t time_role
Time Role Set

esp_ble_mesh_server_recv_scene_store_t scene_store
Scene Store/Scene Store Unack

esp_ble_mesh_server_recv_scene_recall_t scene_recall
Scene Recall/Scene Recall Unack

esp_ble_mesh_server_recv_scene_delete_t scene_delete
Scene Delete/Scene Delete Unack

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

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

esp_ble_mesh_time_scene_server_state_change_t state_change
ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT

esp_ble_mesh_time_scene_server_recv_get_msg_t get
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_GET_MSG_EVT

esp_ble_mesh_time_scene_server_recv_set_msg_t set
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_SET_MSG_EVT

esp_ble_mesh_time_scene_server_recv_status_msg_t status
ESP_BLE_MESH_TIME_SCENE_SERVER_RECV_STATUS_MSG_EVT
Chapter 2. API Reference

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 : 1`
  - 0 = No Time Authority, 1 = Time Authority
- `uint16_t tai_utc_delta : 15`
  - 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 Seconds 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 : 15`
  - Upcoming difference between TAI and UTC in seconds
- `uint16_t padding : 1`
  - 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_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: 4
  Index of the Schedule Register entry to set
```

```
uint64_t year: 7
  Scheduled year for the action
```

```
uint64_t month: 12
  Scheduled month for the action
```

```
uint64_t day: 5
  Scheduled day of the month for the action
```

```
uint64_t hour: 5
  Scheduled hour for the action
```
Chapter 2. API Reference

uint64_t minute: 6
Scheduled minute for the action

uint64_t second: 6
Scheduled second for the action

uint64_t day_of_week: 7
Schedule days of the week for the action

uint64_t action: 4
Action to be performed at the scheduled time

uint64_t trans_time: 8
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: 1
0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta: 15
Current difference between TAI and UTC in seconds

uint8_t time_zone_offset
The local timezone 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 Seconds 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: 15
Current difference between TAI and UTC in seconds
Chapter 2. API Reference

uint16_t padding_1: 1
Always 0b0. Other values are Prohibited.

uint16_t tai_utc_delta_new: 15
Upcoming difference between TAI and UTC in seconds

uint16_t padding_2: 1
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: 4
Enumerates (selects) a Schedule Register entry

uint64_t year: 7
Scheduled year for the action

uint64_t month: 12
Scheduled month for the action

uint64_t day: 5
Scheduled day of the month for the action

uint64_t hour: 5
Scheduled hour for the action

uint64_t minute: 6
Scheduled minute for the action

uint64_t second: 6
Scheduled second for the action

uint64_t day_of_week: 7
Scheduled days of the week for the action

uint64_t action: 4
Action to be performed at the scheduled time

uint64_t trans_time: 8
Transition time for this action

uint16_t scene_number
Transition time for this action

struct esp_ble_mesh_time_scene_client_cb_param_t
Time Scene 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_time_scene_client_status_cb_t status_cb
The scene status message callback values

struct esp_ble_mesh_time_state_t
Parameters of Time state

Public Members

uint8_t tai_seconds[5]
The value of the TAI Seconds state

uint8_t subsecond
The value of the Subsecond field
```c
uint8_t uncertainty
  The value of the Uncertainty field

uint8_t timezone_offset_curr
  The value of the Time Zone Offset Current field

uint8_t timezone_offset_new
  The value of the Time Zone Offset New state

uint8_t tai_zone_change[5]
  The value of the TAI of Zone Chaneg field

uint16_t time_authority : 1
  The value of the Time Authority bit

uint16_t tai_utc_delta_curr : 15
  The value of the TAI-UTC Delta Current state

uint16_t tai_utc_delta_new : 15
  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

struct esp_ble_mesh_time_setup_srv_t
  User data of Time Setup Server Model

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

struct esp_ble_mesh_scene_register_t
  1. Scene Store is an operation of storing values of a present state of an element.
  2. The structure and meaning of the stored state is determined by a model. States to be stored are specified
     by each model.
  3. 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.
```
4. If a model is extending another model, the extending model shall determine the Stored with Scene behavior 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

```c
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 : 7`
  The value of Scheduled year for the action
- `uint64_t month : 12`
  The value of Scheduled month for the action
- `uint64_t day : 5`
  The value of Scheduled day of the month for the action
- `uint64_t hour : 5`
  The value of Scheduled hour for the action
uint64_t minute : 6
    The value of Scheduled minute for the action

tuint64_t second : 6
    The value of Scheduled second for the action

tuint64_t day_of_week : 7
    The value of Schedule days of the week for the action

uint64_t action : 4
    The value of Action to be performed at the scheduled time

uint64_t trans_time : 8
    The value of Transition time for this action

uint16_t scene_number
    The value of Scene Number to be used for some actions

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

    esp_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

    esp_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

    esp_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

    esp_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 timezone 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 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 timezone 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

- `uint8_t tai_zone_change[5]`
  - TAI Second 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

- `uint16_t tai_utc_delta_new`
  - Upcoming difference between TAI and UTC in seconds
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

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

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

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

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

uint64_t index: 4
    Index of the Schedule Register entry to set

uint64_t year: 7
    Scheduled year for the action

uint64_t month: 12
    Scheduled month for the action

uint64_t day: 5
    Scheduled day of the month for the action

uint64_t hour: 5
    Scheduled hour for the action

uint64_t minute: 6
    Scheduled minute for the action

uint64_t second: 6
    Scheduled second for the action
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uint64_t day_of_week : 7
    Schedule days of the week for the action

uint64_t action : 4
    Action to be performed at the scheduled time

uint64_t trans_time : 8
    Transition time for this action

uint16_t scene_number
    Scene number to be used for some actions

**struct esp_ble_mesh_server_recv_scheduler_act_get_t**
    Context of the received Scheduler Action Get message

**Public Members**

uint8_t index
    Index of the Schedule Register entry to get

**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 : 1
    0 = No Time Authority, 1 = Time Authority

uint16_t tai_utc_delta : 15
    Current difference between TAI and UTC in seconds

uint8_t time_zone_offset
    The local timezone 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 Seconds 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 : 15
    Upcoming difference between TAI and UTC in seconds
uint16_t padding: 1
    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_time_role_set_t
    Context of the received Time Role Set message

Public Members

uint8_t time_role
    The Time Role for the element

struct esp_ble_mesh_server_recv_scene_store_t
    Context of the received Scene Store message

Public Members

uint16_t scene_number
    The number of scenes to be stored

struct esp_ble_mesh_server_recv_scene_recall_t
    Context of the received Scene Recall message

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_server_recv_scene_delete_t
    Context of the received Scene Delete message

Public Members

uint16_t scene_number
    The number of scenes to be deleted

struct esp_ble_mesh_server_recv_scheduler_act_set_t
    Context of the received Scheduler Action Set message

Public Members

uint64_t index: 4
    Index of the Schedule Register entry to set

uint64_t year: 7
    Scheduled year for the action
uint64_t \textit{month}: 12
Scheduled month for the action

uint64_t \textit{day}: 5
Scheduled day of the month for the action

uint64_t \textit{hour}: 5
Scheduled hour for the action

uint64_t \textit{minute}: 6
Scheduled minute for the action

uint64_t \textit{second}: 6
Scheduled second for the action

uint64_t \textit{day_of_week}: 7
Scheduled days of the week for the action

uint64_t \textit{action}: 4
Action to be performed at the scheduled time

uint64_t \textit{trans_time}: 8
Transition time for this action

uint16_t \textit{scene_number}
Scene number to be used for some actions

\textbf{struct esp_ble_mesh_server_recv_time_status_t}
Context of the received Time Status message

\textbf{Public Members}

uint8_t \textit{tai_seconds}[5]
The current TAI time in seconds

uint8_t \textit{subsecond}
The sub-second time in units of 1/256 second

uint8_t \textit{uncertainty}
The estimated uncertainty in 10-millisecond steps

uint16_t \textit{time_authority}: 1
0 = No Time Authority, 1 = Time Authority

uint16_t \textit{tai_utc_delta}: 15
Current difference between TAI and UTC in seconds

uint8_t \textit{time_zone_offset}
The local time zone offset in 15-minute increments

\textbf{struct esp_ble_mesh_time_scene_server_cb_param_t}
Time Scene Server Model callback parameters

\textbf{Public Members}

\textit{esp_ble_mesh_model_t} \*\textit{model}
Pointer to Time and Scenes Server Models

\textit{esp_ble_mesh_msg_ctx_t} \textit{ctx}
Context of the received messages

\textit{esp_ble_mesh_time_scene_server_cb_value_t} \textit{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.

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.

Return: New Scene Client Model instance.

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.

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.

Return: New Scheduler Client Model instance.

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.

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.
   1. 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.

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.
   1. 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.
   2. This model does not support subscribing nor publishing.


Parameters:
- srv_data: Pointer to the unique struct esp_ble_mesh_time_setup_srv_t.

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.
   1. This model shall support model publication and model subscription.
   2. The model may be present only on the Primary element of a node.

Return: New Scene Server Model instance.
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`.

`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.
2. This model shall support model subscription.
3. The model may be present only on the Primary element of a node.

**Return**
New Scene Setup Server Model instance.

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`.

`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.
2. This model shall support model publication and model subscription.
3. The model may be present only on the Primary element of a node.
4. The model requires the Time Server model shall be present on the element.

**Return**
New Scheduler Server Model instance.

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`.

`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.
2. This model shall support model subscription.
3. The model may be present only on the Primary element of a node.

**Return**
New Scheduler Setup Server Model instance.

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`.

`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

`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_CLIENT
  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

Parameters
• event: Event type
• 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

Parameters
• event: Event type
• param: Pointer to callback parameter

Enumerations

denum esp_ble_mesh_time_scene_client_cb_event_t
This enum value is the event of Time Scene Client Model

Values:

ESP_BLE_MESH_TIME_SCENE_CLIENT_GET_STATE_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_TIME_SCENE_CLIENT_EVT_MAX

denum esp_ble_mesh_time_scene_server_cb_event_t
This enum value is the event of Time Scene Server Model

Values:

ESP_BLE_MESH_TIME_SCENE_SERVER_STATE_CHANGE_EVT
1. 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.
2. 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.

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.

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.
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.

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.
Return ESP_OK on success or error code otherwise.
Parameters
  • [in] callback: pointer to the callback function.

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
Return ESP_OK on success or error code otherwise.
Parameters
  • [in] params: Pointer to BLE Mesh common client parameters,
  • [in] get_state: Pointer of light get message value. Shall not be set to NULL.

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
Return ESP_OK on success or error code otherwise.
Parameters
  • [in] params: Pointer to BLE Mesh common client parameters.
  • [in] set_state: Pointer of light set message value. Shall not be set to NULL.

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.
Return ESP_OK on success or error code otherwise.
Parameters
  • [in] callback: Pointer to the callback function.

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

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
For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LC_MODE_SET_UNACK

For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LC_OM_SET_UNACK

For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LC_LIGHT_ONOFF_SET_UNACK

For ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_SET & ESP_BLE_MESH_MODEL_OP_LIGHT_LC_PROPERTY_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

For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LINEAR_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_LAST_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_DEFAULT_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_LIGHTNESS_RANGE_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_CTL_TEMPERATURE_RANGE_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_TARGET_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_HUE_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_SATURATION_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_DEFAULT_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_HSL_RANGE_STATUS

For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_STATUS
Chapter 2. API Reference

*esp_ble_mesh_light_xyl_target_status_cb_t* xyl_target_status
For ESP_BLE_MESH_MODEL_OP_LIGHT_XYL_TARGET_STATUS

*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
Chapter 2. API Reference

```c
#include <esp_ble_mesh_lighting_model_api.h>

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
```
Chapter 2. API Reference

```c
union esp_ble_mesh_lighting_server_recv_status_msg_t
#include <esp_ble_mesh_lighting_model_api.h> Lighting Server Model received status message union.

Public Members

esp_ble_mesh_server_recv_sensor_status_t sensor_status
Sensor Status

union esp_ble_mesh_lighting_server_cb_value_t
#include <esp_ble_mesh_lighting_model_api.h> Lighting Server Model callback value union.

Public Members

esp_ble_mesh_lighting_server_state_change_t state_change
ESP_BLE_MESH_LIGHTING_SERVER_STATE_CHANGE_EVT

esp_ble_mesh_lighting_server_recv_msg_t get
ESP_BLE_MESH_LIGHTING_SERVER_RECV_GET_MSG_EVT

esp_ble_mesh_lighting_server_recv_set_msg_t set
ESP_BLE_MESH_LIGHTING_SERVER_RECV_SET_MSG_EVT

esp_ble_mesh_lighting_server_recv_status_msg_t status
ESP_BLE_MESH_LIGHTING_SERVER_RECV_STATUS_MSG_EVT

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
```
### Public Members

```c
bool op_en
Indicate if optional parameters are included
```

```c
uint16_t lightness
Target value of light lightness 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)
```

### struct esp_ble_mesh_light_lightness_linear_set_t

Parameters of Light Lightness Linear Set

### Public Members

```c
bool op_en
Indicate if optional parameters are included
```

```c
uint16_t lightness
Target value of light lightness linear 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)
```

### struct esp_ble_mesh_light_lightness_default_set_t

Parameter of Light Lightness Default Set

### Public Members

```c
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

```c
uint16_t range_min
Value of range min field of light lightness range state
```

```c
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

```c
bool op_en
Indicate if optional parameters are included
```

```c
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

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_range_set_t**
Parameters of Light CTL Temperature Range Set

**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_light_ctl_default_set_t**
Parameters of Light CTL Default Set

**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_light_hsl_set_t**

Parameters of Light HSL Set

**Public Members**

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)
Chapter 2. API Reference

```c
uint8_t delay
   Indicate message execution delay (C.1)
```

```c
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
```

```c
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
```

```c
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)
```

```c
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**

uint16_t property_id
Property ID identifying a Light LC Property

**struct esp_ble_mesh_light_lc_property_set_t**
Parameters of Light LC Property Set

**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_lightness_status_cb_t**
Bluetooth Mesh Light Lightness Client Model Get and Set callback parameters structure.
Parameters of Light Lightness Status

**Public Members**

bool op_en
Indicate if optional parameters are included

uint16_t present_lightness
Current value of light lightness actual state

uint16_t target_lightness
Target value of light lightness actual state (optional)

uint8_t remain_time
Time to complete state transition (C.1)

**struct esp_ble_mesh_light_lightness_linear_status_cb_t**
Parameters of Light Lightness Linear Status

**Public Members**

bool op_en
Indicate if optional parameters are included

uint16_t present_lightness
Current value of light lightness linear state

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**

bool op_en
Indicate if optional parameters are included

uint16_t present_lightness
Current value of light lightness last state

uint16_t target_lightness
Target value of light lightness last state (optional)

uint8_t remain_time
Time to complete state transition (C.1)
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

uint16_t present_ctl_temperature
Current value of light ctl temperature state

uint16_t target_ctl_lightness
Target value of light ctl lightness state (optional)

uint16_t target_ctl_temperature
Target value of light ctl 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 ctl temperature state


uint16_t `present_ctl_delta_uv`
Current value of light ctl delta UV state

uint16_t `target_ctl_temperature`
Target value of light ctl temperature state (optional)

uint16_t `target_ctl_delta_uv`
Target value of light ctl 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 ctl temperature range state

uint16_t `range_max`
Value of temperature range max field of light ctl temperature range state

`struct esp_ble_mesh_light_ctl_default_status_cb_t`
Parameters of Light CTL Default Status

**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_light_hsl_status_cb_t`
Parameters of Light HSL Status

**Public Members**

`bool op_en`
Indicate if optional parameters are included

uint16_t `hsl_lightness`
Current value of light hsl lightness state

uint16_t `hsl_hue`
Current value of light hsl hue state

uint16_t `hsl_saturation`
Current value of light hsl saturation state

uint8_t `remain_time`
Time to complete state transition (optional)

`struct esp_ble_mesh_light_hsl_target_status_cb_t`
Parameters of Light HSL Target Status

**Public Members**


Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t hsl_lightness_target
   Target value of light hsl lightness state

uint16_t hsl_hue_target
   Target value of light hsl hue state

uint16_t hsl_saturation_target
   Target value of light hsl saturation state

uint8_t remain_time
   Time to complete state transition (optional)

struct esp_ble_mesh_light_hsl_hue_status_cb_t
   Parameters of Light HSL Hue Status

Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t present_hue
   Current value of light hsl hue state

uint16_t target_hue
   Target value of light hsl hue state (optional)

uint8_t remain_time
   Time to complete state transition (C.1)

struct esp_ble_mesh_light_hsl_saturation_status_cb_t
   Parameters of Light HSL Saturation Status

Public Members

bool op_en
   Indicate if optional parameters are included

uint16_t present_saturation
   Current value of light hsl saturation state

uint16_t target_saturation
   Target value of light hsl saturation state (optional)

uint8_t remain_time
   Time to complete state transition (C.1)

struct esp_ble_mesh_light_hsl_default_status_cb_t
   Parameters of Light HSL Default Status

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_status_cb_t
   Parameters of Light HSL Range Status

Public Members

uint8_t status_code
   Status code for the request message

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_status_cb_t
   Parameters of Light xyL Status

Public Members

bool op_en
   Indicate whether optional parameters included

uint16_t xyl_lightness
   The present value of the Light xyL Lightness state

uint16_t xyl_x
   The present value of the Light xyL x state

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_om_status_cb_t**  
Parameter of Light LC OM Status

**Public Members**

uint8_t **mode**  
The present value of the Light LC Occupancy 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
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```c
uint8_t target_light_onoff
    The target value of the Light LC LightOnOff 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
Point 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
Point 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 status 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 *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_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_hsl_state_t`
  Parameters of Light HSL state

**Public Members**

`uint16_t lightness`
  The present value of Light HSL Lightness state

`uint16_t target_lightness`
  The target value of Light HSL Lightness state

`uint16_t hue`
  The present value of Light HSL Hue state

`uint16_t target_hue`
  The target value of Light HSL Hue state

`uint16_t saturation`
  The present value of Light HSL Saturation state

`uint16_t target_saturation`
  The target value of Light HSL Saturation state

`uint16_t lightness_default`
  The value of Light Lightness Default state

`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

esp_ble_mesh_model_t *model
Pointer to the Lighting HSL 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_hsl_state_t *state
Parameters of the Light HSL state

struct esp_ble_mesh_light_hsl_hue_srv_t
User data of Light HSL Hue Server Model

Public Members

esp_ble_mesh_model_t *model
Pointer to the Lighting HSL Hue 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
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`esp_ble_mesh_state_transition_t transition`  
Parameters of state transition

`int32_t tt_delta_hue`  
Delta change value of hue state transition

`struct esp_ble_mesh_light_hsl_sat_srv_t`  
User data of Light HSL Saturation Server Model

**Public Members**

`esp_ble_mesh_model_t *model`  
Pointer to the Lighting HSL Saturation 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_saturation`  
Delta change value of saturation state transition

`struct esp_ble_mesh_light_xyl_state_t`  
Parameters of Light xyL state

**Public Members**

`uint16_t lightness`  
The present value of Light xyL Lightness state

`uint16_t target_lightness`  
The target value of Light xyL Lightness state

`uint16_t x`  
The present value of Light xyL x state

`uint16_t target_x`  
The target value of Light xyL x state

`uint16_t y`  
The present value of Light xyL y state

`uint16_t target_y`  
The target value of Light xyL y state

`uint16_t lightness_default`  
The value of Light Lightness Default state

`uint16_t x_default`  
The value of Light xyL x Default state

`uint16_t y_default`  
The value of Light xyL y Default state

`uint8_t status_code`  
The status code of setting Light xyL x & y Range state

`uint16_t x_range_min`  
The minimum value of Light xyL x Range state
uint16_t \textbf{x\_range\_max}
  The maximum value of Light \textit{xyL x Range state}

uint16_t \textbf{y\_range\_min}
  The minimum value of Light \textit{xyL y Range state}

uint16_t \textbf{y\_range\_max}
  The maximum value of Light \textit{xyL y Range state}

\textbf{struct esp\_ble\_mesh\_light\_xyl\_srv\_t}
User data of Light \textit{xyL Server Model}

\textbf{Public Members}

\textit{esp\_ble\_mesh\_model\_t *model}
  Pointer to the Lighting \textit{xyL Server Model}. Initialized internally.

\textit{esp\_ble\_mesh\_server\_rsp\_ctrl\_t *rsp\_ctrl}
  Response control of the server model received messages

\textit{esp\_ble\_mesh\_light\_xyl\_state\_t *state}
  Parameters of the Light \textit{xyL 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

int32_t \textbf{tt\_delta\_lightness}
  Delta change value of lightness state transition

int32_t \textbf{tt\_delta\_x}
  Delta change value of \textit{x} state transition

int32_t \textbf{tt\_delta\_y}
  Delta change value of \textit{y} state transition

\textbf{struct esp\_ble\_mesh\_light\_xyl\_setup\_srv\_t}
User data of Light \textit{xyL Setup Server Model}

\textbf{Public Members}

\textit{esp\_ble\_mesh\_model\_t *model}
  Pointer to the Lighting \textit{xyL Setup Server Model}. Initialized internally.

\textit{esp\_ble\_mesh\_server\_rsp\_ctrl\_t *rsp\_ctrl}
  Response control of the server model received messages

\textit{esp\_ble\_mesh\_light\_xyl\_state\_t *state}
  Parameters of the Light \textit{xyL state}

\textit{struct esp\_ble\_mesh\_light\_lc\_state\_t}
Parameters of Light \textit{LC states}

\textbf{Public Members}

uint32_t \textbf{mode} : 1
  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 : 1
    The value of Light LC Occupancy Mode state

uint32_t light_onoff : 1
    The present value of Light LC Light OnOff state

uint32_t target_light_onoff : 1
    The target value of Light LC Light OnOff state

uint32_t occupancy : 1
    The value of Light LC Occupancy state

uint32_t ambient_luxlevel : 24
    The value of Light LC Ambient LuxLevel state

uint16_t linear_output

1. Light LC Linear Output = max((Lightness Out)^2/65535, Regulator Output)
2. 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
3. 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**

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 Occupancy Delay state and the received Time Since Motion value. The value of the difference between 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

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

esp_ble_mesh_state_transition_t transition
Parameters of state transition
```

```
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

*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

*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

*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

*struct esp_ble_mesh_state_change_light_lightness_range_set_t*
  Parameters of Light Lightness Range state change event

Public Members

uint16_t range_min
  The minimum value of Light Lightness state

uint16_t range_max
  The maximum value of Light Lightness 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

uint16_t lightness
The value of Light HSL Lightness Default state

uint16_t hue
The value of Light HSL Hue Default state

uint16_t saturation
The value of Light HSL Saturation Default state

struct esp_ble_mesh_state_change_light_hsl_range_set_t
Parameters of Light HSL Range state change event

Public Members

uint16_t hue_range_min
The minimum hue value of Light HSL Range state

uint16_t hue_range_max
The maximum hue value of Light HSL Range state

uint16_t saturation_range_min
The minimum saturation value of Light HSL Range state

uint16_t saturation_range_max
The maximum saturation value of Light HSL Range state

struct esp_ble_mesh_state_change_light_xyl_set_t
Parameters of Light xyL state change event

Public Members

uint16_t lightness
The value of Light xyL Lightness state

uint16_t x
The value of Light xyL x state

uint16_t y
The value of Light xyL y state

struct esp_ble_mesh_state_change_light_xyl_default_set_t
Parameters of Light xyL Default state change event

Public Members

uint16_t lightness
The value of Light Lightness Default state

uint16_t x
The value of Light xyL x Default state
uint16_t y
The value of Light xyL y Default state

struct esp_ble_mesh_state_change_light_xyl_range_set_t
Parameters of Light xyL Range state change event

Public Members

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_state_change_light_lc_mode_set_t
Parameter of Light LC Mode state change event

Public Members

uint8_t mode
The value of Light LC Mode state

struct esp_ble_mesh_state_change_light_lc_om_set_t
Parameter of Light LC Occupancy Mode state change event

Public Members

uint8_t mode
The value of Light LC Occupancy Mode state

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

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

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

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
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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

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)

```c
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

`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

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

**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

```c
esp_ble_mesh_model_t *model
```
Pointer to Lighting Server Models

```c
esp_ble_mesh_msg_ctx_t ctx
```
Context of the received messages

```c
esp_ble_mesh_lighting_server_cb_value_t value
```
Value of the received Lighting Messages

Macros

```c
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.

**Return** New Light Lightness Client Model instance.

**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`.

```c
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.

**Return** New Light CTL Client Model instance.

**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`.

```c
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.

**Return** New Light HSL Client Model instance.

**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`.

```c
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.

**Return** New Light xyL Client Model instance.

**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`.

```c
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.

**Return** New Light LC Client Model instance.

**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`.

```c
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.

1. This model shall support model publication and model subscription.

**Return** New Light Lightness Server Model instance.

**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`.

**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.

1. This model shall support model subscription.

**Return** New Light Lightness Setup Server Model instance.

**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`.

**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.

1. This model shall support model publication and model subscription.

2. 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.

**Return** New Light CTL Server Model instance.

**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`.

**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.

1. This model shall support model subscription.

**Return** New Light CTL Setup Server Model instance.

**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`.

**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.

1. This model shall support model publication and model subscription.

**Return** New Light CTL Temperature Server Model instance.

**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`.

**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.

1. This model shall support model publication and model subscription.

2. 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.

Return New Light HSL Server Model instance.

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`.

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.

Return New Light HSL Setup Server Model instance.

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`.

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.

Return New Light HSL Hue Server Model instance.

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`.

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.

Return New Light HSL Saturation Server Model instance.

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`.

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.

1. This model shall support model publication and model subscription.

Return New Light xYL Server Model instance.

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`.

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.
1. This model shall support model subscription.

Return New Light xyL Setup Server Model instance.

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`.

**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.
1. This model shall support model publication and model subscription.
2. 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.

Return New Light LC Server Model instance.

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`.

**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.
1. This model shall support model publication and model subscription.
2. This model may be used to configure setup parameters for the Light LC Server model.

Return New Light LC Setup Server Model instance.

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`.

**Type Definitions**

```cpp
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

Parameters
- `event`: Event type
- `param`: Pointer to callback parameter

```cpp
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

Parameters
- `event`: Event type
- `param`: Pointer to callback parameter

**Enumerations**

*esp_ble_mesh_light_client_cb_event_t*

This enum value is the event of Lighting Client Model

Values:

```
ESP_BLE_MESH_LIGHT_CLIENT_GET_STATE_EVT
```
ESP_BLE_MESH_LIGHT_CLIENT_SET_STATE_EVT
ESP_BLE_MESH_LIGHT_CLIENT_PUBLISH_EVT
ESP_BLE_MESH_LIGHT_CLIENT_TIMEOUT_EVT
ESP_BLE_MESH_LIGHT_CLIENT_EVT_MAX

c enum esp_ble_mesh_lc_state_t
This enum value is the Light LC State Machine states

Values:

ESP_BLE_MESH_LC_OFF
ESP_BLE_MESH_LC_STANDBY
ESP_BLE_MESH_LC_FADE_ON
ESP_BLE_MESH_LC_RUN
ESP_BLE_MESH_LC_FADE
ESP_BLE_MESH_LC_PROLONG
ESP_BLE_MESH_LC_FADE_STANDBY_AUTO
ESP_BLE_MESH_LC_FADE_STANDBY_MANUAL

c enum esp_ble_mesh_lighting_server_cb_event_t
This enum value is the event of Lighting Server Model

Values:

ESP_BLE_MESH_LIGHTING_SERVER_STATE_CHANGE_EVT
1. 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.
2. 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.

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.

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.

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.

ESP_BLE_MESH_LIGHTING_SERVER_EVT_MAX

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
run time memory, making it suitable for such scenarios.

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
Chapter 2. API Reference

2.2 Networking APIs

2.2.1 Wi-Fi

Wi-Fi

Introduction The Wi-Fi libraries provide support for configuring and monitoring the ESP32-S3 Wi-Fi networking functionality. This includes configuration for:

- Station mode (aka STA mode or Wi-Fi client mode). ESP32-S3 connects to an access point.
- AP mode (aka Soft-AP mode or Access Point mode). Stations connect to the ESP32-S3.
- Station/AP-coexistence mode (ESP32-S3 is concurrently an access point and a station connected to another access point).
- Various security modes for the above (WPA, WPA2, WEP, etc.)
- Scanning for access points (active & passive scanning).
- Promiscuous mode for monitoring of IEEE802.11 Wi-Fi packets.

Application Examples The wifi directory of ESP-IDF examples contains the following applications:

- Code examples for Wi-Fi.
- A simple esp-idf-template application to demonstrate a minimal IDF project structure.

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!

Return

- ESP_OK: succeed
- ESP_ERR_NO_MEM: out of memory
- others: refer to error code esp_err.h

Parameters

- config: pointer to WiFi initialized configuration structure; can point to a temporary variable.

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

Return

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

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 or station+soft-AP, The default mode is station mode.
Return
• 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

Parameters
• mode: WiFi operating mode

\textbf{esp_err_t esp_wifi_get_mode(wifi_mode_t \_mode)}

Get current operating mode of WiFi.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument

Parameters
• \textbf{[out]} \_mode: store current WiFi mode

\textbf{esp_err_t esp_wifi_start(void)}

Start WiFi according to current configuration If mode is WIFI_MODE_STA, it create station control block and start station If mode is WIFI_MODE_AP, it create soft-AP control block and start soft-AP If mode is WIFI_MODE_APSTA, it creates soft-AP and station control block and start soft-AP and station.

Return
• 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

\textbf{esp_err_t esp_wifi_stop(void)}

Stop WiFi If mode is WIFI_MODE_STA, it stop station and free station control block If mode is WIFI_MODE_AP, it stop soft-AP and free soft-AP control block If mode is WIFI_MODE_APSTA, it stop station/soft-AP and free station/soft-AP control block.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

\textbf{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 related
• esp_wifi_set_mode

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

\textbf{esp_err_t esp_wifi_connect(void)}

Connect the ESP32 WiFi station to the AP.

Attention 1. This API only impact WIFI_MODE_STA or WIFI_MODE_APSTA mode
Attention 2. If the ESP32 is connected to an AP, call esp_wifi_disconnect to disconnect.
Attention 3. The scanning triggered by esp_wifi_start_scan() will not be effective until connection between ESP32 and the AP is established. If ESP32 is scanning and connecting at the same time, ESP32 will abort scanning and return a warning message and error number ESP_ERR_WIFI_STATE. If you want to do reconnection after ESP32 received disconnect event, remember to add the maximum retry time, otherwise
the called scan will not work. This is especially true when the AP doesn’t exist, and you still try reconnection after ESP32 received disconnect event with the reason code WIFI_REASON_NO_AP_FOUND.

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
- 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 the ESP32 WiFi station from the AP.

Return
- 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 a stub API.

Return
- ESP_OK: succeed
- others: fail

*esp_err_t esp_wifi_deauth_sta (uint16_t aid)*

deauthenticate all stations or associated id equals to aid

Return
- 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

Parameters
- aid: when aid is 0, deauthenticate all stations, otherwise deauthenticate station whose associated id is aid

*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.

Return
- 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

Parameters
- config: configuration of scanning
- block: if block is true, this API will block the caller until the scan is done, otherwise it will return immediately

*esp_err_t esp_wifi_scan_stop (void)*

Stop the scan in process.

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

`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.

**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
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**
- [out] number: store number of APs found in last scan

`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.

**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
- ESP_ERR_INVALID_ARG: invalid argument
- ESP_ERR_NO_MEM: out of memory

**Parameters**
- [inout] number: 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

`esp_err_t esp_wifi_sta_get_ap_info (wifi_ap_record_t *ap_info)`

Get information of AP which the ESP32 station is associated with.

**Attention** When the obtained country information is empty, it means that the AP does not carry country information.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_CONN: The station interface not initialized
- ESP_ERR_WIFI_NOT_CONNECT: The station is in disconnect status

**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_l in the wifi_ap_record_t struct.
  For example, phy_11b = 1 imply that ap support 802.11b mode

`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.

**Return** ESP_OK: succeed

**Parameters**
- type: power save type

`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.

**Return** ESP_OK: succeed

**Parameters**
- [out] type: store current power save type

`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) for the interface.

**Attention** Currently we only support 802.11b or 802.11bg or 802.11bgn mode

**Return**
Chapter 2. API Reference

- 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

**Parameters**
- ifx: interfaces
- protocol_bitmap: WiFi protocol bitmap

```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.

**Return**
- 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

**Parameters**
- ifx: interface
- protocol_bitmap: store current WiFi protocol bitmap of interface ifx

```c
esp_err_t esp_wifi_set_bandwidth (wifi_interface_t ifx, wifi_bandwidth_t bw)
```
Set the bandwidth of ESP32 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

**Return**
- 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

**Parameters**
- ifx: interface to be configured
- bw: bandwidth

```c
esp_err_t esp_wifi_set_channel (uint8_t primary, wifi_second_chan_t second)
```
Set primary/secondary channel of ESP32.

**Attention**
1. This API should be called after esp_wifi_start()
2. When ESP32 is in STA mode, this API should not be called when STA is scanning or connecting to an external AP
3. When ESP32 is in softAP mode, this API should not be called when softAP has connected to external STAs
4. When ESP32 is in STA+softAP mode, this API should not be called when in the scenarios described above

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
Chapter 2. API Reference

- ESP_ERR_WIFI_IF: invalid interface
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- **primary**: for HT20, primary is the channel number, for HT40, primary is the primary channel
- **second**: for HT20, second is ignored, for HT40, second is the second channel

```c
esp_err_t esp_wifi_get_channel(uint8_t* primary, wifi_second_chan_t* second)
```

Get the primary/secondary channel of ESP32.

**Attention** 1. API return false if try to get a interface that is not enable

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- **primary**: store current primary channel
- **[out]** second: store current second channel

```c
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 CHINA { .cc="CN", .schan=1, .nchan=13, policy=WIFI_COUNTRY_POLICY_AUTO }

**Attention** 3. 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** 4. When the country policy is WIFI_COUNTRY_POLICY_MANUAL, then the configured country info is used always.

**Attention** 5. 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** 6. The country configuration is stored into flash.

**Attention** 7. When this API is called, the PHY init data will switch to the PHY init data type corresponding to the country info.

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- **country**: the configured country info

```c
esp_err_t esp_wifi_get_country(wifi_country_t* country)
```

Get the current country info

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- **country**: country info

```c
esp_err_t esp_wifi_set_mac(wifi_interface_t ifx, const uint8_t mac[6])
```

Set MAC address of the ESP32 WiFi station or the soft-AP interface.

**Attention** 1. This API can only be called when the interface is disabled

**Attention** 2. ESP32 soft-AP and station have different MAC addresses, do not set them to be the same.

**Attention** 3. The bit 0 of the first byte of ESP32 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”.
Return

- 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
- others: refer to error codes in esp_err.h

Parameters

- ifx: interface
- mac: the MAC address

```c
esp_err_t esp_wifi_get_mac(wifi_interface_t ifx, uint8_t mac[6])
```

Get mac of specified interface.

Return

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

Parameters

- ifx: 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.

Return

- ESP_OK: succeed

Parameters

- cb: callback

```c
esp_err_t esp_wifi_set_promiscuous(bool en)
```

Enable the promiscuous mode.

Return

- ESP_OK: succeed

Parameters

- en: false - disable, true - enable

```c
esp_err_t esp_wifi_get_promiscuous(bool *en)
```

Get the promiscuous mode.

Return

- ESP_OK: succeed

Parameters

- [out] en: store the current status of promiscuous mode

```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

Return

- ESP_OK: succeed

Parameters

- filter: the packet type filtered in promiscuous mode.
esp_err_t esp_wifi_get_promiscuous_filter(wifi_promiscuous_filter_t *filter)
Get the promiscuous filter.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_INVALID_ARG: invalid argument

Parameters
• [out] filter: store the current status of promiscuous filter

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.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

Parameters
• filter: the subtype of the control packet filtered in promiscuous mode.

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.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

Parameters
• [out] filter: store the current status of subtype filter of the control packet in promiscuous mode

esp_err_t esp_wifi_set_config(wifi_interface_t interface, wifi_config_t *conf)
Set the configuration of the ESP32 STA or AP.

Attention 1. This API can be called only when specified interface is enabled, otherwise, API fail
Attention 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.
Attention 3. ESP32 is 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 ESP32 station.

Return
• 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 erro code in esp_err.h

Parameters
• interface: interface
• conf: station or soft-AP configuration

esp_err_t esp_wifi_get_config(wifi_interface_t interface, wifi_config_t *conf)
Get configuration of specified interface.

Return
• 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

Parameters
• interface: interface
• [out] conf: station or soft-AP configuration
**esp_err_t esp_wifi_ap_get_sta_list (wifi_sta_list_t *sta)**

Get STAs associated with soft-AP.

**Attention**  SSC only API

**Return**

- 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

**Parameters**

- **[out]** sta: 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

**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.

**Return**

- 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

**Parameters**

- mac: STA’s mac address
- **[out]** aid: Store the AID corresponding to STA mac

**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

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**

- **storage**:: storage type

**esp_err_t esp_wifi_set_vendor_ie (bool enable, wifi_vendor_ie_type_t type, wifi_vendor_ie_id_t idx, void *vnd_ie)**

Set 802.11 Vendor-Specific Information Element.

**Return**

- 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

**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.

**esp_err_t esp_wifi_set_vendor_ie_cb (esp_vendor_ie_cb_t cb, void *ctx)**

Register Vendor-Specific Information Element monitoring callback.

**Return**

- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**Parameters**
- **cb**: Callback function
- **ctx**: Context argument, passed to callback function.

`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, 8), (20, 20), (28, 28), (34, 34), (44, 44), (52, 52), (56, 56), (60, 60), (66, 66), (72, 72), (80, 80)\}.

**Return**
- **ESP_OK**: succeed
- **ESP_ERR_WIFI_NOT_INIT**: WiFi is not initialized by esp_wifi_init
- **ESP_ERR_WIFI_NOT_START**: WiFi is not started by esp_wifi_start
- **ESP_ERR_WIFI_ARG**: invalid argument, e.g. parameter is out of range

**Parameters**
- **power**: Maximum WiFi transmitting power.

`esp_err_t esp_wifi_get_max_tx_power(int8_t *power)`
Get maximum transmitting power after WiFi start.

**Return**
- **ESP_OK**: succeed
- **ESP_ERR_WIFI_NOT_INIT**: WiFi is not initialized by esp_wifi_init
- **ESP_ERR_WIFI_NOT_START**: WiFi is not started by esp_wifi_start
- **ESP_ERR_WIFI_ARG**: invalid argument

**Parameters**
- **power**: Maximum WiFi transmitting power, unit is 0.25dBm.

`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 WIFIEVENTMASKAPPROBEREQRECEIVED.
**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.

**Return**
- **ESP_OK**: succeed
- **ESP_ERR_WIFI_NOT_INIT**: WiFi is not initialized by esp_wifi_init

**Parameters**
- **mask**: WiFi event mask.

`esp_err_t esp_wifi_get_event_mask(uint32_t *mask)`
Get mask of WiFi events.

**Return**
- **ESP_OK**: succeed
- **ESP_ERR_WIFI_NOT_INIT**: WiFi is not initialized by esp_wifi_init
- **ESP_ERR_WIFI_ARG**: invalid argument

**Parameters**
- **mask**: WiFi event mask.

`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

**Return**
- ESP_OK: success
- ESP_ERR_WIFI_IF: Invalid interface
- ESP_ERR_INVALID_ARG: Invalid parameter
- ESP_ERR_WIFI_NO_MEM: out of memory

**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_WIFI_ARG is returned.

```c
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.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init

**Parameters**
- cb: callback
- ctx: context argument, passed to callback function

```c
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_START: WiFi is not started by esp_wifi_start or promiscuous mode is not enabled
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**
- config: configuration

```c
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_START: 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

```c
esp_err_t esp_wifi_set_ant_gpio (const wifi_ant_gpio_config_t *config)
```

Set antenna GPIO configuration.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_WIFI_NOT_START: 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_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_ARG: Invalid argument, e.g. parameter is NULL, invalid GPIO number etc

Parameters
• config: Antenna GPIO configuration.

`esp_err_t esp_wifi_get_ant_gpio(wifi_ant_gpio_config_t *config)`
Get current antenna GPIO configuration.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_ARG: invalid argument, e.g. parameter is NULL

Parameters
• config: Antenna GPIO configuration.

`esp_err_t esp_wifi_set_ant(const wifi_ant_config_t *config)`
Set antenna configuration.

Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_ARG: invalid argument, e.g. parameter is NULL, invalid antenna mode or invalid GPIO number

Parameters
• config: Antenna configuration.

`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

Return
0 or the TSF time

Parameters
• interface: The interface whose tsf_time is to be retrieved.

`esp_err_t esp_wifi_set_inactive_time(wifi_interface_t ifx, uint16_t sec)`
Set the inactive time of the ESP32 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.

Attention
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.

Attention
3. The inactive time configuration is not stored into flash

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
• ESP_ERR_WIFI_ARG: invalid argument, For Station, if sec is less than 3. For SoftAP, if sec is less than 10.

Parameters
• ifx: interface to be configured.
• sec: Inactive time. Unit seconds.
esp_err_t esp_wifi_get_inactive_time (wifi_interface_t ifx, uint16_t* sec)
Get inactive time of specified interface.
Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_ARG: invalid argument
Parameters
• ifx: Interface to be configured.
• sec: Inactive time. Unit seconds.

esp_err_t esp_wifi_stats_dump (uint32_t modules)
Dump WiFi statistics.
Return
• ESP_OK: succeed
• others: failed
Parameters
• modules: statistic modules to be dumped

esp_err_t esp_wifi_set_rssi_threshold (int32_t rssi)
Set RSSI threshold below which APP will get an event.
Attention This API needs to be called every time after WIFI_EVENT_STA_BSS_RSSI_LOW event is received.
Return
• ESP_OK: succeed
• ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
• ESP_ERR_WIFI_ARG: invalid argument
Parameters
• rssi: threshold value in dbm between -100 to 0

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 Use this API only in Station mode
Return
• ESP_OK: succeed
• others: failed
Parameters
• cfg: FTM Initiator session configuration

esp_err_t esp_wifi_ftm_end_session (void)
End the ongoing FTM Initiator session.
Attention This API works only on FTM Initiator
Return
• 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
Return
• ESP_OK: succeed
• others: failed
Parameters
• offset_cm: T1 Offset to be added in centimeters

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.

**Return**
- ESP_OK: succeed
- others: failed

**Parameters**
- *ifx*: Interface to be configured.
- *disable*: true means disable 11b rate while false means enable 11b rate.

```c
esp_err_t esp_wifi_config_espnow_rate(wifi_interface_t ifx, wifi_phy_rate_t rate)
```
Config ESPNOW rate of specified interface.

**Attention** 1. This API should be called after esp_wifi_init() and before esp_wifi_start().

**Return**
- ESP_OK: succeed
- others: failed

**Parameters**
- *ifx*: Interface to be configured.
- *rate*: Phy rate to be configured.

```c
esp_err_t esp_wifi_set_connectionless_wake_interval(uint16_t interval)
```
Set interval for station to wake up periodically at disconnected.

**Attention** 1. Only when ESP_WIFI_STA_DISCONNECTED_PM_ENABLE is enabled, this configuration could work

**Attention** 2. This configuration only work for station mode and disconnected status

**Attention** 3. This configuration would influence nothing until some module configure wake_window

**Attention** 4. A sensible interval which is not too small is recommended (e.g. 100ms)

**Parameters**
- *interval*: how much microsecond would the chip wake up, from 1 to 65535.

```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 “CN” and ieee80211d_enabled is TRUE.

**Return**
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

**Parameters**
- *country*: the configured country ISO code
- *ieee80211d_enabled*: 802.11d is enabled or not

```c
esp_err_t esp_wifi_get_country_code(char *country)
```
get the current country code
Chapter 2. API Reference

Return
- ESP_OK: succeed
- ESP_ERR_WIFI_NOT_INIT: WiFi is not initialized by esp_wifi_init
- ESP_ERR_INVALID_ARG: invalid argument

Parameters
- country: country code

```
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().

Return
- ESP_OK: succeed
- others: failed

Parameters
- ifx: Interface to be configured.
- rate: Phy rate to be configured.

Structures
```
struct wifi_init_config_t
```
WiFi stack configuration parameters passed to esp_wifi_init call.

Public Members

```
const system_event_handler_t event_handler
```
WiFi event handler

```
wifi_osi_funcs_t *osi_funcs
```
WiFi OS functions

```
wpa_crypto_funcs_t wpa_crypto_funcs
```
WiFi station crypto functions when connect

```
int static_rx_buf_num
```
WiFi static RX buffer number

```
int dynamic_rx_buf_num
```
WiFi dynamic RX buffer number

```
int tx_buf_type
```
WiFi TX buffer type

```
int static_tx_buf_num
```
WiFi static TX buffer number

```
int dynamic_tx_buf_num
```
WiFi dynamic TX 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 `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_TX_DISALLOW
The WiFi TX is disallowed

WIFI_STATIC_TX_BUFFER_NUM
WIFI_CACHE_TX_BUFFER_NUM
WIFI_DYNAMIC_TX_BUFFER_NUM
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()

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.

Parameters
• buf: Data received. Type of data in buffer (wifi_promiscuous_pkt_t or wifi_pkt_rx_ctrl_t) indicated by ‘type’ parameter.
• 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.

Parameters
- ctx: Context argument, as passed to esp_wifi_set_vendor_ie_cb() when registering callback.
- type: Information element type, based on frame type received.
- sa: Source 802.11 address.
- vnd_ie: Pointer to the vendor specific element data received.
- 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.

Parameters
- ctx: context argument, passed to esp_wifi_set_csi_rx_cb() when registering callback function.
- 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

#include <esp_wifi_types.h> Configuration data for ESP32 AP or STA.

The usage of this union (for ap or sta 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

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.
Chapter 2. API Reference

**wifi_country_policy_t**

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 the 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 the 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.
- `wifi_scan_type_t scan_type`
  - Scan type, active or passive.
- `wifi_scan_time_t scan_time`
  - Scan time per channel.

**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.
Chapter 2. API Reference

```c
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 : 1
bit: 0 flag to identify if 11b mode is enabled or not

uint32_t phy_11g : 1
bit: 1 flag to identify if 11g mode is enabled or not

uint32_t phy_11n : 1
bit: 2 flag to identify if 11n mode is enabled or not

uint32_t phy_lr : 1
bit: 3 flag to identify if low rate is enabled or not

uint32_t wps : 1
bit: 4 flag to identify if WPS is supported or not

uint32_t ftm_responder : 1
bit: 5 flag to identify if FTM is supported in responder mode

uint32_t ftm_initiator : 1
bit: 6 flag to identify if FTM is supported in initiator mode

uint32_t reserved : 25
bit: 7..31 reserved

wifi_country_t country
country information of AP
```

**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

**struct wifi_pmf_config_t**
Configuration structure for Protected Management Frame

**Public Members**

- **bool capable**
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 ESP32.

**Public Members**

uint8_t **ssid**[32]
SSID of ESP32 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 ESP32 soft-AP.

uint8_t **ssid_len**
Optional length of SSID field.

uint8_t **channel**
Channel of ESP32 soft-AP

**wifi_auth_mode_t authmode**
Auth mode of ESP32 soft-AP. Do not support AUTH_WEP in soft-AP mode

uint8_t **ssid_hidden**
Broadcast SSID or not, default 0, broadcast the SSID

uint8_t **max_connection**
Max number of stations allowed to connect in, default 4, max 10

uint16_t **beacon_interval**
Beacon interval which should be multiples of 100. Unit: TU(time unit, 1 TU = 1024 us). Range: 100 ~ 60000. Default value: 100

**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 **ftm_responder**
Enable FTM Responder mode

**wifi_pmf_config_t pmf_cfg**
Configuration for Protected Management Frame

**struct wifi_sta_config_t**
STA configuration settings for the ESP32.

**Public Members**

uint8_t **ssid**[32]
SSID of target AP.

uint8_t **password**[64]
Password of target AP.

**wifi_scan_method_t scan_method**
do all channel scan or fast scan
bool 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 bssid[6]
MAC address of target AP

uint8_t 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 sort_method 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 : 1
Whether Radio Measurements are enabled for the connection

uint32_t btm_enabled : 1
Whether BSS Transition Management is enabled for the connection

uint32_t mbo_enabled : 1
Whether MBO is enabled for the connection

uint32_t reserved : 29
Reserved for future feature set

struct wifi_sta_info_t
Description of STA associated with AP.

Public Members

uint8_t mac[6]
cmac address

int8_t rssi
current average rssi of sta connected

uint32_t phy_11b : 1
bit: 0 flag to identify if 11b mode is enabled or not

uint32_t phy_11g : 1
bit: 1 flag to identify if 11g mode is enabled or not

uint32_t phy_11n : 1
bit: 2 flag to identify if 11n mode is enabled or not

uint32_t phy_lr : 1
bit: 3 flag to identify if low rate is enabled or not

uint32_t is_mesh_child : 1
bit: 4 flag to identify mesh child

uint32_t reserved : 27
bit: 5..31 reserved
struct wifi_sta_list_t
List of stations associated with the ESP32 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 : 8
Received Signal Strength Indicator (RSSI) of packet. unit: dBm
unsigned rate : 5
PHY rate encoding of the packet. Only valid for non HT(11bg) packet
unsigned __pad0__ : 1
reserved
unsigned sig_mode : 2
0: non HT(11bg) packet; 1: HT(11n) packet; 3: VHT(11ac) packet
unsigned __pad1__ : 16
reserved
unsigned mcs : 7
Modulation Coding Scheme. If is HT(11n) packet, shows the modulation, range from 0 to 76(MCS0 ~ MCS76)
unsigned cwb : 1
Channel Bandwidth of the packet. 0: 20MHz; 1: 40MHz
unsigned __pad2__ : 16
reserved
unsigned smoothing : 1
    reserved
unsigned not_sounding : 1
    reserved
unsigned __pad3__ : 1
    reserved
unsigned aggregation : 1
    Aggregation. 0: MPDU packet; 1: AMPDU packet
unsigned stbc : 2
    Space Time Block Code(STBC). 0: non STBC packet; 1: STBC packet
unsigned fec_coding : 1
    Flag is set for 11n packets which are LDPC
unsigned sgi : 1
    Short Guide Interval(SGI). 0: Long GI; 1: Short GI
unsigned __pad4__ : 8
    reserved
unsigned ampdu_cnt : 8
    ampdu cnt
unsigned channel : 4
    primary channel on which this packet is received
unsigned secondary_channel : 4
    secondary channel on which this packet is received. 0: none; 1: above; 2: below
unsigned __pad5__ : 8
    reserved
unsigned timestamp : 32
    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 __pad6__ : 32
    reserved
signed noise_floor : 8
    noise floor of Radio Frequency Module(RF). unit: 0.25dBm
unsigned __pad7__ : 24
    reserved
unsigned __pad8__ : 32
    reserved
unsigned __pad9__ : 31
    reserved
unsigned ant : 1
    antenna number from which this packet is received. 0: WiFi antenna 0; 1: WiFi antenna 1
unsigned __pad10__ : 32
    reserved
unsigned __pad11__ : 32
    reserved
unsigned __pad12__ : 32
    reserved
unsigned sig_len : 12
    length of packet including Frame Check Sequence(FCS)
unsigned __pad13__: 12
    reserved
unsigned rx_state: 8
    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 htltf 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 [6] mac`
- source 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`: 1
- Whether this GPIO is connected to external antenna switch

`uint8_t gpio_num`: 7
- The GPIO number that connects to external antenna switch

**struct wifi_ant_gpio_config_t**
- WiFi GPIOs configuration for antenna selection.

Public Members

`wifi_ant_gpio_t gpio_cfg[4]`
- The configurations of GPIOs that connect to external antenna switch

**struct wifi_ant_config_t**
- WiFi antenna configuration.

Public Members

`wifi_ant_mode_t rx_ant_mode`
- WiFi antenna mode for receiving

`wifi_ant_t rx_ant_default`
- Default antenna mode for receiving, it’s ignored if rx_ant_mode is not WIFI_ANT_MODE_AUTO

`wifi_ant_mode_t tx_ant_mode`
- WiFi 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

`uint8_t enabled_ant0`: 4
- Index (in antenna GPIO configuration) of enabled WIFI_ANT_MODE_ANT0

`uint8_t enabled_ant1`: 4
- Index (in antenna GPIO configuration) of enabled WIFI_ANT_MODE_ANT1

**struct wifi_action_tx_req_t**
- Action Frame Tx Request.
Public Members

\texttt{wifi\_interface\_t ifx}

WiFi interface to send request to

\texttt{uint8\_t dest\_mac[6]}

Destination MAC address

\texttt{bool no\_ack}

Indicates no ack required

\texttt{wifi\_action\_rx\_cb\_t rx\_cb}

Rx Callback to receive any response

\texttt{uint32\_t data\_len}

Length of the appended Data

\texttt{uint8\_t data[0]}

Appended Data payload

\texttt{struct wifi\_ftm\_initiator\_cfg\_t}

FTM Initiator configuration.

Public Members

\texttt{uint8\_t resp\_mac[6]}

MAC address of the FTM Responder

\texttt{uint8\_t channel}

Primary channel of the FTM Responder

\texttt{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)

\texttt{uint16\_t burst\_period}

Requested time period between consecutive FTM bursts in 100’s of milliseconds (0 - No pref)

\texttt{struct wifi\_event\_sta\_scan\_done\_t}

Argument structure for WIFI\_EVENT\_SCAN\_DONE event

Public Members

\texttt{uint32\_t status}

status of scanning APs: 0 — success, 1 - failure

\texttt{uint8\_t number}

number of scan results

\texttt{uint8\_t scan\_id}

scan sequence number, used for block scan

\texttt{struct wifi\_event\_sta\_connected\_t}

Argument structure for WIFI\_EVENT\_STA\_CONNECTED event

Public Members

\texttt{uint8\_t ssid[32]}

SSID of connected AP

\texttt{uint8\_t ssid\_len}

SSID length of connected AP
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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

struct wifi_event_sta_disconnected_t
    Argument structure for WIFI_EVENT_STA_DISCONNECTED event

Public Members

uint8_t ssid[32]
    SSID of disconnected AP

uint8_t ssid_len
    SSID length of disconnected AP

uint8_t bssid[6]
    BSSID of disconnected AP

uint8_t reason
    reason of disconnection

struct wifi_event_sta_authmode_change_t
    Argument structure for WIFI_EVENT_STA_AUTHMODE_CHANGE event

Public Members

wifi_auth_mode_t old_mode
    the old auth mode of AP

wifi_auth_mode_t new_mode
    the new auth mode of AP

struct wifi_event_sta_wps_er_pin_t
    Argument structure for WIFI_EVENT_STA_WPS_ER_PIN event

Public Members

uint8_t pin_code[8]
    PIN code of station in enrollee mode

struct wifi_event_sta_wps_er_success_t
    Argument structure for WIFI_EVENT_STA_WPS_ER_SUCCESS event

Public Members

uint8_t ap_cred_cnt
    Number of AP credentials received

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 mac[6]
   MAC address of the station connected to ESP32 soft-AP

uint8_t aid
   the aid that ESP32 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 mac[6]
   MAC address of the station disconnects to ESP32 soft-AP

uint8_t aid
   the aid that ESP32 soft-AP gave to the station disconnects to

bool is_mesh_child
   flag to identify mesh child

struct wifi_event_ap_probe_req_rx_t
Argument structure for WIFI_EVENT_AP_PROBEREQRECVED 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

`struct wifi_event_action_tx_status_t`
Argument structure for WIFI_EVENT_ACTION_TX_STATUS event

**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_roc_done_t`
Argument structure for WIFI_EVENT_ROC_DONE event

**Public Members**

uint32_t context
   Context to identify the request
Chapter 2  API Reference

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
ESP_WIFI_MAX_CONN_NUM
  max number of stations which can connect to ESP32 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
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_t len, uint8_t channel)
The Rx callback function of Action Tx operations.
    Parameters
    • hdr: pointer to the IEEE 802.11 Header structure
    • payload: pointer to the Payload following 802.11 Header
    • len: length of the Payload
    • channel: channel number the frame is received on

Enumerations
enum wifi_mode_t
    Values:
    WiFi_MODE_NULL = 0
    null mode
    WiFi_MODE_STA
    WiFi station mode
    WiFi_MODE_AP
    WiFi soft-AP mode
    WiFi_MODE_APSTA
    WiFi station + soft-AP mode
    WiFi_MODE_MAX
enum wifi_interface_t
    Values:
    WiFi_IF_STA = ESP_IF_WIFI_STA
    WiFi_IF_AP = ESP_IF_WIFI_AP
enum wifi_country_policy_t
    Values:
WIFI_COUNTRY_POLICY_AUTO
Country policy is auto, use the country info of AP to which the station is connected

WIFI_COUNTRY_POLICY_MANUAL
Country policy is manual, always use the configured country info

enum wifi_auth_mode_t
Values:

WIFI_AUTH_OPEN = 0
authenticate mode : open

WIFI_AUTH_WEP
authenticate mode : WEP

WIFI_AUTH_WPA_PSK
authenticate mode : WPA_PSK

WIFI_AUTH_WPA2_PSK
authenticate mode : WPA2_PSK

WIFI_AUTH_WPA_WPA2_PSK
authenticate mode : WPA_WPA2_PSK

WIFI_AUTH_WPA2_ENTERPRISE
authenticate mode : WPA2_ENTERPRISE

WIFI_AUTH_WPA3_PSK
authenticate mode : WPA3_PSK

WIFI_AUTH_WPA2_WPA3_PSK
authenticate mode : WPA2_WPA3_PSK

WIFI_AUTH_WAPI_PSK
authenticate mode : WAPI_PSK

WIFI_AUTH_MAX

enum wifi_err_reason_t
Values:

WIFI_REASON_UNSPECIFIED = 1

WIFI_REASON_AUTH_EXPIRE = 2

WIFI_REASON_ASSOC_EXPIRE = 4

WIFI_REASON_ASSOC_TOOMANY = 5

WIFI_REASON_NOT_AUTHED = 6

WIFI_REASON_NOT_ASSOCED = 7

WIFI_REASON_ASSOC_LEAVE = 8

WIFI_REASON_ASSOC_NOT_AUTHED = 9

WIFI_REASON_DISASSOC_PWRCAP_BAD = 10

WIFI_REASON_DISASSOC_SUPCHAN_BAD = 11

WIFI_REASON_BSS_TRANSITION_DISASSOC = 12

WIFI_REASON_IE_INVALID = 13

WIFI_REASON_MIC_FAILURE = 14

WIFI_REASON_4WAY_HANDSHAKE_TIMEOUT = 15

WIFI_REASON_GROUP_KEY_UPDATE_TIMEOUT = 16
WIFI_REASON_IE_IN_4WAY_DIFFERS = 17
WIFI_REASON_GROUP_CIPHER_INVALID = 18
WIFI_REASON_PAIRWISE_CIPHER_INVALID = 19
WIFI_REASON_AKMP_INVALID = 20
WIFI_REASON_UNSUPP_RSN_IE_VERSION = 21
WIFI_REASON_INVALID_RSN_IE_CAP = 22
WIFI_REASON_802_1X_AUTH_FAILED = 23
WIFI_REASON_CIPHER_SUITE_REJECTED = 24
WIFI_REASON_INVALID_PMKID = 53
WIFI_REASON_BEACON_TIMEOUT = 200
WIFI_REASON_NO_AP_FOUND = 201
WIFI_REASON_AUTH_FAIL = 202
WIFI_REASON_ASSOC_FAIL = 203
WIFI_REASON_HANDSHAKE_TIMEOUT = 204
WIFI_REASON_CONNECTION_FAIL = 205
WIFI_REASON_AP_TSF_RESET = 206
WIFI_REASON_ROAMING = 207

enum wifi_second_chan_t

Values:

WIFI_SECOND_CHAN_NONE = 0
the channel width is HT20

WIFI_SECOND_CHAN_ABOVE
the channel width is HT40 and the secondary channel is above the primary channel

WIFI_SECOND_CHAN_BELOW
the channel width is HT40 and the secondary channel is below the primary channel

enum wifi_scan_type_t

Values:

WIFI_SCAN_TYPE_ACTIVE = 0
active scan

WIFI_SCAN_TYPE_PASSIVE
passive scan

enum wifi_cipher_type_t

Values:

WIFI_CIPHER_TYPE_NONE = 0
the cipher type is none

WIFI_CIPHER_TYPE_WEP40
the cipher type is WEP40

WIFI_CIPHER_TYPE_WEP104
the cipher type is WEP104

WIFI_CIPHER_TYPE_TKIP
the cipher type is TKIP

WIFI_CIPHER_TYPE_CCMP
the cipher type is CCMP
WIFI_CIPHER_TYPE_TKIP_CCMP
the cipher type is TKIP and CCMP

WIFI_CIPHER_TYPE_AES_CMAC128
the cipher type is AES-CMAC-128

WIFI_CIPHER_TYPE_SMS4
the cipher type is SMS4

WIFI_CIPHER_TYPE_GCMP
the cipher type is GCMP

WIFI_CIPHER_TYPE_GCMP256
the cipher type is GCMP-256

WIFI_CIPHER_TYPE_AES_GMAC128
the cipher type is AES-GMAC-128

WIFI_CIPHER_TYPE_AES_GMAC256
the cipher type is AES-GMAC-256

WIFI_CIPHER_TYPE_UNKNOWN
the cipher type is unknown

enum wifi_ant_t
WiFi antenna.
Values:

WIFI_ANT_ANT0
WiFi antenna 0

WIFI_ANT_ANT1
WiFi antenna 1

WIFI_ANT_MAX
Invalid WiFi antenna

enum wifi_scan_method_t
Values:

WIFI_FAST.Scan = 0
Do fast scan, scan will end after find SSID match AP

WIFI_ALL_CHANNEL.Scan
All channel scan, scan will end after scan all the channel

enum wifi_sort_method_t
Values:

WIFI_CONNECT.AP_BY_SIGNAL = 0
Sort match AP in scan list by RSSI

WIFI_CONNECT.AP_BY_SECURITY
Sort match AP in scan list by security mode

enum wifi_ps_type_t
Values:

WIFI_PS_NONE
No power save

WIFI_PS_MIN_MODEM
Minimum modem power saving. In this mode, station wakes up to receive beacon every DTIM period

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:

WIFI_BW_HT20 = 1
WIFI_BW_HT40

enum wifi_storage_t

Values:

WIFI_STORAGE_FLASH
  all configuration will store in both memory and flash
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:

WIFI_VND_IE_TYPE_BEACON
WIFI_VND_IE_TYPE_PROBE_REQ
WIFI_VND_IE_TYPE_PROBE_RESP
WIFI_VND_IE_TYPE_ASSOC_REQ
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:

WIFI_VND_IE_ID_0
WIFI_VND_IE_ID_1

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:

WIFI_PKT_MGMT
  Management frame, indicates ‘buf’ argument is wifi_promiscuous_pkt_t
WIFI_PKT_CTRL
  Control frame, indicates ‘buf’ argument is wifi_promiscuous_pkt_t
WIFI_PKT_DATA
  Data frame, indicates ‘buf’ argument is wifi_promiscuous_pkt_t
WIFI_PKT_MISC
  Other type, such as MIMO etc. ‘buf’ argument is wifi_promiscuous_pkt_t but the payload is zero length.

enum wifi_ant_mode_t

WiFi antenna mode.

Values:

WIFI_ANT_MODE_ANT0
  Enable WiFi antenna 0 only
WIFI_ANT_MODE_ANT1
  Enable WiFi antenna 1 only
**WIFI_ANT_MODE_AUTO**
Enable WiFi antenna 0 and 1, automatically select an antenna

**WIFI_ANT_MODE_MAX**
Invalid WiFi enabled antenna

```c
enum wifi_phy_rate_t
```

WiFi PHY rate encodings.

*Values:*

```c
WIFI_PHY_RATE_1M_L = 0x00
  1 Mbps with long preamble
WIFI_PHY_RATE_2M_L = 0x01
  2 Mbps with long preamble
WIFI_PHY_RATE_5M_L = 0x02
  5.5 Mbps with long preamble
WIFI_PHY_RATE_11M_L = 0x03
  11 Mbps with long preamble
WIFI_PHY_RATE_2M_S = 0x05
  2 Mbps with short preamble
WIFI_PHY_RATE_5M_S = 0x06
  5.5 Mbps with short preamble
WIFI_PHY_RATE_11M_S = 0x07
  11 Mbps with short preamble
WIFI_PHY_RATE_48M = 0x08
  48 Mbps
WIFI_PHY_RATE_24M = 0x09
  24 Mbps
WIFI_PHY_RATE_12M = 0x0A
  12 Mbps
WIFI_PHY_RATE_6M = 0x0B
  6 Mbps
WIFI_PHY_RATE_54M = 0x0C
  54 Mbps
WIFI_PHY_RATE_36M = 0x0D
  36 Mbps
WIFI_PHY_RATE_18M = 0x0E
  18 Mbps
WIFI_PHY_RATE_9M = 0x0F
  9 Mbps
WIFI_PHY_RATE_MCS0_LGI = 0x10
  MCS0 with long GI, 6.5 Mbps for 20MHz, 13.5 Mbps for 40MHz
WIFI_PHY_RATE_MCS1_LGI = 0x11
  MCS1 with long GI, 13 Mbps for 20MHz, 27 Mbps for 40MHz
WIFI_PHY_RATE_MCS2_LGI = 0x12
  MCS2 with long GI, 19.5 Mbps for 20MHz, 40.5 Mbps for 40MHz
WIFI_PHY_RATE_MCS3_LGI = 0x13
  MCS3 with long GI, 26 Mbps for 20MHz, 54 Mbps for 40MHz
WIFI_PHY_RATE_MCS4_LGI = 0x14
  MCS4 with long GI, 39 Mbps for 20MHz, 81 Mbps for 40MHz
```
Chapter 2. API Reference

**WIFI_PHY_RATE_MCS5_LGI** = 0x15
MCS5 with long GI, 52 Mbps for 20MHz, 108 Mbps for 40MHz

**WIFI_PHY_RATE_MCS6_LGI** = 0x16
MCS6 with long GI, 58.5 Mbps for 20MHz, 121.5 Mbps for 40MHz

**WIFI_PHY_RATE_MCS7_LGI** = 0x17
MCS7 with long GI, 65 Mbps for 20MHz, 135 Mbps for 40MHz

**WIFI_PHY_RATE_MCS0_SGI** = 0x18
MCS0 with short GI, 7.2 Mbps for 20MHz, 15 Mbps for 40MHz

**WIFI_PHY_RATE_MCS1_SGI** = 0x19
MCS1 with short GI, 14.4 Mbps for 20MHz, 30 Mbps for 40MHz

**WIFI_PHY_RATE_MCS2_SGI** = 0x1A
MCS2 with short GI, 21.7 Mbps for 20MHz, 45 Mbps for 40MHz

**WIFI_PHY_RATE_MCS3_SGI** = 0x1B
MCS3 with short GI, 28.9 Mbps for 20MHz, 60 Mbps for 40MHz

**WIFI_PHY_RATE_MCS4_SGI** = 0x1C
MCS4 with short GI, 43.3 Mbps for 20MHz, 90 Mbps for 40MHz

**WIFI_PHY_RATE_MCS5_SGI** = 0x1D
MCS5 with short GI, 57.8 Mbps for 20MHz, 120 Mbps for 40MHz

**WIFI_PHY_RATE_MCS6_SGI** = 0x1E
MCS6 with short GI, 65 Mbps for 20MHz, 135 Mbps for 40MHz

**WIFI_PHY_RATE_MCS7_SGI** = 0x1F
MCS7 with short GI, 72.2 Mbps for 20MHz, 150 Mbps for 40MHz

**WIFI_PHY_RATE_LORA_250K** = 0x29
250 Kbps

**WIFI_PHY_RATE_LORA_500K** = 0x2A
500 Kbps

**WIFI_PHY_RATE_MAX**

```c
enum wifi_event_t
{
    WIFI_EVENT_WIFI_READY = 0,
    ESP32 WiFi ready
    WIFI_EVENT_SCAN_DONE,
    ESP32 finish scanning AP
    WIFI_EVENT_STA_START,
    ESP32 station start
    WIFI_EVENT_STA_STOP,
    ESP32 station stop
    WIFI_EVENT_STA_CONNECTED,
    ESP32 station connected to AP
    WIFI_EVENT_STA_DISCONNECTED,
    ESP32 station disconnected from AP
    WIFI_EVENT_STA_AUTHMODE_CHANGE,
    the auth mode of AP connected by ESP32 station changed
    WIFI_EVENT_STA_WPS_ER_SUCCESS,
    ESP32 station wps succeeds in enrollee mode
};
```
WIFI_EVENT_STA_WPS_ER_FAILED
ESP32 station wps fails in enrollee mode

WIFI_EVENT_STA_WPS_ER_TIMEOUT
ESP32 station wps timeout in enrollee mode

WIFI_EVENT_STA_WPS_ER_PIN
ESP32 station wps pin code in enrollee mode

WIFI_EVENT_STA_WPS_ER_PBC_OVERLAP
ESP32 station wps overlap in enrollee mode

WIFI_EVENT_AP_START
ESP32 soft-AP start

WIFI_EVENT_AP_STOP
ESP32 soft-AP stop

WIFI_EVENT_AP_STACONNECTED
a station connected to ESP32 soft-AP

WIFI_EVENT_AP_STADISCONNECTED
a station disconnected from ESP32 soft-AP

WIFI_EVENT_AP_PROBEREQRECVED
Receive probe request packet in soft-AP interface

WIFI_EVENT_FTM_REPORT
Receive report of FTM procedure

WIFI_EVENT_STA_BSS_RSSI_LOW
AP’s RSSI crossed configured threshold

WIFI_EVENT_ACTION_TX_STATUS
Status indication of Action Tx operation

WIFI_EVENT_ROC_DONE
Remain-on-Channel operation complete

WIFI_EVENT_STA_BEACON_TIMEOUT
ESP32 station beacon timeout

WIFI_EVENT_MAX
Invalid WiFi event ID

typedef enum wifi_event_sta_wps_fail_reason_t
Argument structure for WIFI_EVENT_STA_WPS_ER_FAILED event

Values:

WPS_FAIL_REASON_NORMAL = 0
ESP32 WPS normal fail reason

WPS_FAIL_REASON_RECV_M2D
ESP32 WPS receive M2D frame

WPS_FAIL_REASON_MAX

typedef enum wifi_ftm_status_t
FTM operation status types.

Values:

FTM_STATUS_SUCCESS = 0
FTM exchange is successful

FTM_STATUS_UNSUPPORTED
Peer does not support FTM
Chapter 2. API Reference

FTM_STATUS_CONF_REJECTED
Peer rejected FTM configuration in FTM Request

FTM_STATUS_NO_RESPONSE
Peer did not respond to FTM Requests

FTM_STATUS_FAIL
Unknown error during FTM exchange

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-S3 devices, check Provisioning API.

Application Example  Connect ESP32-S3 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.

Return
- 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 sniff 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.
Attention 2. Can not call esp_smartconfig_start twice before it finish, please call esp_smartconfig_stop first.

Return
- ESP_OK: succeed
- others: fail

Parameters
- config: pointer to smartconfig start configure structure

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 smartconfig_start.

Return
- 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.
Chapter 2. API Reference

Return
- ESP_OK: succeed
- others: fail

Parameters
- time_s: range 15s~255s, offset:45s.

```c
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.

Return
- ESP_OK: succeed
- others: fail

Parameters
- type: Choose from the smartconfig_type_t.

```c
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.
Attention 2. Fast mode have corresponding APP(phone).
Attention 3. Two mode is compatible.

Return
- ESP_OK: succeed
- others: fail

Parameters
- enable: false-disable(default); true-enable;

```c
esp_err_t esp_smartconfig_get_rvd_data(uint8_t *rvd_data, uint8_t len)
```
Get reserved data of ESPTouch v2.

Return
- ESP_OK: succeed
- others: fail

Parameters
- rvd_data: reserved data
- len: length of reserved data

Structures

```c
struct smartconfig_event_got_ssid_pswd_t
```
Argument structure for SC_EVENT_GOT_SSID_PSWD event

Public Members

```c
uint8_t ssid[32]
```
SSID of the AP. Null terminated string.

```c
uint8_t password[64]
```
Password of the AP. Null terminated string.

```c
bool bssid_set
```
whether set MAC address of target AP or not.

```c
uint8_t bssid[6]
```
MAC address of target AP.

```c
smartconfig_type_t type
```
Type of smartconfig(ESPTouch or AirKiss).

```c
uint8_t token
```
Token from cellphone which is used to send ACK to cellphone.
Chapter 2. API Reference

```c
uint8_t cellphone_ip[4]
IP address of cellphone.
```

```c
struct smartconfig_start_config_t
Configure structure for esp_smartconfig_start
```

Public Members

```c
bool enable_log
Enable smartconfig logs.
```

```c
bool esp_touch_v2_enable_crypt
Enable ESPTouch v2 crypt.
```

```c
char* esp_touch_v2_key
ESPTouch v2 crypt key, len should be 16.
```

Macros

```c
SMARTCONFIG_START_CONFIG_DEFAULT ()
```

Enumerations

```c
enum smartconfig_type_t
Values:

SC_TYPE_ESPTOUCH = 0
protocol: ESPTouch
```

```c
SC_TYPE_AIRKISS
protocol: AirKiss
```

```c
SC_TYPE_ESPTOUCH_AIRKISS
protocol: ESPTouch and AirKiss
```

```c
SC_TYPE_ESPTOUCH_V2
protocol: ESPTouch v2
```

```c
enum smartconfig_event_t
Smartconfig event declarations
Values:

SC_EVENT_SCAN_DONE
ESP32 station smartconfig has finished to scan for APs
```

```c
SC_EVENT_FOUND_CHANNEL
ESP32 station smartconfig has found the channel of the target AP
```

```c
SC_EVENT_GOT_SSID_PSWD
ESP32 station smartconfig got the SSID and password
```

```c
SC_EVENT_SEND_ACK_DONE
ESP32 station smartconfig has sent ACK to cellphone
```

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 bit rate 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>
<tbody>
<tr>
<td>24 bytes</td>
<td>1 byte</td>
<td>3 bytes</td>
<td>4 bytes</td>
<td>7-255 bytes</td>
<td>4 bytes</td>
</tr>
</tbody>
</table>

- **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 prevent 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>
<tbody>
<tr>
<td>1 byte</td>
<td>1 byte</td>
<td>3 bytes</td>
<td>1 byte</td>
<td>1 byte</td>
<td>0~250 bytes</td>
</tr>
</tbody>
</table>

- **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.

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 maintains a Primary Master Key (PMK) and several Local Master Keys (LMK). The lengths of both PMK and LMK are 16 bytes.

- **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. The maximum number of paired devices is twenty. 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. 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.

Application Examples
- Example of sending and receiving ESP-NOW data between two devices: `wifi/espnow`.
- 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
- `esp_err_t esp_now_init(void)`  
  Initialize ESPNOW function.
  
  Return
  - `ESP_OK` : succeed
  - `ESP_ERR_ESPNOW_INTERNAL` : Internal error

- `esp_err_t esp_now_deinit(void)`  
  De-initialize ESPNOW function.
  
  Return
  - `ESP_OK` : succeed

- `esp_err_t esp_now_get_version(uint32_t *version)`  
  Get the version of ESPNOW.
  
  Return
  - `ESP_OK` : succeed
  - `ESP_ERR_ESPNOW_ARG` : invalid argument

  Parameters
  - `version`: ESPNOW version

- `esp_err_t esp_now_register_recv_cb(esp_now_recv_cb_t cb)`  
  Register callback function of receiving ESPNOW data.
  
  Return
  - `ESP_OK` : succeed
**Chapter 2. API Reference**

### ESP_ERR_ESPNOW_NOT_INIT
- ESPNOW is not initialized

### ESP_ERR_ESPNOW_INTERNAL
- Internal error

#### Parameters
- cb: callback function of receiving ESPNOW data

**esp_err_t esp_now_unregister_recv_cb (void)**
Unregister callback function of receiving ESPNOW data.

**Return**
- 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.

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_INTERNAL: internal error

#### Parameters
- cb: callback function of sending ESPNOW data

**esp_err_t esp_now_unregister_send_cb (void)**
Unregister callback function of sending ESPNOW data.

**Return**
- 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

**Return**
- 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
- ESP_ERR_ESPNOW_NOT_FOUND: peer is not found
- ESP_ERR_ESPNOW_IF: current WiFi interface doesn’t match that of peer

#### Parameters
- peer_addr: peer MAC address
- data: data to send
- len: length of data

**esp_err_t esp_now_add_peer (const esp_now_peer_info_t *peer)**
Add a peer to peer list.

**Return**
- 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_FULL: peer list is full
- ESP_ERR_ESPNOW_NO_MEM: out of memory
- ESP_ERR_ESPNOW_EXIST: peer has existed

#### Parameters
- peer: peer information

**esp_err_t esp_now_del_peer (const uint8_t *peer_addr)**
Delete a peer from peer list.
Return
• 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

Parameters
• peer_addr: peer MAC address

`esp_err_t esp_now_mod_peer(const esp_now_peer_info_t *peer)`
Modify a peer.

Return
• 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

Parameters
• peer: peer information

`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.

Return
• 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

Parameters
• peer_addr: peer MAC address
• peer: peer information

`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.

Return
• 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

Parameters
• from_head: fetch from head of list or not
• peer: peer information

`bool esp_now_is_peer_exist(const uint8_t *peer_addr)`
Peer exists or not.

Return
• true: peer exists
• false: peer not exists

Parameters
• peer_addr: peer MAC address

`esp_err_t esp_now_get_peer_num(esp_now_peer_num_t *num)`
Get the number of peers.

Return
• ESP_OK: succeed
• ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
• ESP_ERR_ESPNOW_ARG: invalid argument

Parameters
• num: number of peers
**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

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized
- ESP_ERR_ESPNOW_ARG: invalid argument

**Parameters**
- pmk: primary master key

**esp_err_t esp_now_set_wake_window(uint16_t window)**

Set esp_now wake window for sta_disconnected power management.

**Attention** 1. Only when ESP_WIFI_STA_DISCONNECTED_PM_ENABLE is enabled, this configuration could work

**Attention** 2. This configuration only work for station mode and disconnected status

**Attention** 3. If more than one module has configured its wake_window, chip would choose the largest one to stay waked

**Attention** 4. If the gap between interval and window is smaller than 5ms, the chip would keep waked all the time

**Attention** 5. If never configured wake_window, the chip would keep waked at disconnected once it uses esp_now

**Return**
- ESP_OK: succeed
- ESP_ERR_ESPNOW_NOT_INIT: ESPNOW is not initialized

**Parameters**
- window: how much microsecond would the chip keep waked each interval, vary from 0 to 65535

**Structures**

**struct esp_now_peer_info**

ESPNOW peer information parameters.

**Public Members**

```c
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**

```c
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

Macros
ESP_ERR_ESPNOW_BASE
   ESPNOW error number base.
ESP_ERR_ESPNOW_NOT_INIT
   ESPNOW is not initialized.
ESP_ERR_ESPNOW_ARG
   Invalid argument
ESP_ERR_ESPNOW_NO_MEM
   Out of memory
ESP_ERR_ESPNOW_FULL
   ESPNOW peer list is full
ESP_ERR_ESPNOW_NOT_FOUND
   ESPNOW peer is not found
ESP_ERR_ESPNOW_INTERNAL
   Internal error
ESP_ERR_ESPNOW_EXIST
   ESPNOW peer has existed
ESP_ERR_ESPNOW_IF
   Interface error
ESP_NOW_ETH_ALEN
   Length of ESPNOW peer MAC address
ESP_NOW_KEY_LEN
   Length of ESPNOW peer local master key
ESP_NOW_MAX_TOTAL_PEER_NUM
   Maximum number of ESPNOW 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 void (*esp_now_recv_cb_t)(const uint8_t *mac_addr, const uint8_t *data, int data_len)
   Callback function of receiving ESPNOW data.
   Parameters
      • mac_addr: peer MAC address
      • data: received data
      • 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.
   Parameters
      • mac_addr: peer MAC address
Chapter 2. API Reference

- **status**: status of sending ESPNOW data (succeed or fail)

**Enumerations**

```c
enum esp_now_send_status_t
{
    ESP_NOW_SEND_SUCCESS = 0,  // Send ESPNOW data successfully
    ESP_NOW_SEND_FAIL         // Send ESPNOW data fail
};
```

**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)

**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.
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, user’s 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 is required to initialize LwIP by calling** `tcpip_adapter_init()`. In order to prevent non-root node access to LwIP, the application should stop the following services after LwIP initialization:

- DHCP server service on the softAP interface.
- DHCP client service on the station interface.

The following code snippet demonstrates how to initialize LwIP for ESP-WIFI-MESH applications.

```c
/* tcpip initialization */
tcpip_adapter_init();
/*
 * for mesh
 * stop DHCP server on softAP interface by default
 * stop DHCP client on station interface by default
 */
ESP_ERROR_CHECK(tcpip_adapter_dhcps_stop(TCPIP_ADAPTER_IF_AP));
ESP_ERROR_CHECK(tcpip_adapter_dhcpc_stop(TCPIP_ADAPTER_IF_STA));
```

**Note:** 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
#include <tcpip_adapter.h>
#include <lwip/dhcp.h>
#include <lwip/netif.h>
#include <lwip/sockets.h>
#include <lwip/wifi.h>

void tcpip_adapter_init()
{
    tcpip_adapter_dhcps_stop(TCPIP_ADAPTER_IF_AP);
    tcpip_adapter_dhcpc_stop(TCPIP_ADAPTER_IF_STA);
    wifi_init_config_t config = WIFI_INIT_CONFIG_DEFAULT();
    esp_wifi_init(&config);
    esp_event_handler_register(IP_EVENT, IP_EVENT_STA_GOT_IP, &ip_event_handler, NULL);
    esp_wifi_set_storage(WIFI_STORAGE_FLASH);
    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

```c
#include <esp_mesh_api.h>

void mesh_init()
{
    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.
/* 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.

/* 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)

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.

//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 \texttt{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 \texttt{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

- `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.
**Chapter 2. API Reference**

**Return**
- ESP_OK
- ESP_FAIL

`esp_err_t esp_mesh_deinit(void)`
Mesh de-initialization.
- Release resources and stop the mesh

**Return**
- 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.

**Return**
- 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.

**Return**
- 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.

**Return**
- 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
Chapter 2. API Reference

- ESP_ERR_MESH_QUEUE_FULL
- ESP_ERR_MESH_NO_ROUTE_FOUND
- ESP_ERR_MESH_DISCARD

**Parameters**

- **[in]** `to`: 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.
- **[in]** `data`: 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).
- **[in]** `flag`: 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.
- **[in]** `opt`: 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.
- **[in]** `opt_count`: option count
  - Currently, this API only takes one option, so `opt_count` is only supported to be 1.

```c
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.

**Return**

- ESP_OK

**Parameters**

- **[in]** `time_ms`: blocking time of esp_mesh_send(), unit: ms

```c
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.

**Return**

- ESP_OK
• ESP_ERR_MESH_ARGUMENT
• ESP_ERR_MESH_NOT_START
• ESP_ERR_MESH_TIMEOUT
• ESP_ERR_MESH_DISCARD

Parameters

• [out] from: the address of the original source of the packet
• [out] data: 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.
• [in] timeout_ms: wait time if a packet isn’t immediately available (0: no wait, port-MAX_DELAY: wait forever)
• [out] flag: bitmap for data received
  – MESH_DATA_FROMDS represents data from external IP network
  – MESH_DATA_TODS represents data directed upward within the mesh network

Parameters

• [out] opt: options desired to receive
  – MESH_OPT_RECV_DS_ADDR attaches the DS address
• [in] opt_count: option count desired to receive
  – Currently, this API only takes one option, so opt_count is only supported to be 1.

 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.

Return

• ESP_OK
• ESP_ERR_MESH_ARGUMENT
• ESP_ERR_MESH_NOT_START
• ESP_ERR_MESH_TIMEOUT
• ESP_ERR_MESH_DISCARD
• ESP_ERR_MESH_RECV_RELEASE

Parameters

• [out] from: the address of the original source of the packet
• [out] to: the address contains remote IP address and port (IPv4:PORT)
• [out] data: pointer to the received packet
  – Contain the protocol and applications should follow it to parse the data.
• [in] timeout_ms: wait time if a packet isn’t immediately available (0: no wait, port-MAX_DELAY: wait forever)
• [out] flag: 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.

Parameters

• [out] opt: options desired to receive
• [in] opt_count: option count desired to receive

 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.

**Return**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**
- `[in] config`: pointer to mesh stack configuration

```c
esp_err_t esp_mesh_get_config(mesh_cfg_t *config)
```
Get mesh stack configuration.

**Return**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

**Parameters**
- `[out] config`: pointer to mesh stack configuration

```c
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.

**Return**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

**Parameters**
- `[in] router`: pointer to router configuration

```c
esp_err_t esp_mesh_get_router(mesh_router_t *router)
```
Get router configuration.

**Return**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT

**Parameters**
- `[out] router`: pointer to router configuration

```c
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.

**Return**
- ESP_OK
- ESP_ERR_MESH_ARGUMENT: invalid argument

**Parameters**
- `[in] id`: pointer to mesh network ID
Chapter 2. API Reference

• [in] id: pointer to mesh network ID

```
esp_err_t esp_mesh_get_id(mesh_addr_t *id)
```

Get mesh network ID.

Return
• ESP_OK
• ESP_ERR_MESH_ARGUMENT

Parameters
• [out] id: pointer to mesh network ID

```
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

Return
• ESP_OK
• ESP_ERR_MESH_NOT_ALLOWED

Parameters
• [in] type: device type

```
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.

Return 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.

Return
• ESP_OK
• ESP_ERR_MESH_ARGUMENT
• ESP_ERR_MESH_NOT_ALLOWED

Parameters
• [in] max_layer: max layer value

```
int esp_mesh_get_max_layer(void)
```

Get max layer value.

Return 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.

Return
• ESP_OK
• ESP_ERR_MESH_ARGUMENT
• ESP_ERR_MESH_NOT_ALLOWED

Parameters
• [in] pwd: pointer to the password
• [in] len: password length

```
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.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**

- ![in] authmode: authentication mode

```c
wifi_auth_mode_t esp_mesh_get_ap_authmode (void)
```

Get mesh softAP authentication mode.

**Return** 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.

**Return**

- ESP_OK
- ESP_ERR_MESH_ARGUMENT

**Parameters**

- ![in] connections: the number of max connections

```c
int esp_mesh_get_ap_connections (void)
```

Get mesh max connection configuration.

**Return** the number of mesh max connections

```c
int esp_mesh_get_non_mesh_connections (void)
```

Get non-mesh max connection configuration.

**Return** 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.

**Return** 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.

**Return**

- ESP_OK
- ESP_FAIL

**Parameters**

- ![out] bssid: pointer to parent BSSID

```c
bool esp_mesh_is_root (void)
```

Return whether the device is the root node of the network.

**Return** 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.
Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] enable: enable or disable self-organized networking
• [in] select_parent: 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.

bool esp_mesh_get_self_organized (void)
Return whether enable self-organized networking or not.

Return true/false

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.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] vote: 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.
• [in] reason: only accept MESH_VOTE_REASON_ROOT_INITIATED for now

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.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] percentage: vote percentage threshold

float esp_mesh_get_vote_percentage (void)
Get vote percentage threshold for approval of being a root.

Return 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.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] seconds: the expired time

int esp_mesh_get_ap_assoc_expire (void)
Get mesh softAP associate expired time.

Return 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.
Return 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)

Return 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)

Return
• ESP_OK
• ESP_ERR_MESH_ARGUMENT

Parameters
• [out] mac: pointer to routing table
• [in] len: routing table size (in bytes)
• [out] size: pointer to the number of devices in routing table (including itself)

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.
Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] reachable: this state represents whether the root is able to access external IP network

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.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [out] pending: pointer to the TX pending

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.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [out] pending: pointer to the RX pending


```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
- [in] addr: self address or an associate children address
- [out] xseqno_in: sequence number of the last received packet from the specified address
```

```c
esp_err_t esp_mesh_set_xon_qsize(int qsize)

Set the number of queue.

Attention This API shall be called before mesh is started.

Return
- ESP_OK
- ESP_FAIL

Parameters
- [in] qsize: default:32 (min:16)
```

```c
int esp_mesh_get_xon_qsize(void)

Get queue size.

Return the number of queue
```

```c
esp_err_t esp_mesh_set_root_conlicts(bool allowed)

Set whether allow more than one root existing in one network.

Return
- ESP_OK
- ESP_WIFI_ERR_NOT_INIT
- ESP_WIFI_ERR_NOT_START

Parameters
- [in] allowed: allow or not
```

```c
bool esp_mesh_is_root_conlicts_allowed(void)

Check whether allow more than one root to exist in one network.

Return true/false
```

```c
esp_err_t esp_mesh_set_group_id(const mesh_addr_t *addr, int num)

Set group ID addresses.

Return
- ESP_OK
- ESP_MESH_ERR_ARGUMENT

Parameters
- [in] addr: pointer to new group ID addresses
- [in] num: the number of group ID addresses
```

```c
esp_err_t esp_mesh_delete_group_id(const mesh_addr_t *addr, int num)

Delete group ID addresses.

Return
- ESP_OK
- ESP_MESH_ERR_ARGUMENT

Parameters
- [in] addr: pointer to deleted group ID address
- [in] num: the number of group ID addresses
```

```c
int esp_mesh_get_group_num(void)

Get the number of group ID addresses.

Return the number of group ID addresses
```

```c
esp_err_t esp_mesh_get_group_list(mesh_addr_t *addr, int num)

Get group ID addresses.

Return
```
### esp_mesh_is_my_group

Check whether the specified group address is my group.

**Return**
- true
- false

**Parameters**

- `[out] addr`: pointer to group ID addresses
- `[in] num`: the number of group ID addresses

### esp_mesh_set_capacity_num

Set mesh network capacity (max:1000, default:300)

**Attention**
This API shall be called before mesh is started.

**Return**

- ESP_OK
- ESP_ERR_MESH_NOT_ALLOWED
- ESP_MESH_ERR_ARGUMENT

**Parameters**

- `[in] num`: mesh network capacity

### esp_mesh_get_capacity_num

Get mesh network capacity.

**Return**

- mesh network capacity

### esp_mesh_set_ie_crypto_funcs

Set mesh IE crypto functions.

**Attention**
This API can be called at any time after mesh is initialized.

**Return**

- ESP_OK

**Parameters**

- `[in] crypto_funcs`: crypto functions for mesh IE
  - If crypto_funcs is set to NULL, mesh IE is no longer encrypted.

### esp_mesh_set_ie_crypto_key

Set mesh IE crypto key.

**Attention**
This API can be called at any time after mesh is initialized.

**Return**

- ESP_OK
- ESP_MESH_ERR_ARGUMENT

**Parameters**

- `[in] key`: ASCII crypto key
- `[in] len`: length in bytes, range:8-64

### esp_mesh_get_ie_crypto_key

Get mesh IE crypto key.

**Return**

- ESP_OK
- ESP_MESH_ERR_ARGUMENT

**Parameters**

- `[out] key`: ASCII crypto key
- `[in] len`: length in bytes, range:8-64

### esp_mesh_set_root_healing_delay

Set delay time before starting root healing.

**Return**

- ESP_OK

**Parameters**

- `[in] delay_ms`: delay time in milliseconds
```plaintext
int esp_mesh_get_root_healing_delay(void)
Get delay time before network starts root healing.

Return 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.

Return
- ESP_OK

Parameters
- [in] enable: enable or not

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.

Return 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.

Return
- ESP_OK
- ESP_ERR_ARGUMENT
- ESP_ERR_MESH_NOT_CONFIG

Parameters
- [in] parent: 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.
- [in] parent_mesh_id: parent mesh ID,
  - If this value is not set, the original mesh ID is used.
- [in] my_type: 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.
- [in] my_layer: 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.

esp_err_t esp_mesh_scan_get_ap_ie_len(int *len)
Get mesh networking IE length of one AP.

Return
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_WIFI_ARG
- ESP_ERR_WIFI_FAIL

Parameters
- [out] len: mesh networking IE length

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.

Return

- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_WIFI_ARG
- ESP_ERR_WIFI_FAIL

Parameters

- [out] ap_record: pointer to one AP record
- [out] buffer: pointer to the mesh networking IE of this AP

esp_err_t esp_mesh_flush_upstream_packets (void)
Flush upstream packets pending in to_parent queue and to_parent_p2p queue.

Return

- ESP_OK

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.

Return

- ESP_OK
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_ARGUMENT

Parameters

- [in] child_mac: an associated child address of this device
- [out] nodes_num: pointer to the number of nodes in the subnet of a specific child

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.

Return

- ESP_OK
- ESP_ERR_MESH_NOT_START
- ESP_ERR_MESH_ARGUMENT

Parameters

- [in] child_mac: an associated child address of this device
- [out] nodes: pointer to nodes in the subnet of a specific child
- [in] nodes_num: the number of nodes in the subnet of a specific child

esp_err_t esp_mesh_disconnect (void)
Disconnect from current parent.

Return

- ESP_OK

esp_err_t esp_mesh_connect (void)
Connect to current parent.

Return

- ESP_OK

esp_err_t esp_mesh_flush_scan_result (void)
Flush scan result.

Return

- ESP_OK

esp_err_t esp_mesh_switch_channel (const uint8_t *new_hssid, 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
### API Reference

**Attention** This API is only called by the root.

**Return**
- ESP_OK

**Parameters**
- `[in] new_bssid`: the new router BSSID if the router changes
- `[in] csa_newchan`: the new channel number to which the whole network is moving
- `[in] csa_count`: channel switch period (beacon count), unit is based on beacon interval of its softAP, the default value is 15.

#### esp_err_t esp_mesh_get_router_bssid(uint8_t* router_bssid)
Get the router BSSID.

**Return**
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_WIFI_ARG

**Parameters**
- `[out] router_bssid`: pointer to the router BSSID

#### int64_t esp_mesh_get_tsf_time(void)
Get the TSF time.

**Return** the TSF time

#### esp_err_t 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.

**Return**
- ESP_OK
- ESP_MESH_ERR_ARGUMENT
- ESP_ERR_MESH_NOT_ALLOWED

**Parameters**
- `[in] topo`: MESH_TOPO_TREE or MESH_TOPO_CHAIN

#### esp_mesh_topology_t esp_mesh_get_topology(void)
Get mesh topology.

**Return** MESH_TOPO_TREE or MESH_TOPO_CHAIN

#### esp_err_t esp_mesh_enable_ps(void)
Enable mesh Power Save function.

**Attention** This API shall be called before mesh is started.

**Return**
- ESP_OK
- ESP_ERR_WIFI_NOT_INIT
- ESP_ERR_MESH_NOT_ALLOWED

#### esp_err_t esp_mesh_disable_ps(void)
Disable mesh Power Save function.

**Attention** This API shall be called before mesh is started.

**Return**
- 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.

**Return** 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.

**Return** 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_PS_DEVICE_DUTY_REQUEST, the device will use a nwk_duty provided by the network.
- If dev_duty_type is set to MESH_PS_DEVICE_DUTY_DEMAND, the device will use the specified dev_duty.

**Attention** This API can be called at any time after mesh is started.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**

- [in] dev_duty: device duty cycle
- [in] dev_duty_type: device PS duty cycle type, not accept MESH_PS_NETWORK_DUTY_MASTER

**esp_err_t esp_mesh_get_active_duty_cycle** (int *dev_duty, int *dev_duty_type)
Get device duty cycle and type.

**Return**
- ESP_OK

**Parameters**

- [out] dev_duty: device duty cycle
- [out] dev_duty_type: device PS duty cycle type

**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.
- 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.

Return
- ESP_OK
- ESP_FAIL

Parameters
- [in] nwk_duty: network duty cycle
- [in] duration_mins: duration (unit: minutes)
- [in] applied_rule: only support MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE

`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.

Return
- ESP_OK

Parameters
- [out] nwk_duty: current network duty cycle
- [out] duration_mins: the duration of current nwk_duty
- [out] dev_duty_type: if it includes MESH_PS_DEVICE_DUTY_MASTER, this device is the current NWK-DUTY-MASTER.
- [out] applied_rule: MESH_PS_NETWORK_DUTY_APPLIED_ENTIRE

`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_PS_DEVICE_DUTY_REQUEST, the running active duty cycle is nwk_duty provided by the network.
- If duty type is set to MESH_PS_DEVICE_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.

Return the running active duty cycle

`esp_err_t esp_mesh_ps_duty_signaling(int fwd_times)`

Duty signaling.

Return
- ESP_OK

Parameters
- [in] fwd_times: the times of forwarding duty signaling packets

Unions

`union mesh_addr_t`

`#include <esp_mesh.h>` Mesh address.

Public Members

`uint8_t addr[6]`

mac address
mip_t mip
    mip address
union mesh_event_info_t
    #include <esp_mesh.h> Mesh event information.

Public Members

mesh_event_channel_switch_t channel_switch
    channel switch
mesh_event_child_connected_t child_connected
    child connected
mesh_event_child_disconnected_t child_disconnected
    child disconnected
mesh_event_routing_table_change_t routing_table
    routing table change
mesh_event_connected_t connected
    parent connected
mesh_event_disconnected_t disconnected
    parent disconnected
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

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.
Chapter 2. API Reference

Public Members

```c
uint16_t new_layer
    new layer
```

```c
struct mesh_event_vote_started_t
    vote started information
```

Public Members

```c
int reason
    vote reason, vote could be initiated by children or by the root itself
```

```c
int attempts
    max vote attempts before stopped
```

```c
mesh_addr_t rc_addr
    root address specified by users via API esp_mesh_waive_root()
```

```c
struct mesh_event_find_network_t
    find a mesh network that this device can join
```

Public Members

```c
uint8_t channel
    channel number of the new found network
```

```c
uint8_t router_bssid[6]
    router BSSID
```

```c
struct mesh_event_root_switch_req_t
    Root switch request information.
```

Public Members

```c
int reason
    root switch reason, generally root switch is initialized by users via API esp_mesh_waive_root()
```

```c
mesh_addr_t rc_addr
    the address of root switch requester
```

```c
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.
```
Chapter 2. API Reference

Public Members

```c
uint16_t rt_size_new
    the new value
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
```

```c
struct mesh_event_ps_duty_t
    PS duty information.
```

Public Members

```c
uint8_t duty
    parent or child duty
```

```c
mesh_event_child_connected_t child_connected
    child info
```

```c
struct mesh_opt_t
    Mesh option.
```

Public Members

```c
uint8_t type
    option type
uint16_t len
    option length
uint8_t *val
    option value
```

```c
struct mesh_data_t
    Mesh data for esp_mesh_send() and esp_mesh_recv()
```
Chapter 2. API Reference

Public Members

- `data` (uint8_t*)
  - data

- `size` (uint16_t)
  - data size

- `proto` (mesh_proto_t)
  - data protocol

- `tos` (mesh_tos_t)
  - data type of service

**struct mesh_router_t**

Router configuration.

Public Members

- `ssid` (uint8_t[32])
  - SSID

- `ssid_len` (uint8_t)
  - length of SSID

- `bssid` (uint8_t[6])
  - BSSID, if this value is specified, users should also specify “allow_router_switch”.

- `password` (uint8_t[64])
  - password

- `allow_router_switch` (bool)
  - 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

- `password` (uint8_t[64])
  - mesh softAP password

- `max_connection` (uint8_t)
  - max number of stations allowed to connect in, default 6, max 10 = max_connection + non-mesh_max_connection max mesh connections

- `nonmesh_max_connection` (uint8_t)
  - max non-mesh connections

**struct mesh_cfg_t**

Mesh initialization configuration.

Public Members

- `channel` (uint8_t)
  - 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_op_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

int broadcast
    broadcast and multicast queue

struct mesh_rx_pending_t
    The number of packets available in the queue waiting to be received by applications.

Public Members

int toDS
    to external DS
int toSelf
to self

**Macros**

**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
Chapter 2. API Reference

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

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_sta_connected_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
typedef enum mesh_event_id_t
Enumerated list of mesh event id.
Values:

MESH_EVENT_STARTED
mesh is started
MESH_EVENT_STOPPED
mesh is stopped
MESH_EVENT_CHANNEL_SWITCH
channel switch
MESH_EVENT_CHILD_CONNECTED
a child is connected on softAP interface
MESH_EVENT_CHILD_DISCONNECTED
a child is disconnected on softAP interface
MESH_EVENT_ROUTING_TABLE_ADD
routing table is changed by adding newly joined children
MESH_EVENT_ROUTING_TABLE_REMOVE
routing table is changed by removing leave children
MESH_EVENT_PARENT_CONNECTED
parent is connected on station interface
MESH_EVENT_PARENT_DISCONNECTED
parent is disconnected on station interface
MESH_EVENT_NO_PARENT_FOUND
no parent found

MESH_EVENT_LAYER_CHANGE
layer changes over the mesh network

MESH_EVENT_TODS_STATE
state represents whether the root is able to access external IP network

MESH_EVENT_VOTE_STARTED
the process of voting a new root is started either by children or by the root

MESH_EVENT_VOTE_STOPPED
the process of voting a new root is stopped

MESH_EVENT_ROOT_ADDRESS
the root address is obtained. It is posted by mesh stack automatically.

MESH_EVENT_ROOT_SWITCH_REQ
root switch request sent from a new voted root candidate

MESH_EVENT_ROOT_SWITCH_ACK
root switch acknowledgment responds the above request sent from current root

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.

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.

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.

MESH_EVENT_NETWORK_STATE
network state, such as whether current mesh network has a root.

MESH_EVENT_STOP_RECONNECTION
the root stops reconnecting to the router and non-root devices stop reconnecting to their parents.

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.

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.

MESH_EVENT_PS_PARENT_DUTY
parent duty

MESH_EVENT_PS_CHILD_DUTY
child duty

MESH_EVENT_PS_DEVICE_DUTY
device duty

MESH_EVENT_MAX

enum mesh_type_t
Device type.

Values:
MESH_IDLE
hasn’t joined the mesh network yet

MESH_ROOT
the only sink of the mesh network. Has the ability to access external IP network

MESH_NODE
intermediate device. Has the ability to forward packets over the mesh network

MESH_LEAF
has no forwarding ability

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:

MESH_PROTO_BIN
binary

MESH_PROTO_HTTP
HTTP protocol

MESH_PROTO_JSON
JSON format

MESH_PROTO_MQTT
MQTT protocol

MESH_PROTO_AP
IP network mesh communication of node’s AP interface

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:

MESH_TOS_P2P
provide P2P (point-to-point) retransmission on mesh stack by default

MESH_TOS_E2E
provide E2E (end-to-end) retransmission on mesh stack (Unimplemented)

MESH_TOS_DEF
no retransmission on mesh stack

enum mesh_vote_reason_t
Vote reason.

Values:

MESH_VOTE_REASON_ROOT_INITIATED = 1
vote is initiated by the root

MESH_VOTE_REASON_CHILD_INITIATED
vote is initiated by children

enum mesh_disconnect_reason_t
Mesh disconnect reason code.

Values:

MESH_REASON_CYCLIC = 100
cyclic is detected
**Chapter 2. API Reference**

```c
enum esp_mesh_topology_t
Mesh topology.
Values:

MESH_TOPO_TREE
tree topology

MESH_TOPO_CHAIN
chain topology
```

```c
enum mesh_event_toDS_state_t
The reachability of the root to a DS (distribute system)
Values:

MESH_TODS_UNREACHABLE
the root isn’t able to access external IP network

MESH_TODS_REACHABLE
the root is able to access external IP network
```

**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

---

**MESH_REASON_PARENT_IDLE**
parent is idle

**MESH_REASON_LEAF**
the connected device is changed to a leaf

**MESH_REASON_DIFF_ID**
in different mesh ID

**MESH_REASON_ROOTS**
root conflict is detected

**MESH_REASON_PARENT_STOPPED**
parent has stopped the mesh

**MESH_REASON_SCAN_FAIL**
scan fail

**MESH_REASON_IE_UNKNOWN**
unknown IE

**MESH_REASON_WAIVE_ROOT**
waive root

**MESH_REASON_PARENT_WORSE**
pARENT with very poor RSSI

**MESH_REASON_EMPTY_PASSWORD**
use an empty password to connect to an encrypted parent

**MESH_REASON_PARENT_UNENCRYPTED**
connect to an unencrypted parent/router
• 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-S3 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-S3 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-S3 using a supported smartphone:

`wifi/wifi_easy_connect/dpp-enrollee`

**API Reference**

**Header File**

- components/wpa_supplicant/esp_supplicant/include/esp_dpp.h

**Functions**

`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

`void esp_supp_dpp_deinit(void)`

De-initialize DPP Supplicant.

- Frees memory from DPP Supplicant Data Structures.

`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.

  Return
  • ESP_OK: Success
  • ESP_FAIL: Failure

  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) Private Key used to generate a Bootstrapping Public Key
  • `info`: (Optional) Ancilliary Device Information like Serial Number

`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.

Return

- 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

void esp_supp_dpp_stop_listen (void)
Stop listening on Channels.

Stops listening on Channels and cancels ongoing listen operation.

Macros

ESP_ERR_DPP_FAILURE
Generic failure during DPP Operation

ESP_ERR_DPP_TX_FAILURE
DPP Frame Tx failed OR not Acked

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.

Parameters

- \( \text{evt} \): DPP event ID
- \( \text{data} \): Event data payload

Enumerations

class dpp_bootstrap_type
Types of Bootstrap Methods for DPP.

Values:

DPP_BOOTSTRAP_QR_CODE
QR Code Method

DPP_BOOTSTRAP_PKEX
Proof of Knowledge Method

DPP_BOOTSTRAP_NFC_URI
NFC URI record Method

class esp_supp_dpp_event_t
Types of Callback Events received from DPP Supplicant.

Values:

ESP_SUPP_DPP_URI_READY
URI is ready through Bootstrapping

ESP_SUPP_DPP_CFG_RECVD
Config received via DPP Authentication

ESP_SUPP_DPP_FAIL
DPP Authentication failure
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.

## 2.2.2 Ethernet

### 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, 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:

**Fig. 4: Ethernet Data Frame Format**

| 1 | Preamble (7 Bytes) |
| 2 | Start-of-Frame Delimiter (1 Byte) |
| 3 | Destination Address (6 Bytes) |
| 4 | Source Address (6 Bytes) |
| 5 | Type / Length (2 Bytes) |
| 5 | Payload (0 ~ 1500 Bytes) |
| 7 | Pad (if necessary) |
| 8 | Frame Check Sequence (4 Bytes) |

---

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**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 multi-cast 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 multi-cast 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 uni-cast 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 uni-cast destination addresses. When transmitting packets, the host controller is responsible for writing the desired destination address into the transmit buffer.

**Source Address**  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. More information about MAC Address used in ESP-IDF, please see [MAC Address Allocation](https://docs.espressif.com/zh-cn/esp-idf/1.16/esp-idf_api.html). 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 <= 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 >= 1536, it represents the protocol the following packet data belongs to. The following 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 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. Adding the required 4-byte FCS field, packets must be no smaller than 64 bytes. If the data field is less than 46 bytes long, a padding field is required.

The FCS field is a 4-byte field which 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 are 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**  Ethernet driver is composed of two parts: MAC and PHY.

We need to setup necessary parameters for MAC and PHY respectively based on your Ethernet board design and then combine the two together, completing the driver installation.

**Configuration for MAC** is described in `eth_mac_config_t`, including:

- `sw_reset_timeout_ms`: software reset timeout value, in milliseconds, typically MAC reset should be finished within 100ms.
- `rx_task_stack_size` and `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.
- `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 cache is disabled, then you should configure this field with `ETH_MAC_FLAG_WORK_WITH_CACHE_DISABLE`.

**Configuration for PHY** is described in `eth_phy_config_t`, including:

- `phy_addr`: multiple PHY device 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.
- `reset_timeout_ms`: reset timeout value, in milliseconds, typically PHY reset should be finished within 100ms.
- `autonego_timeout_ms`: auto-negotiation timeout value, in milliseconds. 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.
- `reset_GPIO_num`: if your board also connect 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**  Ethernet driver is implemented in an Object-Oriented style. Any operation on MAC and PHY should be based on the instance of them two.

**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,
.quadhd_io_num = -1,
);
ESP_ERROR_CHECK(spi_bus_initialize(CONFIG_EXAMPLE_ETH_SPI_HOST, &buscfg, 1));
// Allocate SPI device from the bus
spi_device_interface_config_t devcfg = {
.command_bits = 1,
.address_bits = 7,
.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,
};
ESP_ERROR_CHECK(spi_bus_add_device(CONFIG_EXAMPLE_ETH_SPI_HOST, &devcfg, &spi_,
handle));
/* dm9051 ethernet driver is based on spi driver */
eth_dm9051_config_t dm9051_config = ETH_DM9051_DEFAULT_CONFIG(spi_handle);
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);

Note:
• When creating MAC and PHY instance 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.
• We have to create an SPI device handle firstly and then pass it to the MAC constructor function. More instructions
on creating SPI device handle, please refer to SPI Master.
• The SPI device configuration (i.e. spi_device_interface_config_t) can be different for other Ethernet modules.
Please check out your module’s spec 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:
• mac: instance that created from MAC generator (e.g. esp_eth_mac_new_esp32()).
• phy: instance that created from PHY generator (e.g. esp_eth_phy_new_ip101()).
• 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.
• stack_input: In most of Ethernet IoT applications, any Ethernet frame that received by driver
should be passed to upper layer (e.g. TCP/IP stack). This field is set to a function which is re-
 sponsible to deal with the incoming frames. You can even update this field at runtime via function
esp_eth_update_input_path() after driver installation.
• on_lowlevel_init_done and 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.

```
estp_eth_config_t config = ETH_DEFAULT_CONFIG(mac, phy); // apply default driver--
configuration
esp_eth_handle_t eth_handle = NULL; // after driver installed, we will get the--
handle of the driver
esp_eth_driver_install(&config, &eth_handle); // install driver
```

Ethernet driver also includes event-driven model, which will send useful and important event 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.
/** 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)
{
  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_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 running in __background
esp_event_handler_register(ETH_EVENT, ESP_EVENT_ANY_ID, &eth_event_handler, NULL);
// register Ethernet event handler (to deal with user specific stuffs when event__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). We can detect link up and down event, we can gain MAC address in user space, but we can’t obtain IP address, let alone send HTTP request. The TCP/IP stack used in ESP-IDF is called LwIP, for more information about it, please refer to LwIP.

To connect Ethernet driver to TCP/IP stack, these three steps need to follow:
1. Create network interface for Ethernet driver
2. Attach the network interface to Ethernet driver
3. Register IP event handlers

More information about 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;

(continues on next page)
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```c
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, "~~~~~~~~~~~~");
```

```c
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 prior registering user’s Ethernet/IP event handlers, i.e. register the event handlers as the last thing prior starting the Ethernet driver. Such approach ensures that Ethernet/IP events get executed first by the Ethernet driver or network interface and so the system is in expected state when executing 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()`

```c
/* 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. Ethernet flow control mechanism allows the receiving node to signal the sender requesting 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 Ethernet driver installation, the flow control feature is disabled by default. You can enable it by:

```c
bool flow_ctrl_enable = true;
esp_eth_ioctl(eth_handle, ETH_CMD_S_FLOW_CTRL, &flow_ctrl_enable);
```

One thing should be kept in mind, is that the pause frame ability will be advertised to peer end by PHY during auto negotiation. Ethernet driver sends pause frame only when both sides of the link support it.

### Application Example

- Ethernet basic example: `ethernet/basic`
- Ethernet iperf example: `ethernet/iperf`
- Ethernet to Wi-Fi AP “router” : `ethernet/eth2ap`
- Most of protocol examples should also work for Ethernet: `protocols`

### API Reference

#### Header File

- `components/esp_eth/include/esp_eth.h`

#### Functions

**esp_err_t esp_eth_driver_install(const esp_eth_config_t *config, esp_eth_handle_t *out_hdl)**

Install Ethernet driver.

**Return**

- `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

**Parameters**

- `[in] config`: configuration of the Ethernet driver
- `[out] out_hdl`: handle of Ethernet driver

**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.

**Return**

- `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

**Parameters**

- `[in] hdl`: handle of Ethernet driver

**esp_err_t esp_eth_start(esp_eth_handle_t hdl)**

Start Ethernet driver ONLY in standalone mode (i.e. without TCP/IP stack)

**Note** This API will start driver state machine and internal software timer (for checking link status).

**Return**

- `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

**Parameters**

- `[in] hdl`: handle of Ethernet driver
**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.

**Return**
- 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

**Parameters**
- [in] hdl: handle of Ethernet driver

```c
esp_err_t esp_eth_update_input_path(esp_eth_handle_t hdl, esp_eth_handle_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.

**Return**
- 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

**Parameters**
- [in] hdl: handle of Ethernet driver
- [in] stack_input: function pointer, which does the actual process on incoming packets
- [in] priv: private resource, which gets passed to stack_input callback without any modification

```c
esp_err_t esp_eth_transmit(esp_eth_handle_t hdl, void *buf, size_t length)
```

General Transmit.

**Return**
- ESP_OK: transmit frame buffer successfully
- ESP_ERR_INVALID_ARG: transmit frame buffer failed because of some invalid argument
- ESP_FAIL: transmit frame buffer failed because some other error occurred

**Parameters**
- [in] hdl: handle of Ethernet driver
- [in] buf: buffer of the packet to transfer
- [in] length: length of the buffer to transfer

```c
esp_err_t esp_eth_receive(esp_eth_handle_t hdl, uint8_t *buf, uint32_t *length)
```

General Receive is deprecated and shall not be accessed from app code, as polling is not supported by Ethernet.

**Note** Before this function got invoked, the value of “length” should set by user, equals the size of buffer. After the function returned, the value of “length” means the real length of received data.

**Note** This API was exposed by accident, users should not use this API in their applications. Ethernet driver is interrupt driven, and doesn’t support polling mode. Instead, users should register input callback with esp_eth_update_input_path.

**Return**
- ESP_OK: receive frame buffer successfully
- ESP_ERR_INVALID_ARG: receive frame buffer failed because of some invalid argument
- ESP_ERR_INVALID_SIZE: input buffer size is not enough to hold the incoming data. in this case, value of returned “length” indicates the real size of incoming data.
- ESP_FAIL: receive frame buffer failed because some other error occurred

**Parameters**
- [in] hdl: handle of Ethernet driver
- [out] buf: buffer to preserve the received packet
- [out] length: length of the received packet

```c
esp_err_t esp_eth_ioctl(esp_eth_handle_t hdl, esp_eth_ioctl_cmd cmd, void *data)
```

Misc IO function of Ethernet driver.
The following 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.

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

Parameters

```c
[in] hdl: handle of Ethernet driver
[in] cmd: IO control command
[inout] data: address of data for set command or address where to store the data when used with get command
```

```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.

Return

- ESP_OK: increase reference successfully
- ESP_ERR_INVALID_ARG: increase reference failed because of some invalid argument

Parameters

```c
[in] hdl: handle of Ethernet driver
```

```c
esp_err_t esp_eth_decrease_reference (esp_eth_handle_t hdl)
```

Decrease Ethernet driver reference.

Return
• ESP_OK: increase reference successfully
• ESP_ERR_INVALID_ARG: increase reference failed because of some invalid argument

**Parameters**

- [in] hdl: handle of Ethernet driver

**Structures**

```c
struct esp_eth_config_t
```

Configuration of Ethernet driver.

**Public Members**

```c
esp_eth_mac_t *mac
```
Ethernet MAC object.

```c
esp_eth_phy_t *phy
```
Ethernet PHY object.

```c
uint32_t check_link_period_ms
```
Period time of checking Ethernet link status.

```c
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.

**Return**

- ESP_OK: input frame buffer to upper stack successfully
- ESP_FAIL: error occurred when inputting buffer to upper stack

**Parameters**

- [in] eth_handle: handle of Ethernet driver
- [in] buffer: frame buffer that will get input to upper stack
- [in] length: length of the frame buffer

```c
esp_err_t (*on_lowlevel_init_done)(esp_eth_handle_t eth_handle)
```
Callback function invoked when lowlevel initialization is finished.

**Return**

- ESP_OK: process extra lowlevel initialization successfully
- ESP_FAIL: error occurred when processing extra lowlevel initialization

**Parameters**

- [in] eth_handle: handle of Ethernet driver

```c
esp_err_t (*on_lowlevel_deinit_done)(esp_eth_handle_t eth_handle)
```
Callback function invoked when lowlevel deinitialization is finished.

**Return**

- ESP_OK: process extra lowlevel deinitialization successfully
- ESP_FAIL: error occurred when processing extra lowlevel deinitialization

**Parameters**

- [in] eth_handle: handle of Ethernet driver

```c
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.

**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
Parameters
• [in] eth_handle: handle of Ethernet driver
• [in] phy_addr: PHY chip address (0~31)
• [in] phy_reg: PHY register index code
• [out] reg_value: PHY register value

```c
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.

Return
• ESP_OK: write PHY register successfully
• ESP_ERR_INVALID_ARG: read 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

Parameters
• [in] eth_handle: handle of Ethernet driver
• [in] phy_addr: PHY chip address (0~31)
• [in] phy_reg: PHY register index code
• [in] reg_value: PHY register value

Macros
ETH_DEFAULT_CONFIG (emac, ephy)
Default configuration for Ethernet driver.

Type Definitions
typedef void *esp_eth_handle_t
Handle of Ethernet driver.

Enumerations
defined esp_eth_io_cmd_t
Command list for ioctl API.

Values:

- ETH_CMD_G_MAC_ADDR
  Get MAC address
- ETH_CMD_S_MAC_ADDR
  Set MAC address
- ETH_CMD_G_PHY_ADDR
  Get PHY address
- ETH_CMD_S_PHY_ADDR
  Set PHY address
- ETH_CMD_G_AUTONEGO
  Get PHY Auto Negotiation
- ETH_CMD_S_AUTONEGO
  Set PHY Auto Negotiation
- ETH_CMD_G_SPEED
  Get Speed
- ETH_CMD_S_SPEED
  Set Speed
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ETH_CMD_S_PROMISCUOUS
    Set promiscuous mode

ETH_CMD_S_FLOW_CTRL
    Set flow control

ETH_CMD_G_DUPLEX_MODE
    Get Duplex mode

ETH_CMD_S_DUPLEX_MODE
    Set Duplex mode

ETH_CMD_S_PHY_LOOPBACK
    Set PHY loopback

Header File

- components/esp_eth/include/esp_eth_com.h

Functions

esp_err_t esp_eth_detect_phy_addr(esp_eth_mediator_t *eth, int *detected_addr)
    Detect PHY address.

    Return
    - 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

    Parameters
    - [in] eth: mediator of Ethernet driver
    - [out] detected_addr: a valid address after detection

Structures

struct esp_eth_mediator_s
    Ethernet mediator.

Public Members

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.

    Return
    - ESP_OK: read PHY register successfully
    - ESP_FAIL: read PHY register failed because some error occurred

    Parameters
    - [in] eth: mediator of Ethernet driver
    - [in] phy_addr: PHY Chip address (0~31)
    - [in] phy_reg: PHY register index code
    - [out] reg_value: PHY register value

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.

    Return
    - ESP_OK: write PHY register successfully
    - ESP_FAIL: write PHY register failed because some error occurred

    Parameters
    - [in] eth: mediator of Ethernet driver
Chapter 2. API Reference

- [in] phy_addr: PHY Chip address (0~31)
- [in] phy_reg: PHY register index code
- [in] reg_value: PHY register value

```c
esp_err_t (*stack_input)(esp_eth_mediator_t *eth, uint8_t *buffer, uint32_t length)
```
Deliver packet to upper stack.

**Return**
- ESP_OK: deliver packet to upper stack successfully
- ESP_FAIL: deliver packet failed because some error occurred

**Parameters**
- [in] eth: mediator of Ethernet driver
- [in] buffer: packet buffer
- [in] length: length of the packet

```c
esp_err_t (*on_state_changed)(esp_eth_mediator_t *eth, esp_eth_state_t state, void *args)
```
Callback on Ethernet state changed.

**Return**
- ESP_OK: process the new state successfully
- ESP_FAIL: process the new state failed because some error occurred

**Parameters**
- [in] eth: mediator of Ethernet driver
- [in] state: new state
- [in] args: optional argument for the new state

**Type Definitions**

```c
typedef struct esp_eth_mediator_s esp_eth_mediator_t
```
Ethernet mediator.

**Enumerations**

```c
enum esp_eth_state_t
```
Ethernet driver state.

**Values:**

- ETH_STATE_LLINE_INIT
  Lowlevel init done
- ETH_STATE_DEINIT
  Deinit done
- ETH_STATE_LINK
  Link status changed
- ETH_STATE_SPEED
  Speed updated
- ETH_STATE_DUPLEX
  Duplex updated
- ETH_STATE_PAUSE
  Pause ability updated

```c
enum eth_event_t
```
Ethernet event declarations.

**Values:**

- ETHERNET_EVENT_START
  Ethernet driver start
- ETHERNET_EVENT_STOP
  Ethernet driver stop
**Chapter 2. API Reference**

**ETHERNET_EVENT_CONNECTED**
Ethernet got a valid link

**ETHERNET_EVENT_DISCONNECTED**
Ethernet lost a valid link

**Header File**
- components/esp_eth/include/esp_eth_mac.h

**Unions**

union eth_mac_clock_config_t

```c
#include <esp_eth_mac.h>
```
EthernetMACClockConfiguration.

**Public Members**

```c
struct eth_mac_clock_config_t::[anonymous] mii
```
EMAC MII Clock Configuration

```c
t_enum emac_rmii_clock_mode_t clock_mode
```
RMII Clock Mode Configuration

```c
t_enum 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.

**Return**
- ESP_OK: set mediator for Ethernet MAC successfully
- ESP_ERR_INVALID_ARG: set mediator for Ethernet MAC failed because of invalid argument

**Parameters**
- [in] mac: Ethernet MAC instance
- [in] eth: Ethernet mediator

```c
esp_err_t (*init)(esp Eth_mac_t *mac)
```
Initialize Ethernet MAC.

**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

**Parameters**
- [in] mac: Ethernet MAC instance

```c
esp_err_t (*deinit)(esp Eth_mac_t *mac)
```
Deinitialize Ethernet MAC.

**Return**
• ESP_OK: deinitialize Ethernet MAC successfully
• ESP_FAIL: deinitialize Ethernet MAC failed because some error occurred

### Parameters

- `[in] mac`: Ethernet MAC instance

```c
esp_err_t (*start)(esp_eth_mac_t *mac)
```

Start Ethernet MAC.

#### Return

- ESP_OK: start Ethernet MAC successfully
- ESP_FAIL: start Ethernet MAC failed because some other error occurred

#### Parameters

- `[in] mac`: Ethernet MAC instance

```c
esp_err_t (*stop)(esp_eth_mac_t *mac)
```

Stop Ethernet MAC.

#### Return

- ESP_OK: stop Ethernet MAC successfully
- ESP_FAIL: stop Ethernet MAC failed because some other error occurred

#### Parameters

- `[in] mac`: Ethernet MAC instance

```c
esp_err_t (*transmit)(esp_eth_mac_t *mac, uint8_t* buf, uint32_t length)
```

Transmit packet from Ethernet MAC.

#### Return

- ESP_OK: transmit packet successfully
- ESP_ERR_INVALID_ARG: transmit packet failed because of invalid argument
- ESP_ERR_INVALID_STATE: transmit packet failed because of wrong state of MAC
- ESP_FAIL: transmit packet failed because some other error occurred

#### Parameters

- `[in] mac`: Ethernet MAC instance
- `[in] buf`: packet buffer to transmit
- `[in] length`: length of packet

```c
esp_err_t (*receive)(esp_eth_mac_t *mac, uint8_t* buf, uint32_t* length)
```

Receive packet from Ethernet MAC.

#### Note

- Memory of `buf` is allocated in the Layer2, make sure it get free after process.
- Before this function got invoked, the value of “length” should set by user, equals the size of buffer.
- After the function returned, the value of “length” means the real length of received data.

#### Return

- ESP_OK: receive packet successfully
- ESP_ERR_INVALID_ARG: receive packet failed because of invalid argument
- ESP_ERR_INVALID_SIZE: input buffer size is not enough to hold the incoming data. in this case, value of returned “length” indicates the real size of incoming data.
- ESP_FAIL: receive packet failed because some other error occurred

#### Parameters

- `[in] mac`: Ethernet MAC instance
- `[out] buf`: packet buffer which will preserve the received frame
- `[out] length`: length of the received packet

```c
esp_err_t (*read_phy_reg)(esp_eth_mac_t *mac, uint32_t phy_addr, uint32_t phy_reg, uint32_t *reg_value)
```

Read PHY register.

#### Return

- ESP_OK: read PHY register successfully
- ESP_ERR_INVALID_ARG: read PHY register failed because of invalid argument
- ESP_ERR_INVALID_STATE: read PHY register failed because of wrong state of MAC
- ESP_ERR_TIMEOUT: read PHY register failed because of timeout
- ESP_FAIL: read PHY register failed because some other error occurred
Parameters
- [in] mac: Ethernet MAC instance
- [in] phy_addr: PHY chip address (0-31)
- [in] phy_reg: PHY register index code
- [out] reg_value: PHY register value

```
esp_err_t (*write_phy_reg)(esp_eth_mac_t *mac, uint32_t phy_addr, uint32_t phy_reg, uint32_t reg_value)
```

Write PHY register.

Return
- ESP_OK: write PHY register successfully
- ESP_ERR_INVALID_STATE: write PHY register failed because of wrong state of MAC
- ESP_ERR_TIMEOUT: write PHY register failed because of timeout
- ESP_FAIL: write PHY register failed because some other error occurred

Parameters
- [in] mac: Ethernet MAC instance
- [in] phy_addr: PHY chip address (0-31)
- [in] phy_reg: PHY register index code
- [in] reg_value: PHY register value

```
esp_err_t (*set_addr)(esp_eth_mac_t *mac, uint8_t *addr)
```

Set MAC address.

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

Parameters
- [in] mac: Ethernet MAC instance
- [in] addr: MAC address

```
esp_err_t (*get_addr)(esp_eth_mac_t *mac, uint8_t *addr)
```

Get 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

Parameters
- [in] mac: Ethernet MAC instance
- [out] addr: MAC address

```
esp_err_t (*set_speed)(esp_eth_mac_t *mac, eth_speed_t speed)
```

Set speed of MAC.

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

Parameters
- [in] mac: Ethernet MAC instance
- [in] speed: MAC speed

```
esp_err_t (*set_duplex)(esp_eth_mac_t *mac, eth_duplex_t duplex)
```

Set duplex mode of MAC.

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

Parameters
- [in] mac: Ethernet MAC instance
Chapter 2. API Reference

- [in] duplex: MAC duplex

```c
esp_err_t (*set_link)(esp_eth_mac_t *mac, eth_link_t link)
```
Set link status of MAC.

**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

**Parameters**
- [in] mac: Ethernet MAC instance
- [in] link: Link status

```c
esp_err_t (*set_promiscuous)(esp_eth_mac_t *mac, bool enable)
```
Set promiscuous of MAC.

**Return**
- ESP_OK: set promiscuous mode successfully
- ESP_FAIL: set promiscuous mode failed because some error occurred

**Parameters**
- [in] mac: Ethernet MAC instance
- [in] enable: set true to enable promiscuous mode; set false to disable promiscuous mode

```c
esp_err_t (*enable_flow_ctrl)(esp_eth_mac_t *mac, bool enable)
```
Enable flow control on MAC layer or not.

**Return**
- ESP_OK: set flow control successfully
- ESP_FAIL: set flow control failed because some error occurred

**Parameters**
- [in] mac: Ethernet MAC instance
- [in] enable: set true to enable flow control; set false to disable flow control

```c
esp_err_t (*set_peer_pause_ability)(esp_eth_mac_t *mac, uint32_t ability)
```
Set the PAUSE ability of peer node.

**Return**
- ESP_OK: set peer pause ability successfully
- ESP_FAIL: set peer pause ability failed because some error occurred

**Parameters**
- [in] mac: Ethernet MAC instance
- [in] ability: zero indicates that pause function is supported by link partner; non-zero indicates that pause function is not supported by link partner

```c
esp_err_t (*del)(esp_eth_mac_t *mac)
```
Free memory of Ethernet MAC.

**Return**
- ESP_OK: free Ethernet MAC instance successfully
- ESP_FAIL: free Ethernet MAC instance failed because some error occurred

**Parameters**
- [in] mac: Ethernet MAC instance

```c
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

**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.

**Type Definitions**

typedef struct esp_eth_mac_s esp_eth_mac_t
    Ethernet MAC.

**Enumerations**

define emac_rmii_clock_mode_t
    RMII Clock Mode Options.
    Values:

    EMAC_CLK_DEFAULT
        Default values configured using Kconfig are going to be used when “Default” selected.

    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.

    EMAC_CLK_OUT
        Output RMII Clock from internal APLL Clock. EMAC Clock GPIO number needs to be configured when this option is selected.

define emac_rmii_clock_gpio_t
    RMII Clock GPIO number Options.
    Values:

    EMAC_CLK_IN_GPIO = 0
        MAC will get RMII clock from outside at this GPIO.
        Note ESP32 only supports GPIO0 to input the RMII clock.

    EMAC_CLK_OUT_GPIO = 0
        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.

    EMAC_CLK_OUT_GPIO = 16
        Output RMII Clock from internal APLL Clock available at GPIO16.

    EMAC_CLK_OUT_180_GPIO = 17
        Inverted Output RMII Clock from internal APLL Clock available at GPIO17.
Header File

- components/esp_eth/include/esp_eth_phy.h

Functions

`esp_eth_phy_t* esp_eth_phy_new_ip101(const eth_phy_config_t *config)`
Create a PHY instance of IP101.

Return
- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

Parameters
- [in] config: configuration of PHY

`esp_eth_phy_t* esp_eth_phy_new_rtl8201(const eth_phy_config_t *config)`
Create a PHY instance of RTL8201.

Return
- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

Parameters
- [in] config: configuration of PHY

`esp_eth_phy_t* esp_eth_phy_new_lan87xx(const eth_phy_config_t *config)`
Create a PHY instance of LAN87xx.

Return
- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

Parameters
- [in] config: configuration of PHY

`esp_eth_phy_t* esp_eth_phy_new_dp83848(const eth_phy_config_t *config)`
Create a PHY instance of DP83848.

Return
- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

Parameters
- [in] config: configuration of PHY

`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

Return
- instance: create PHY instance successfully
- NULL: create PHY instance failed because some error occurred

Parameters
- [in] config: configuration of PHY

Structures

`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.

**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

**Parameters**
- [in] phy: Ethernet PHY instance
- [in] mediator: mediator of Ethernet driver

```c
esp_err_t (*reset)(esp_eth_phy_t *phy)
```
Software Reset Ethernet PHY.

**Return**
- ESP_OK: reset Ethernet PHY successfully
- ESP_FAIL: reset Ethernet PHY failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance

```c
esp_err_t (*reset_hw)(esp_eth_phy_t *phy)
```
Hardware Reset Ethernet PHY.

**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

**Parameters**
- [in] phy: Ethernet PHY instance

```c
esp_err_t (*init)(esp_eth_phy_t *phy)
```
Initialize Ethernet PHY.

**Return**
- ESP_OK: initialize Ethernet PHY successfully
- ESP_FAIL: initialize Ethernet PHY failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance

```c
esp_err_t (*deinit)(esp_eth_phy_t *phy)
```
Deinitialize Ethernet PHY.

**Return**
- ESP_OK: deinitialize Ethernet PHY successfully
- ESP_FAIL: deinitialize Ethernet PHY failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance

```c
esp_err_t (*autonego_ctrl)(esp_eth_phy_t *phy, eth_phy_autoneg_cmd_t cmd, bool *autonego_en_stat)
```
Configure auto negotiation.

**Return**
- ESP_OK: restart auto negotiation successfully
- ESP_FAIL: restart auto negotiation failed because some error occurred
- ESP_ERR_INVALID_ARG: invalid command

**Parameters**
- [in] phy: Ethernet PHY instance
- [in] cmd: Configuration command, it is possible to Enable (restart), Disable or get current status of PHY auto negotiation
- [out] autonego_en_stat: Address where to store current status of auto negotiation configuration
esp_err_t (*get_link)(esp_eth_phy_t *phy)
Get Ethernet PHY link status.

Return
• ESP_OK: get Ethernet PHY link status successfully
• ESP_FAIL: get Ethernet PHY link status failed because some error occurred

Parameters
• [in] phy: Ethernet PHY instance

esp_err_t (*pwrctl)(esp_eth_phy_t *phy, bool enable)
Power control of Ethernet PHY.

Return
• ESP_OK: control Ethernet PHY power successfully
• ESP_FAIL: control Ethernet PHY power failed because some error occurred

Parameters
• [in] phy: Ethernet PHY instance
• [in] enable: set true to power on Ethernet PHY; set false to power off Ethernet PHY

esp_err_t (*set_addr)(esp_eth_phy_t *phy, uint32_t addr)
Set PHY chip address.

Return
• ESP_OK: set Ethernet PHY address successfully
• ESP_FAIL: set Ethernet PHY address failed because some error occurred

Parameters
• [in] phy: Ethernet PHY instance
• [in] addr: PHY chip address

esp_err_t (*get_addr)(esp_eth_phy_t *phy, uint32_t *addr)
Get PHY chip address.

Return
• ESP_OK: get Ethernet PHY address successfully
• ESP_ERR_INVALID_ARG: get Ethernet PHY address failed because of invalid argument

Parameters
• [in] phy: Ethernet PHY instance
• [out] addr: PHY chip address

esp_err_t (*advertise_pause_ability)(esp_eth_phy_t *phy, uint32_t ability)
Advertise pause function supported by MAC layer.

Return
• ESP_OK: Advertise pause ability successfully
• ESP_ERR_INVALID_ARG: Advertise pause ability failed because of invalid argument

Parameters
• [in] phy: Ethernet PHY instance
• [out] addr: Pause ability

esp_err_t (*loopback)(esp_eth_phy_t *phy, bool enable)
Sets the PHY to loopback mode.

Return
• ESP_OK: PHY instance loopback mode has been configured successfully
• ESP_FAIL: PHY instance loopback configuration failed because some error occurred

Parameters
• [in] phy: Ethernet PHY instance
• [in] enable: enables or disables PHY loopback

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

Return
- ESP_OK: PHY instance speed mode has been configured successfully
- ESP_FAIL: PHY instance speed mode configuration failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance
- [in] speed: Speed mode to be set

```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

**Return**
- ESP_OK: PHY instance duplex mode has been configured successfully
- ESP_FAIL: PHY instance duplex mode configuration failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance
- [in] duplex: Duplex mode to be set

```c
esp_err_t (*del)(esp_eth_phy_t *phy)
```
Free memory of Ethernet PHY instance.

**Return**
- ESP_OK: free PHY instance successfully
- ESP_FAIL: free PHY instance failed because some error occurred

**Parameters**
- [in] phy: Ethernet PHY instance

```c
struct eth_phy_config_t
```
Ethernet PHY configuration.

**Public Members**

```c
int32_t phy_addr
```
PHY address, set -1 to enable PHY address detection at initialization stage

```c
uint32_t reset_timeout_ms
```
Reset timeout value (Unit: ms)

```c
uint32_t autonego_timeout_ms
```
Auto-negotiation timeout value (Unit: ms)

```c
int reset_gpio_num
```
Reset GPIO number, -1 means no hardware reset

**Macros**

```c
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**

```c
ESP_ETH_PHY_AUTONEGO_RESTART
```
Chapter 2. API Reference

ESP_ETH_PHY_AUTONEGO_EN
ESP_ETH_PHY_AUTONEGO_DIS
ESP_ETH_PHY_AUTONEGO_G_STAT

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
Return  glue object, which inherits esp_netif_driver_base_t
Parameters
• eth_hdl: Ethernet driver handle

esp_err_t esp_eth_del_netif_glue(esp_eth_netif_glue_handle_t eth_netif_glue)
Delete netif glue of Ethernet driver.

Return  -ESP_OK: delete netif glue successfully
Parameters
• eth_netif_glue: netif glue

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.

2.2.3  Thread

Thread

Introduction  Thread is a 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

**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.

**Return**
- 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

**Parameters**
- **[in] init_config**: The initialization configuration.

**esp_err_t esp_openthread_launch_mainloop (void)**

Launches the OpenThread main loop.

**Note** The function will not return unless error happens when running the OpenThread stack.

**Return**
- 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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if not initialized

**otInstance *esp_openthread_get_instance (void)**

This function acquires the underlying OpenThread instance.

**Note** This function can be called on other tasks without lock.

**Return** The OpenThread instance pointer

Header File

- components/openthread/include/esp_openthread_types.h

Structures

**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

*int rx_pin*
  UART RX pin

*int tx_pin*
  UART TX 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

*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_config`*
  The uart 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
Chapter 2. API Reference

**esp_openthread_port_config_t** `port_config`

The port configuration

**Enumerations**

**enum esp_openthread_event_t**

OpenThread event declarations.

Values:

- **OPENTHREAD_EVENT_START**
  OpenThread stack start

- **OPENTHREAD_EVENT_STOP**
  OpenThread stack stop

- **OPENTHREAD_EVENT_IF_UP**
  OpenThread network interface up

- **OPENTHREAD_EVENT_IF_DOWN**
  OpenThread network interface down

- **OPENTHREAD_EVENT_GOT_IP6**
  OpenThread stack added IPv6 address

- **OPENTHREAD_EVENT_LOST_IP6**
  OpenThread stack removed IPv6 address

- **OPENTHREAD_EVENT_MULTICAST_GROUP_JOIN**
  OpenThread stack joined IPv6 multicast group

- **OPENTHREAD_EVENT_MULTICAST_GROUP_LEAVE**
  OpenThread stack left IPv6 multicast group

- **OPENTHREAD_EVENT_TREL_ADD_IP6**
  OpenThread stack added TREL IPv6 address

- **OPENTHREAD_EVENT_TREL_REMOVE_IP6**
  OpenThread stack removed TREL IPv6 address

**enum esp_openthread_radio_mode_t**

The radio mode of OpenThread.

Values:

- **RADIO_MODE_NATIVE** = 0x0
  Use the native 15.4 radio

- **RADIO_MODE_UART_RCP** = 0x1
  UART connection to a 15.4 capable radio co-processor (RCP)

- **RADIO_MODE_SPI_RCP** = 0x2
  SPI connection to a 15.4 capable radio co-processor (RCP)

**enum esp_openthread_host_connection_mode_t**

How OpenThread connects to the host.

Values:

- **HOST_CONNECTION_MODE_NONE** = 0x0
  Disable host connection

- **HOST_CONNECTION_MODE_CLI_UART** = 0x1
  CLI UART connection to the host

- **HOST_CONNECTION_MODE_RCP_UART** = 0x2
  RCP UART connection to the host
Chapter 2. API Reference

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.

Return

- 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.

Note Every OT APIs that takes an otInstance argument MUST be protected with this API lock except that the call site is in OT callbacks.

Return

- True on lock acquired
- False on failing to acquire the lock with the timeout.

Parameters

- [in] block_ticks: The maximum number of RTOS ticks to wait for the lock.

void `esp_openthread_lock_release(void)`
This function releases the OpenThread API 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.

Return

- glue pointer on success
- NULL on failure

Parameters

- [in] config: The platform configuration.

void `esp_openthread_netif_glue_deinit(void)`
This function deinitializes the OpenThread network interface glue.

esp_netif_t *`esp_openthread_get_netif(void)`
This function acquires the OpenThread netif.

Return The OpenThread netif or NULL if not initialized.

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

• [in] backbone_netif: 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.

**Return**
- 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.

**Return**
- 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.

**Return** The backbone interface or NULL if border router not initialized.

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.

### 2.2.4 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.

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 component is a successor of the tcpip_adapter, former network interface abstraction, which has become deprecated since IDF v4.1. Please refer to the TCP/IP Adapter Migration Guide section in case existing applications to be ported to use the esp-netif API instead.

**ESP-NETIF architecture**

```
<table>
<thead>
<tr>
<th>(A) USER CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>..............</td>
</tr>
</tbody>
</table>
| .             +--------------------------+
| .             | *                          |
| ------------- | *                          |
| +------------- | *                          |
| | new/config get/set | *                  |
| | ----------------- | * | init |
```

(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, former tcpip_adapter  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
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 open(), read(), write(), etc). Refer to Virtual filesystem component to learn more.

There is only one ESP-NETIF L2 TAP interface device (path name) 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 the NETIF internal structure. Important is then specific configuration of particular file descriptor. It can be configured to give an access to specific Network Interface identified by if_key (e.g. 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 work 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.

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 with different configuration may access the Data Link Layer in the NETIF.

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`. 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_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 set configuration options have getter counterpart option to read the current settings.

**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.

On success, `ioctl()` returns 0. On error, -1 is returned, and `errno` is set to indicate the error.

- **EBADF** - not a valid file descriptor.
- **EINVAL** - invalid configuration argument. Ethernet type filter is already used by other file descriptor.
- **ENODEV** - no such Network Interface which is tried to be assigned to the file descriptor exists.
- **ENOSPC** - NETIF L2 receive hook is already taken by other function when trying to assign Network Interface to the file descriptor.
- **ENOSYS** - unsupported operation, passed configuration option does not exists.

**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.

| +-------------------+-------------------+-------------+---------------------------- |
| | Destination MAC   | Source MAC        | Type/Length | Payload (protocol header/  |
| |                   |                   |             | data) ...                  |
| +-------------------+-------------------+-------------+---------------------------- |
| -                 | 6B                | 6B          | 2B                        | 0-1486B                   |

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.

### 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`
- 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*. 
Chapter 2. API Reference

**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`

**Functions**

- `esp_err_t esp_netif_init (void)`
  Initialize the underlying TCP/IP stack.
  
  **Return**
  - ESP_OK on success
  - ESP_FAIL if initializing failed

  **Note** This function should be called exactly once from application code, when the application starts up.

- `esp_err_t esp_netif_deinit (void)`
  Deinitialize the esp-netif component (and the underlying TCP/IP stack)
  
  **Return**
  - ESP_ERR_INVALID_STATE if esp_netif not initialized
  - ESP_ERR_NOT_SUPPORTED otherwise

- `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.
  
  **Return**
  - pointer to esp-netif object on success
  - NULL otherwise

  **Parameters**
  - [in] `esp_netif_config`: pointer esp-netif configuration

- `void esp_netif_destroy (esp_netif_t* esp_netif)`
  Destroys the esp_netif object.

  **Parameters**
  - [in] `esp_netif`: pointer to the object to be deleted

- `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.

  **Return**
  - ESP_OK on success
  - ESP_ERR_ESP_NETIF_INVALID_PARAMS if invalid parameters provided

  **Parameters**
  - [in] `esp_netif`: pointer esp_netif object
  - [in] `driver_config`: pointer to driver config
Chapter 2. API Reference

- [inout] esp_netif: pointer to the object to be configured
- [in] driver_config: pointer esp_netif io driver related configuration

`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).

**Return**
- ESP_OK on success
- ESP_ERR_ESP_NETIF_DRIVER_ATTACH_FAILED if driver’s post_attach callback failed

**Parameters**
- [inout] esp_netif: pointer to esp_netif object to be attached
- [in] driver_handle: pointer to the driver handle

`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.

**Return**
- ESP_OK

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] buffer: Received data
- [in] len: Length of the data frame
- [in] eb: Pointer to internal buffer (used in Wi-Fi driver)

`esp_err_t esp_netif_transmit_hook_attach (esp_netif_t *esp_netif, void* hook_fn)`

Add transmit hook callback function reference into ESP-NETIF. This callback function is then called just prior the ESP-NETIF passes data to network driver.

**Return**
- ESP_OK - success
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] hook_fn: reference to transmit hook call-back function

`esp_err_t esp_netif_post_transmit_hook_attach (esp_netif_t *esp_netif, void* hook_fn)`

Add post transmit hook callback function reference into ESP-NETIF. This callback function is then called just after the ESP-NETIF passes data to network driver.

**Note** Intention of this function is either to release resources allocated by transmit hook function or for other use cases such as time stamping, etc.

**Return**
- ESP_OK - success
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] hook_fn: reference to post transmit hook call-back function

`esp_err_t esp_netif_recv_hook_attach (esp_netif_t *esp_netif, void* hook_fn)`

Add receive hook callback function reference into ESP-NETIF. This callback function is then called when network driver receives data.

**Return**
- ESP_OK - success
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
• [in] hook_fn: reference to receive hook callback function

`esp_err_t esp_netif_transmit_hook_detach(esp_netif_t *esp_netif)`

Removes reference to previously attached transmit hook callback function.

**Return**
- ESP_OK - success
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

`esp_err_t esp_netif_post_transmit_hook_detach(esp_netif_t *esp_netif)`

Removes reference to previously attached posttransmit hook callback function.

**Return**
- ESP_OK - success
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

`esp_err_t esp_netif_recv_hook_detach(esp_netif_t *esp_netif)`

Removes reference to previously attached receive hook callback function.

**Return**
- ESP_OK - success
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

`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**
- [in] esp_netif: 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**
- [in] esp_netif: 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**
- [in] esp_netif: 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.

**Note** This API can be directly used as event handler
Chapter 2. API Reference

Parameters
- [in] esp_netif: Handle to esp-netif instance
- base:
- event_id:
- data:

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 an event handler

Parameters
- [in] esp_netif: Handle to esp-netif instance
- base:
- event_id:
- data:

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 an event handler

Parameters
- [in] esp_netif: Handle to esp-netif instance
- base:
- event_id:
- data:

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 an event handler

Parameters
- [in] esp_netif: Handle to esp-netif instance
- base:
- event_id:
- data:

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 an event handler

Parameters
- [in] esp_netif: Handle to esp-netif instance
- base:
- event_id:
- data:

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 an event handler

Parameters
- [in] esp_netif: Handle to esp-netif instance
- base:
- event_id:
- data:

**esp_err_t esp_netif_set_mac** *(esp_netif_t *)esp_netif, uint8_t mac[])*

Set the mac address for the interface instance.

**Return**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_NOT_SUPPORTED - mac not supported on this interface

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] mac: Desired mac address for the related network interface

**esp_err_t esp_netif_get_mac**(esp_netif_t *esp_netif, uint8_t mac[])
Get the mac address for the interface instance.

**Return**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_NOT_SUPPORTED - mac not supported on this interface

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] mac: Resultant mac address for the related network 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

**Return**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_ESP_NETIF_INVALID_PARAMS - parameter error

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**esp_err_t esp_netif_get_hostname**(esp_netif_t *esp_netif, const char **hostname)
Get interface hostname.

**Return**
- ESP_OK - success
- ESP_ERR_ESP_NETIF_IF_NOT_READY - interface status error
- ESP_ERR_ESP_NETIF_INVALID_PARAMS - parameter error

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] hostname: Returns a pointer to the hostname. Maybe NULL if no hostname is set. If set non-NULL, pointer remains valid (and string may change if the hostname changes).

**bool esp_netif_is_netif_up**(esp_netif_t *esp_netif)
Test if supplied interface is up or down.

**Return**
- true - Interface is up
- false - Interface is down

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**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

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
**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.

**Return**

- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
- **[out]** ip_info: If successful, IP information will be returned in this argument.

**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.

**Return**

- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_NOT_STOPPED If DHCP server or client is still running

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
- **[in]** ip_info: IP information to set on the specified interface

**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.

**Return**

- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
- **[in]** ip_info: Store the old IP information for the specified interface

**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

**Return** implementation specific index of interface represented with supplied esp_netif

**Parameters**

- **[in]** esp_netif: Handle to esp-netif instance
Chapter 2. API Reference

- [in] esp_netif: Handle to esp-netif instance

`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

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] name: 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)

`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.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] opt_op: ESP_NETIF_OP_SET to set an option, ESP_NETIF_OP_GET to get an option.
- [in] opt_id: Option index to get or set, must be one of the supported enum values.
- [inout] opt_val: Pointer to the option parameter.
- [in] opt_len: Length of the option parameter.

`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.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [in] opt_op: ESP_NETIF_OP_SET to set an option, ESP_NETIF_OP_GET to get an option.
- [in] opt_id: Option index to get or set, must be one of the supported enum values.
- [inout] opt_val: Pointer to the option parameter.
- [in] opt_len: Length of the option parameter.

`esp_err_t esp_netif_dhcpc_start(esp_netif_t *esp_netif)`

Start DHCP client (only if enabled in interface object)

**Note** The default event handlers for the SYSTEM_EVENT_STA_CONNECTED and SYSTEM_EVENT_ETH_CONNECTED events call this function.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED
- ESP_ERR_ESP_NETIF_DHCP_START_FAILED

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
**esp_err_t** **esp_netif_dhcpc_stop**(esp_netif_t *esp_netif)
Stop DHCP client (only if enabled in interface object)

**Note** Calling action_netif_stop() will also stop the DHCP Client if it is running.

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_IF_NOT_READY

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**esp_err_t** **esp_netif_dhcpc_get_status**(esp_netif_t *esp_netif, esp_netif_dhcp_status_t *status)
Get DHCP client status.

**Return**
- ESP_OK

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] status: If successful, the status of DHCP client will be returned in this argument.

**esp_err_t** **esp_netif_dhcps_get_status**(esp_netif_t *esp_netif, esp_netif_dhcp_status_t *status)
Get DHCP Server status.

**Return**
- ESP_OK

**Parameters**
- [in] esp_netif: Handle to esp-netif instance
- [out] status: If successful, the status of the DHCP server will be returned in this argument.

**esp_err_t** **esp_netif_dhcps_start**(esp_netif_t *esp_netif)
Start DHCP server (only if enabled in interface object)

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STARTED

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**esp_err_t** **esp_netif_dhcps_stop**(esp_netif_t *esp_netif)
Stop DHCP server (only if enabled in interface object)

**Return**
- ESP_OK
- ESP_ERR_ESP_NETIF_INVALID_PARAMS
- ESP_ERR_ESP_NETIF_DHCP_ALREADY_STOPPED
- ESP_ERR_ESP_NETIF_IF_NOT_READY

**Parameters**
- [in] esp_netif: Handle to esp-netif instance

**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 Wi-Fi AP interface itself.
This function can override it by setting server type ESP_NETIF_DNS_MAIN.
Other DNS Server types are not supported for the Wi-Fi AP interface.

Return
- ESP_OK on success
- ESP_ERR_ESP_NETIF_INVALID_PARAMS invalid params

Parameters
- [in] esp_netif: Handle to esp-netif instance
- [in] type: Type of DNS Server to set: ESP_NETIF_DNS_MAIN, ESP_NETIF_DNS_BACKUP, ESP_NETIF_DNS_FALLBACK
- [in] dns: DNS Server address to set

Get DNS Server information.

Return
- ESP_OK on success
- ESP_ERR_ESP_NETIF_INVALID_PARAMS invalid params

Parameters
- [in] esp_netif: Handle to esp-netif instance
- [in] type: Type of DNS Server to get: ESP_NETIF_DNS_MAIN, ESP_NETIF_DNS_BACKUP, ESP_NETIF_DNS_FALLBACK
- [out] dns: DNS Server result is written here on success

Create interface link-local IPv6 address.

Return
- 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.

Parameters
- [in] esp_netif: Handle to esp-netif instance
- [out] if_ip6: IPv6 information will be returned in this argument if successful.

Get interface global IPv6 address.

Return
- ESP_OK

Other DNS Server types are not supported for the Wi-Fi AP interface.
• ESP_FAIL If interface is down, does not have a global IPv6 address, or the global IPv6 address is not a preferred address.

Parameters
• [in] esp_netif: Handle to esp-netif instance
• [out] if_ip6: IPv6 information will be returned in this argument if successful.

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.

Return number of returned IPv6 addresses

Parameters
• [in] esp_netif: Handle to esp-netif instance
• [out] if_ip6: Array of IPv6 addresses will be copied to the argument

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
• [out] addr: IP address to be set
• a: the first octet (127 for IP 127.0.0.1)
• b:
• c:
• d:

cchar *esp_ip4addr_ntoa (const esp_ip4_addr_t *addr, char *buf, int buflen) Converts numeric IP address into decimal dotted ASCII representation.

Return either pointer to buf which now holds the ASCII representation of addr or NULL if buf was too small

Parameters
• addr: IP address in network order to convert
• buf: target buffer where the string is stored
• buflen: length of buf

uint32_t esp_ip4addr_aton (const char *addr) Ascii internet address interpretation routine The value returned is in network order.

Return ip address in network order

Parameters
• addr: IP address in ascii representation (e.g. “127.0.0.1”)

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.

Return
• ESP_OK on success
• ESP_FAIL if conversion failed
• ESP_ERR_INVALID_ARG if invalid parameter is passed into

Parameters
• [in] src: IPv4 address in ascii representation (e.g. “127.0.0.1”)
• [out] dst: Address of the target esp_ip4_addr_t structure to receive converted address

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 ommitted: “2001:db8:85a3:0:0:0:2:1” or “2001:db8::2:1”

Return
• ESP_OK on success
• ESP_FAIL if conversion failed
• ESP_ERR_INVALID_ARG if invalid parameter is passed into

Parameters
• [in] src: IPv6 address in ascii representation (e.g. “2001:db8:85a3:0:0:0:2:1”)
• [out] dst: Address of the target esp_ip6_addr_t structure to receive converted address
esp_netif_iodriver_handle esp_netif_get_io_driver (esp_netif_t *esp_netif)
Gets media driver handle for this esp-netif instance.

Return opaque pointer of related IO driver
Parameters
• [in] esp_netif: Handle to esp-netif instance

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.

Return Handle to esp-netif instance
Parameters
• if_key: Textual description of network interface

esp_netif_flags_t esp_netif_get_flags (esp_netif_t *esp_netif)
Returns configured flags for this interface.

Return Configuration flags
Parameters
• [in] esp_netif: Handle to esp-netif instance

const char *esp_netif_get_ifkey (esp_netif_t *esp_netif)
Returns configured interface key for this esp-netif instance.

Return Textual description of related interface
Parameters
• [in] esp_netif: Handle to esp-netif instance

const char *esp_netif_get_desc (esp_netif_t *esp_netif)
Returns configured interface type for this esp-netif instance.

Return Enumerated type of this interface, such as station, AP, ethernet
Parameters
• [in] esp_netif: Handle to esp-netif instance

int esp_netif_get_route_prio (esp_netif_t *esp_netif)
Returns configured routing priority number.

Return Integer representing the instance’s route-prio, or -1 if invalid parameters
Parameters
• [in] esp_netif: Handle to esp-netif instance

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.

Return 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
Parameters
• [in] esp_netif: Handle to esp-netif instance
• event_type: (either get or lost IP)

esp_netif_t *esp_netif_next (esp_netif_t *esp_netif)
Iterates over list of interfaces. Returns first netif if NULL given as parameter.

Return First netif from the list if supplied parameter is NULL, next one otherwise
Parameters
• [in] esp_netif: Handle to esp-netif instance

size_t esp_netif_get_nr_of_ifs (void)
Returns number of registered esp_netif objects.

Return Number of esp_netifs

void esp_netif_netstack_buf_ref (void *netstack_buf)
increase the reference counter of net stack buffer

Parameters
• [in] netstack_buf: the net stack buffer
void esp_netif_netstack_buf_free (void *netstack_buf)
    free the netstack buffer

Parameters
    • [in] netstack_buf: the net stack buffer

Macros
    _ESP_NETIF.Suppress.LEGACY.WARNING_

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.
            Return
                • ESP_OK on success
                • ESP_FAIL if attach failed
            Parameters
                • esp_netif: instance to attach the wifi station to
    esp_err_t esp_netif_attach_wifi_ap (esp_netif_t *esp_netif)
        Attaches wifi soft AP interface to supplied netif.
            Return
                • ESP_OK on success
                • ESP_FAIL if attach failed
            Parameters
                • esp_netif: instance to attach the wifi AP to
    esp_err_t esp_wifi_set_default_wifi_sta_handlers (void)
        Sets default wifi event handlers for STA interface.
            Return
                • 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.
            Return
                • 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 *esp_netif)
        Clears default wifi event handlers for supplied network interface.
            Return
                • ESP_OK on success, error returned from esp_event_handler_register if failed
            Parameters
                • esp_netif: instance of corresponding if object
    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 default wifi handlers.
            Return
                pointer to esp-netif instance
    esp_netif_t *esp_netif_create_default_wifi_sta (void)
        Creates default WIFI STA. In case of any init error this API aborts.
Chapter 2. API Reference

**Note** The API creates esp_netif object with default WiFi station config, attaches the netif to wifi and registers default wifi handlers.

**Return** pointer to esp-netif instance

```c
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**
- [in] esp_netif: object to detach from WiFi and destroy

```c
esp_netif_t *esp_netif_create_wifi(wifi_interface_t wifi_if, 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!

**Return** pointer to esp-netif instance

**Parameters**
- [in] wifi_if: type of wifi interface
- [in] esp_netif_config: inherent esp-netif configuration pointer

```c
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.

**Return** ESP_OK on success

**Parameters**
- [out] p_netif_sta: pointer where the resultant STA interface is saved (if non NULL)
- [out] p_netif_ap: pointer where the resultant AP interface is saved (if non NULL)

### 2.2.5 IP Network Layer

**TCP/IP Adapter Migration Guide**

TCP/IP Adapter is a network interface abstraction component used in IDF prior to v4.1. This page outlines migration from tcpip_adapter API to its successor ESP-NETIF.

**Updating network connection code**

**Network stack initialization** Simply replace tcpip_adapter_init() with esp_netif_init(). Please note that the ESP-NETIF initialization API returns standard error code and the esp_netif_deinit() for un-initialization is available.

Also replace #include "tcpip_adapter.h" with #include "esp_netif.h".

**Network interface creation** TCP/IP Adapter defined these three interfaces statically:

- WiFi Station
- WiFi Access Point
- Ethernet

Network interface instance shall be explicitly constructed for the ESP-NETIF to enable its connection to the TCP/IP stack. For example initialization code for WiFi has to explicitly call esp_netif_create_default_wifi_sta(); or esp_netif_create_default_wifi_ap();
Chapter 2. API Reference

after the TCP/IP stack and the event loop have been initialized. Please consult an 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

**Replacing other tcpip_adapter API**  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, all events shall be handled in the same way. Please note that within IP related event handlers, application code usually receives IP addresses in a form of esp-netif specific struct (not the LwIP structs, but binary compatible). This is the preferred way of printing the address:

```c
ESP_LOGI(TAG, "got ip:", IP2STR(&event->ip_info.ip));
```

Instead of

```c
ESP_LOGI(TAG, "got ip:%s", ip4addr_ntoa(&event->ip_info.ip));
```

Since `ip4addr_ntoa()` is a LwIP API, the esp-netif provides `esp_ip4addr_ntoa()` as a replacement, but the above method is generally preferred.

**IP addresses**  It is preferred to use esp-netif defined IP structures. Please note that the LwIP structs will still work when default compatibility enabled. * esp-netif IP address definitions

**Next steps**  Additional step in porting an application to fully benefit from the ESP-NETIF is to disable the tcpip_adapter compatibility layer in the component configuration: ESP NETIF Adapter -> Enable backward compatible tcpip_adapter interface and check if the project compiles. TCP/IP adapter brings many include dependencies and this step might help in decoupling the application from using specific TCP/IP stack API directly.

**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_t *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));
    my_driver_start(driver->driver_impl);
    return ESP_OK;
}
```

**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 -> 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. 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.

Return handle to related esp-netif instance

Parameters
• [in] dev: opaque ptr to network interface of specific TCP/IP stack

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

Return handle to related network stack netif handle

Parameters
• [in] esp_netif: Handle to esp-netif instance

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.

Return ESP_OK on success, an error passed from the I/O driver otherwise

Parameters
• [in] esp_netif: Handle to esp-netif instance
• [in] data: Data to be transmitted
• [in] len: Length of the data frame

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.

Return ESP_OK on success, an error passed from the I/O driver otherwise

Parameters
• [in] esp_netif: Handle to esp-netif instance
• [in] data: Data to be transmitted
• [in] len: Length of the data frame
• [in] netstack_buf: net stack buffer

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
• [in] esp_netif: Handle to esp-netif instance
• [in] buffer: Rx buffer pointer

Code examples for TCP/IP socket APIs are provided in the protocols/sockets directory of ESP-IDF examples.

The TCP/IP Adapter (legacy network interface library) has been deprecated, please consult the TCP/IP Adapter Migration Guide to update existing IDF applications.

2.2.6 Application Layer

Documentation for Application layer network protocols (above the IP Network layer) are provided in Application Protocols.
2.3 Peripherals API

2.3.1 Analog to Digital Converter (ADC)

ADC Channels

The ESP32-S3 integrates 2 SAR (Successive Approximation Register) ADCs, supporting a total of 20 measurement channels (analog enabled pins).

These channels are supported:

ADC1:
- 10 channels: GPIO1 - GPIO10

ADC2:
- 10 channels: GPIO11 - GPIO20

ADC Attenuation

Vref is the reference voltage used internally by ESP32-S3 ADCs for measuring the input voltage. The ESP32-S3 ADCs can measure analog voltages from 0 V to Vref. Among different chips, the Vref varies, the median is 1.1 V. In order to convert voltages larger than Vref, input voltages can be attenuated before being input to the ADCs. There are 4 available attenuation options, the higher the attenuation is, the higher the measurable input voltage could be.

<table>
<thead>
<tr>
<th>Attenuation</th>
<th>Measurable input voltage range</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADC_ATTEN_DB_0</td>
<td>0 mV ~ 950 mV</td>
</tr>
<tr>
<td>ADC_ATTEN_DB_2_5</td>
<td>0 mV ~ 1250 mV</td>
</tr>
<tr>
<td>ADC_ATTEN_DB_6</td>
<td>0 mV ~ 1750 mV</td>
</tr>
<tr>
<td>ADC_ATTEN_DB_11</td>
<td>0 mV ~ 3100 mV</td>
</tr>
</tbody>
</table>

ADC Conversion

An ADC conversion is to convert the input analog voltage to a digital value. The ADC conversion results provided by the ADC driver APIs are raw data. Resolution of ESP32-S3 ADC raw results under Single Read mode is 12-bit.

- `adc1_get_raw()`
- `adc2_get_raw()`

To calculate the voltage based on the ADC raw results, this formula can be used:

\[ V_{out} = D_{out} \times \frac{V_{max}}{D_{max}} \]  \hspace{1cm} (1)

where:

<table>
<thead>
<tr>
<th>Vout</th>
<th>Digital output result, standing for the voltage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dout</td>
<td>ADC raw digital reading result.</td>
</tr>
<tr>
<td>Vmax</td>
<td>Maximum measurable input analog voltage, see ADC Attenuation.</td>
</tr>
<tr>
<td>Dmax</td>
<td>Maximum of the output ADC raw digital reading result, which is 4095 under Single Read mode, 8191 under Continuous Read mode.</td>
</tr>
</tbody>
</table>

For boards with eFuse ADC calibration bits, `esp_adc_cal_raw_to_voltage()` can be used to get the calibrated conversion results. These results stand for the actual voltage (in mV). No need to transform these data via the formula (1). If ADC calibration APIs are used on boards without eFuse ADC calibration bits, warnings will be generated. See ADC Calibration.
Chapter 2. API Reference

ADC Limitations

Note:
- Since the ADC2 module is also used by the Wi-Fi, reading operation of `adc2_get_raw()` may fail between `esp_wifi_start()` and `esp_wifi_stop()`. Use the return code to see whether the reading is successful.

Driver Usage

Both of the ADC units support single read mode, which is suitable for low-frequency sampling operations.

Note: ADC readings from a pin not connected to any signal are random.

ADC Single Read mode
The ADC should be configured before reading is taken.
- For ADC1, configure desired precision and attenuation by calling functions `adc1_config_width()` and `adc1_config_channel_atten()`.
- For ADC2, configure the attenuation by `adc2_config_channel_atten()`. The reading width of ADC2 is configured every time you take the reading.

Attenuation configuration is done per channel, see `adc1_channel_t` and `adc2_channel_t`, set as a parameter of above functions.

Then it is possible to read ADC conversion result with `adc1_get_raw()` and `adc2_get_raw()`. Reading width of ADC2 should be set as a parameter of `adc2_get_raw()` instead of in the configuration functions.

Single Read mode ADC example can be found in peripherals/adc/single_read directory of ESP-IDF examples.

This API provides convenient way to configure ADC1 for reading from ULP. To do so, call function `adc1_ulp_enable()` and then set precision and attenuation as discussed above.

Note: See **ADC Limitations** for the limitation of using ADC single read mode.

Minimizing Noise

The ESP32-S3 ADC can be sensitive to noise leading to large discrepancies in ADC readings. Depending on the usage scenario, users may 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.

ADC Calibration

ESP32-S3 ADC Calibration contains 2 steps: Hardware Calibration and Software Calibration.

Hardware Calibration
Based on series of comparisons with the reference voltage, ESP32-S3 ADC determines each bit of the output digital result. Per design the ESP32-S3 ADC reference voltage is 1100 mV, however the true reference voltage can range from 1000 mV to 1200 mV among different chips. To minimize this difference, hardware calibration is introduced.

Hardware calibration contains 2 steps:
1. Set an auto-calibration parameter of bandgap voltage reference. In this way, the difference mentioned above can be minimized.
2. Correct the offset of the ADC Vin-Dout characteristics. ADC characteristics is generally a function: \( f(x) = A \cdot x + B \), where \( B \) is the offset.

An uncalibrated ADC characteristics is as follows:

The offset in the uncalibrated characteristics is significant. Step 2 is to correct the offset to 0.

After hardware calibration, the ADC characteristics would be like:

Hardware calibration is done internally by the ADC driver. The consequent results are raw data. A transformation is needed to get the final result, see \textit{ADC Conversion}.

**Software Calibration** To convert ADC raw data to calibrated digital data, following steps should be followed:

1. Check the eFuse to know if the software calibration is supported via \texttt{esp_adc_cal_check_efuse()}. 
2. Calculate the ADC calibration characteristics via \texttt{esp_adc_cal_characterize()}. The ADC software calibration characteristics are per ADC module and per attenuation. For example, characteristics of ADC1 channel 0 under 11 dB attenuation are the same as characteristics of ADC1 channel 2 under 11 dB attenuation. But characteristics of ADC1 channel 0 under 11 dB attenuation are different with characteristics of ADC2 channel 0 under 11 dB attenuation. Also characteristics of ADC1 channel 0 under 11 dB attenuation are different with characteristics of ADC1 channel 0 under 6 dB attenuation. 
3. Get the actual voltage value via \texttt{esp_adc_cal_raw_to_voltage()}. 

After software calibration, the ADC characteristics would be like:

The results provided by the ADC calibration APIs indicate the actual voltage values. ADC software calibration example can be found in \texttt{peripherals/adc/single_read} directory of ESP-IDF examples.

**GPIO Lookup Macros**

There are macros available to specify the GPIO number of a ADC channel, or vice versa. e.g.

1. \texttt{ADC1\_CHANNEL\_0\_GPIO\_NUM} is the GPIO number of ADC1 channel 0.
2. \texttt{ADC1\_GPIO\_n\_CHANNEL} is the ADC1 channel number of GPIO n.
API Reference

This reference covers three components:

- **ADC driver**
- **ADC Calibration**
- **GPIO Lookup Macros**

## ADC driver

### Header File

- components/driver/include/driver/adc.h

### Functions

- **void adc_power_on (void)**
  
  Enable ADC power.

- **void adc_power_off (void)**
  
  Power off SAR ADC.

- **void adc_power_acquire (void)**
  
  Increment the usage counter for ADC module. ADC will stay powered on while the counter is greater than 0. Call adc_power_release when done using the ADC.

- **void adc_power_release (void)**
  
  Decrement the usage counter for ADC module. ADC will stay powered on while the counter is greater than 0. Call this function when done using the ADC.

- **esp_err_t adc1_pad_get_io_num (adc1_channel_t channel, gpio_num_t *gpio_num)**
  
  Get the GPIO number of a specific ADC1 channel.

  **Return**

  - ESP_OK if success
  - ESP_ERR_INVALID_ARG if channel not valid

  **Parameters**

  - **channel**: Channel to get the GPIO number
  - **gpio_num**: output buffer to hold the GPIO number

- **esp_err_t adc1_config_channel_atten (adc1_channel_t channel, adc_atten_t atten)**
  
  Set the attenuation of a particular channel on ADC1, and configure its associated GPIO pin mux.

  The default ADC voltage is for attenuation 0 dB and listed in the table below. By setting higher attenuation it is possible to read higher voltages.

  Due to ADC characteristics, most accurate results are obtained within the “suggested range” shown in the following table.

<table>
<thead>
<tr>
<th>SoC</th>
<th>attenuation (dB)</th>
<th>suggested range (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>100 ~ 950</td>
</tr>
<tr>
<td>ESP32</td>
<td>2.5</td>
<td>100 ~ 1250</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>150 ~ 1750</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>150 ~ 2450</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0 ~ 750</td>
</tr>
</tbody>
</table>

(continues on next page)
For maximum accuracy, use the ADC calibration APIs and measure voltages within these recommended ranges.

**Note** For any given channel, this function must be called before the first time `adc1_get_raw()` is called for that channel.

**Note** This function can be called multiple times to configure multiple ADC channels simultaneously. You may call `adc1_get_raw()` only after configuring a channel.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `channel`: ADC1 channel to configure
- `atten`: Attenuation level

```c
esp_err_t adc1_config_width(adc_bits_width_t width_bit)
```
Configure ADC1 capture width, meanwhile enable output invert for ADC1. The configuration is for all channels of ADC1.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `width_bit`: Bit capture width for ADC1

```c
int adc1_get_raw(adc1_channel_t channel)
```
Take an ADC1 reading from a single channel.

**Note** ESP32: When the power switch of SARADC1, SARADC2, HALL sensor and AMP sensor is turned on, the input of GPIO36 and GPIO39 will be pulled down for about 80ns. When enabling power for any of these peripherals, ignore input from GPIO36 and GPIO39. Please refer to section 3.11 of ‘ECO_and_Workarounds_for_Bugs_in_ESP32’ for the description of this issue. As a workaround, call `adc_power_acquire()` in the app. This will result in higher power consumption (by ~1mA), but will remove the glitches on GPIO36 and GPIO39.

**Note** Call `adc1_config_width()` before the first time this function is called.

**Note** For any given channel, `adc1_config_channel_atten(channel)` must be called before the first time this function is called. Configuring a new channel does not prevent a previously configured channel from being read.

**Return**
- -1: Parameter error
- Other: ADC1 channel reading.

**Parameters**
- `channel`: ADC1 channel to read

```c
esp_err_t adc_set_data_inv(adc_unit_t adc_unit, bool inv_en)
```
Set ADC data invert.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `adc_unit`: ADC unit index
- `inv_en`: whether enable data invert

```c
esp_err_t adc_set_clk_div(uint8_t clk_div)
```

---

<table>
<thead>
<tr>
<th></th>
<th>2.5</th>
<th>6</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP32-S2</td>
<td>0 ~ 1050</td>
<td>0 ~ 1300</td>
<td>0 ~ 2500</td>
</tr>
</tbody>
</table>
Set ADC source clock.

Return
- ESP_OK success

Parameters
- clk_div: ADC clock divider, ADC clock is divided from APB clock

`esp_err_t adc_set_data_width (adc_unit_t adc_unit, adc_bits_width_t width_bit)` Configure ADC capture width.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- adc_unit: ADC unit index
- width_bit: Bit capture width for ADC unit.

`void adc1_ulp_enable (void)`
Configure ADC1 to be usable by the ULP.

This function reconfigures ADC1 to be controlled by the ULP. Effect of this function can be reverted using adc1_get_raw() function.

Note that adc1_config_channel_atten, adc1_config_width() functions need to be called to configure ADC1 channels, before ADC1 is used by the ULP.

`esp_err_t adc2_pad_get_io_num (adc2_channel_t channel, gpio_num_t *gpio_num)`
Get the GPIO number of a specific ADC2 channel.

Return
- ESP_OK if success
- ESP_ERR_INVALID_ARG if channel not valid

Parameters
- channel: Channel to get the GPIO number
- gpio_num: output buffer to hold the GPIO number

`esp_err_t adc2_config_channel_atten (adc2_channel_t channel, adc_atten_t atten)`
Configure the ADC2 channel, including setting attenuation.

The default ADC voltage is for attenuation 0 dB and listed in the table below. By setting higher attenuation it is possible to read higher voltages.

Due to ADC characteristics, most accurate results are obtained within the “suggested range” shown in the following table.

<table>
<thead>
<tr>
<th>SoC</th>
<th>attenuation (dB)</th>
<th>suggested range (mV)</th>
</tr>
</thead>
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<td></td>
<td>11</td>
<td>150 ~ 2450</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0 ~ 750</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>0 ~ 1050</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0 ~ 1300</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>0 ~ 2500</td>
</tr>
<tr>
<td>ESP32-S2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For maximum accuracy, use the ADC calibration APIs and measure voltages within these recommended ranges.

**Note** This function also configures the input GPIO pin mux to connect it to the ADC2 channel. It must be called before calling `adc2_get_raw()` for this channel.

**Note** For any given channel, this function must be called before the first time `adc2_get_raw()` is called for that channel.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `channel`: ADC2 channel to configure
- `atten`: Attenuation level

```c
esp_err_t adc2_get_raw(adc2_channel_t channel, adc_bits_width_t width_bit, int *raw_out)
```
Take an ADC2 reading on a single channel.

**Note** ESP32: When the power switch of SARADC1, SARADC2, HALL sensor and AMP sensor is turned on, the input of GPIO36 and GPIO39 will be pulled down for about 80ns. When enabling power for any of these peripherals, ignore input from GPIO36 and GPIO39. Please refer to section 3.11 of `ECO_and_Workarounds_for_Bugs_in_ESP32` for the description of this issue. As a workaround, call `adc_power_acquire()` in the app. This will result in higher power consumption (by ~1mA), but will remove the glitches on GPIO36 and GPIO39.

**Note** ESP32: For a given channel, `adc2_config_channel_atten()` must be called before the first time this function is called. If Wi-Fi is started via `esp_wifi_start()`, this function will always fail with ESP_ERR_TIMEOUT.

**Note** ESP32-S2: ADC2 supports hardware arbiter. The arbiter is to improve the usage efficiency of ADC2. After the control right is robbed by the high priority, the low priority controller will read the invalid ADC2 data.

**Default priority**: Wi-Fi > RTC > Digital;

**Return**
- ESP_OK if success
- ESP_ERR_TIMEOUT ADC2 is being used by other controller and the request timed out.
- ESP_ERR_INVALID_STATE The controller status is invalid. Please try again.

**Parameters**
- `channel`: ADC2 channel to read
- `width_bit`: Bit capture width for ADC2
- `raw_out`: the variable to hold the output data.

```c
esp_err_t adc_vref_to_gpio(adc_unit_t adc_unit, gpio_num_t gpio)
```
Output ADC1 or ADC2’s reference voltage to ADC2 channel’s IO.

This function routes the internal reference voltage of ADCn to one of ADC2’s channels. This reference voltage can then be manually measured for calibration purposes.

**Note** ESP32 only supports output of ADC2’s internal reference voltage.

**Return**
- ESP_OK: v_ref successfully routed to selected GPIO
- ESP_ERR_INVALID_ARG: Unsupported GPIO

**Parameters**
- `[in]` `adc_unit`: ADC unit index
- `[in]` `gpio`: GPIO number (Only ADC2’s channels IO are supported)

```c
esp_err_t adc2_vref_to_gpio(gpio_num_t gpio)
```
Output ADC2 reference voltage to ADC2 channel’s IO.

This function routes the internal reference voltage of ADCn to one of ADC2’s channels. This reference voltage can then be manually measured for calibration purposes.

**Return**
- ESP_OK: v_ref successfully routed to selected GPIO
- ESP_ERR_INVALID_ARG: Unsupported GPIO

**Parameters**
- `[in]` `gpio`: GPIO number (ADC2’s channels are supported)
**esp_err_t adc_digi_initialize(const adc_digi_init_config_t *init_config)**

Initialize the Digital ADC.

**Return**

- 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

**Parameters**

- `init_config`: Pointer to Digital ADC initialization config. Refer to `adc_digi_init_config_t`.

**esp_err_t adc_digi_read_bytes(uint8_t *buf, uint32_t length_max, uint32_t *out_length, uint32_t timeout_ms)**

Read bytes from Digital ADC through DMA.

**Return**

- 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

**Parameters**

- `buf`: Buffer to read from ADC.
- `length_max`: Expected length of data read from the ADC.
- `out_length`: Real length of data read from the ADC via this API.
- `timeout_ms`: Time to wait for data via this API, in millisecond.

**esp_err_t adc_digi_start(void)**

Start the Digital ADC and DMA peripherals. After this, the hardware starts working.

**Return**

- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_OK On success

**esp_err_t adc_digi_stop(void)**

Stop the Digital ADC and DMA peripherals. After this, the hardware stops working.

**Return**

- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_OK On success

**esp_err_t adc_digi_deinitialize(void)**

Deinitialize the Digital ADC.

**Return**

- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_OK On success

**esp_err_t adc_digi_controller_configure(const adc_digi_configuration_t *config)**

Setting the digital controller.

**Return**

- ESP_ERR_INVALID_STATE Driver state is invalid.
- ESP_ERR_INVALID_ARG If the combination of arguments is invalid.
- ESP_OK On success

**Parameters**

- `config`: Pointer to digital controller parameter. Refer to `adc_digi_config_t`.

**Structures**

**struct adc_digi_init_config_s**

ADC DMA driver configuration.
Public Members

uint32_t max_store_buf_size
Max length of the converted data that driver can store before they are processed.

uint32_t conv_num_each_intr
Bytes of data that can be converted in 1 interrupt.

uint32_t adc1_chan_mask
Channel list of ADC1 to be initialized.

uint32_t adc2_chan_mask
Channel list of ADC2 to be initialized.

struct adc_digi_configuration_t
ADC digital controller settings.

Public Members

bool conv_limit_en
To limit ADC conversion times. Conversion stops after finishing conv_limit_num times conversion.

uint32_t conv_limit_num
Set the upper limit of the number of ADC conversion triggers. Range: 1 ~ 255.

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. Range: 611Hz ~ 83333Hz Fs = Fd / interval / 2 Fs: sampling frequency; Fd: digital controller frequency, no larger than 5M for better performance interval: interval between 2 measurement trigger signal, the smallest interval should not be smaller than the ADC measurement period, the largest interval should not be larger than 4095

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.

Macros

ADC_ATTEN_0db
ADC rtc controller attenuation option.

Note This definitions are only for being back-compatible

ADC_ATTEN_2_5db
ADC_ATTEN_6db
ADC_ATTEN_11db
ADC_WIDTH_BIT_DEFAULT
The default (max) bit width of the ADC of current version. You can also get the maximum bitwidth by SOC_ADC_MAX_BITWIDTH defined in soc_caps.h.

ADC_WIDTH_9Bit
ADC_WIDTH_10Bit
ADC_WIDTH_11Bit
ADC_WIDTH_12Bit
ADC_MAX_DELAY
Digital ADC DMA read max timeout value, it may make the adc_digi_read_bytes block forever if the OS supports.

Type Definitions
typedef struct adc_digi_init_config_s adc_digi_init_config_t
ADC DMA driver configuration.

Enumerations
enum adc1_channel_t
Values:
ADC1_CHANNEL_0 = 0
ADC1 channel 0 is GPIO1
ADC1_CHANNEL_1
ADC1 channel 1 is GPIO2
ADC1_CHANNEL_2
ADC1 channel 2 is GPIO3
ADC1_CHANNEL_3
ADC1 channel 3 is GPIO4
ADC1_CHANNEL_4
ADC1 channel 4 is GPIO5
ADC1_CHANNEL_5
ADC1 channel 5 is GPIO6
ADC1_CHANNEL_6
ADC1 channel 6 is GPIO7
ADC1_CHANNEL_7
ADC1 channel 7 is GPIO8
ADC1_CHANNEL_8
ADC1 channel 8 is GPIO9
ADC1_CHANNEL_9
ADC1 channel 9 is GPIO10
ADC1_CHANNEL_MAX

enum adc2_channel_t
Values:
ADC2_CHANNEL_0 = 0
ADC2 channel 0 is GPIO4 (ESP32), GPIO11 (ESP32-S2)
ADC2_CHANNEL_1
ADC2 channel 1 is GPIO0 (ESP32), GPIO12 (ESP32-S2)
ADC2_CHANNEL_2
ADC2 channel 2 is GPIO2 (ESP32), GPIO13 (ESP32-S2)
ADC2_CHANNEL_3
ADC2 channel 3 is GPIO15 (ESP32), GPIO14 (ESP32-S2)
ADC2_CHANNEL_4
ADC2 channel 4 is GPIO13 (ESP32), GPIO15 (ESP32-S2)
ADC2_CHANNEL_5
ADC2 channel 5 is GPIO12 (ESP32), GPIO16 (ESP32-S2)
ADC2_CHANNEL_6
ADC2 channel 6 is GPIO14 (ESP32), GPIO17 (ESP32-S2)
ADC2_CHANNEL_7
ADC2 channel 7 is GPIO27 (ESP32), GPIO18 (ESP32-S2)

ADC2_CHANNEL_8
ADC2 channel 8 is GPIO25 (ESP32), GPIO19 (ESP32-S2)

ADC2_CHANNEL_9
ADC2 channel 9 is GPIO26 (ESP32), GPIO20 (ESP32-S2)

ADC2_CHANNEL_MAX

enum adc_i2s_encode_t
ADC digital controller encode option.
Values:

ADC_ENCODE_12BIT
ADC to DMA data format, [15:12]-channel[11:0]-12 bits ADC data

ADC_ENCODE_11BIT
ADC to DMA data format, [15]-unit, [14:11]-channel[10:0]-11 bits ADC data

ADC_ENCODE_MAX

Header File
- components/hal/include/hal/adc_types.h

Structures

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.

Public Members

uint32_t data: 13
ADC real output data info. Resolution: 13 bit.

uint32_t channel: 4
ADC channel index info. If (channel < ADC_CHANNEL_MAX), The data is valid. If (channel > ADC_CHANNEL_MAX), The data is invalid.

uint32_t unit: 1
ADC unit index info. 0: ADC1; 1: ADC2.

uint32_t reserved17_31: 14
Reserved17.
struct adc_digi_output_data_t:

When the configured output format is 12bit. ADC_DIGI_FORMAT_11BIT

uint32_t val
Raw data value

struct adc_arbiter_t
ADC arbiter work mode and priority setting.

Note ESP32-S2: Only ADC2 support arbiter.

Public Members

adc_arbiter_mode_t mode
Refer to adc_arbiter_mode_t. Note: only support ADC2.

uint8_t rtc_pri
RTC controller priority. Range: 0 ~ 2.

uint8_t dig_pri
Digital controller priority. Range: 0 ~ 2.

uint8_t pwdet_pri
Wi-Fi controller priority. Range: 0 ~ 2.

struct adc_digi_filter_t
ADC digital controller (DMA mode) filter configuration.

Note For ESP32-S2, The filter object of the ADC is fixed.
Note For ESP32-S2, The filter object is always all enabled channels.

Public Members

adc_unit_t adc_unit
Set adc unit number for filter. For ESP32-S2, Filter IDX0/IDX1 can only be used to filter all enabled channels of ADC1/ADC2 unit at the same time.

adc_channel_t channel
Set adc channel number for filter. For ESP32-S2, it’s always ADC_CHANNEL_MAX

adc_digi_filter_mode_t mode
Set adc filter mode for filter. See adc_digi_filter_mode_t.

struct adc_digi_monitor_t
ADC digital controller (DMA mode) monitor configuration.

Note For ESP32-S2, The monitor object of the ADC is fixed.
Note For ESP32-S2, The monitor object is always all enabled channels.

Public Members

adc_unit_t adc_unit
Set adc unit number for monitor. For ESP32-S2, monitor IDX0/IDX1 can only be used to monitor all enabled channels of ADC1/ADC2 unit at the same time.

adc_channel_t channel
Set adc channel number for monitor. For ESP32-S2, it’s always ADC_CHANNEL_MAX

adc_digi_monitor_mode_t mode
Set adc monitor mode. See adc_digi_monitor_mode_t.

uint32_t threshold
Set monitor threshold of adc digital controller.
Chapter 2. API Reference

Macros

ADC_ARBITER_CONFIG_DEFAULT ()
ADC arbiter default configuration.

Note ESP32S2: Only ADC2 supports (needs) an arbiter.

Enumerations

enum adc_unit_t
ADC unit enumeration.

Note For ADC digital controller (DMA mode), ESP32 doesn’t support ADC_UNIT_2, ADC_UNIT_BOTH, ADC_UNIT_ALTER.

Values:

ADC_UNIT_1 = 1
SAR ADC 1.
ADC_UNIT_2 = 2
SAR ADC 2.
ADC_UNIT_BOTH = 3
SAR ADC 1 and 2.
ADC_UNIT_ALTER = 7
SAR ADC 1 and 2 alternative mode.
ADC_UNIT_MAX
enum adc_channel_t
ADC channels handle. See adc1_channel_t, adc2_channel_t.

Note For ESP32 ADC1, don’t use ADC_CHANNEL_8, ADC_CHANNEL_9. See adc1_channel_t.

Values:

ADC_CHANNEL_0 = 0
ADC channel
ADC_CHANNEL_1
ADC channel
ADC_CHANNEL_2
ADC channel
ADC_CHANNEL_3
ADC channel
ADC_CHANNEL_4
ADC channel
ADC_CHANNEL_5
ADC channel
ADC_CHANNEL_6
ADC channel
ADC_CHANNEL_7
ADC channel
ADC_CHANNEL_8
ADC channel
ADC_CHANNEL_9
ADC channel
ADC_CHANNEL_MAX
Chapter 2. API Reference

enum adc_atten_t
ADC attenuation parameter. Different parameters determine the range of the ADC. See adc1_config_channel_atten.

Values:

ADC_ATTEN_DB_0 = 0
No input attenuation, ADC can measure up to approx. 800 mV.

ADC_ATTEN_DB_2_5 = 1
The input voltage of ADC will be attenuated extending the range of measurement by about 2.5 dB (1.33 x)

ADC_ATTEN_DB_6 = 2
The input voltage of ADC will be attenuated extending the range of measurement by about 6 dB (2 x)

ADC_ATTEN_DB_11 = 3
The input voltage of ADC will be attenuated extending the range of measurement by about 11 dB (3.55 x)

ADC_ATTEN_MAX

enum adc_bits_width_t
ADC resolution setting option.

Note Only used in single read mode

Values:

ADC_WIDTH_BIT_12 = 3
ADC capture width is 12Bit.

ADC_WIDTH_MAX

enum adc_digi_convert_mode_t
ADC digital controller (DMA mode) work mode.

Values:

ADC_CONV_SINGLE_UNIT_1 = 1
Only use ADC1 for conversion.

ADC_CONV_SINGLE_UNIT_2 = 2
Only use ADC2 for conversion.

ADC_CONV_BOTH_UNIT = 3
Use Both ADC1 and ADC2 for conversion simultaneously.

ADC_CONV_ALTER_UNIT = 7
Use both ADC1 and ADC2 for conversion by turn. e.g. ADC1 -> ADC2 -> ADC1 -> ADC2 ...

ADC_CONV_UNIT_MAX

enum adc_digi_output_format_t
ADC digital controller (DMA mode) output data format option.

Values:

ADC_DIGI_FORMAT_12BIT
ADC to DMA data format, [15:12]-channel, [11: 0]-12 bits ADC data (adc_digi_output_data_t). Note: For single convert mode.

ADC_DIGI_FORMAT_11BIT
ADC to DMA data format, [15]-adc unit, [14:11]-channel, [10: 0]-11 bits ADC data (adc_digi_output_data_t). Note: For multi or alter convert mode.

ADC_DIGI_FORMAT_MAX

ADC_DIGI_OUTPUT_FORMAT_TYPE1
See adc_digi_output_data_t.type1
ADC_DIGI_OUTPUT_FORMAT_TYPE2
See \texttt{adc_digi_output_data_t.type2}

\begin{verbatim}
enum adc_arbiter_mode_t
ADC arbiter work mode option.
\textbf{Note} ESP32-S2: Only ADC2 support arbiter.
\end{verbatim}
\textbf{Values}:

\texttt{ADC_ARB_MODE_SHIELD}
Forceshieldarbiter,Selectthehighestprioritycontrollertowork.

\texttt{ADC_ARB_MODE_FIX}
Fixedpriorityswitchcontrollermode.

\texttt{ADC_ARB_MODE_LOOP}
Loop priority switch controller mode. Each controller has the same priority, and the arbiter will switch
to the next controller after the measurement is completed.

\begin{verbatim}
enum adc_digi_filter_idx_t
ADC digital controller (DMA mode) filter index options.
\textbf{Note} For ESP32-S2, The filter object of the ADC is fixed.
\end{verbatim}
\textbf{Values}:

\texttt{ADC_DIGI_FILTER_IDX0} = 0
The filter index 0. For ESP32-S2, It can only be used to filter all enabled channels of ADC1 unit at the same time.

\texttt{ADC_DIGI_FILTER_IDX1}
The filter index 1. For ESP32-S2, It can only be used to filter all enabled channels of ADC2 unit at the same time.

\texttt{ADC_DIGI_FILTER_IDX_MAX}

\begin{verbatim}
enum adc_digi_filter_mode_t
ADC digital controller (DMA mode) filter type options. Expression: filter_data = (k-1)/k * last_data +
new_data / k.
\end{verbatim}
\textbf{Values}:

\texttt{ADC_DIGI_FILTER_IIR_2} = 0
The filter mode is first-order IIR filter. The coefficient is 2.

\texttt{ADC_DIGI_FILTER_IIR_4}
The filter mode is first-order IIR filter. The coefficient is 4.

\texttt{ADC_DIGI_FILTER_IIR_8}
The filter mode is first-order IIR filter. The coefficient is 8.

\texttt{ADC_DIGI_FILTER_IIR_16}
The filter mode is first-order IIR filter. The coefficient is 16.

\texttt{ADC_DIGI_FILTER_IIR_64}
The filter mode is first-order IIR filter. The coefficient is 64.

\texttt{ADC_DIGI_FILTER_IIR_MAX}

\begin{verbatim}
enum adc_digi_monitor_idx_t
ADC digital controller (DMA mode) monitor index options.
\textbf{Note} For ESP32-S2, The monitor object of the ADC is fixed.
\end{verbatim}
\textbf{Values}:

\texttt{ADC_DIGI_MONITOR_IDX0} = 0
The monitor index 0. For ESP32-S2, It can only be used to monitor all enabled channels of ADC1 unit at the same time.
ADC_DIGI_MONITOR_IDX1
The monitor index 1. For ESP32-S2, it can only be used to monitor all enabled channels of ADC2 unit at the same time.

ADC_DIGI_MONITOR_IDX_MAX

enum adc_digi_monitor_mode_t
Set monitor mode of adc digital controller. MONITOR_HIGH: If ADC_OUT > threshold, Generates monitor interrupt. MONITOR_LOW: If ADC_OUT < threshold, Generates monitor interrupt.

Values:
ADC_DIGI_MONITOR_HIGH = 0
If ADC_OUT > threshold, Generates monitor interrupt.

ADC_DIGI_MONITOR_LOW
If ADC_OUT < threshold, Generates monitor interrupt.

ADC_DIGI_MONITOR_MAX

enum adc_i2s_source_t
ESP32 ADC DMA source selection.

Values:
ADC_I2S_DATA_SRC_IO_SIG = 0
I2S data from GPIO matrix signal

ADC_I2S_DATA_SRC_ADC = 1
I2S data from ADC

ADC_I2S_DATA_SRC_MAX

ADC Calibration

Header File
- components/esp_adc_cal/include/esp_adc_cal.h

Functions

esp_err_t esp_adc_cal_check_efuse(esp_adc_cal_value_t value_type)
Checks if ADC calibration values are burned into eFuse.

This function checks if ADC reference voltage or Two Point values have been burned to the eFuse of the current ESP32

Note in ESP32S2, only ESP_ADC_CAL_VAL_EFUSE_TP is supported. Some old ESP32S2s do not support this, either. In which case you have to calibrate it manually, possibly by performing your own two-point calibration on the chip.

Return
- ESP_OK: The calibration mode is supported in eFuse
- ESP_ERR_NOT_SUPPORTED: Error, eFuse values are not burned
- ESP_ERR_INVALID_ARG: Error, invalid argument (ESP_ADC_CAL_VAL_DEFAULT_VREF)

Parameters
- value_type: Type of calibration value (ESP_ADC_CAL_VAL_EFUSE_VREF or ESP_ADC_CAL_VAL_EFUSE_TP)

esp_adc_cal_value_t esp_adc_cal_characterize(adc_unit_t adc_num, adc_atten_t atten, adc_bits_width_t bit_width, uint32_t default_vref, esp_adc_cal_characteristics_t *chars)

Characterize an ADC at a particular attenuation.

This function will characterize the ADC at a particular attenuation and generate the ADC-Voltage curve in the form of \[ y = \text{coeff}_a \cdot x + \text{coeff}_b \]. Characterization can be based on Two Point values, eFuse Vref, or default Vref and the calibration values will be prioritized in that order.
Note  For ESP32, Two Point values and eFuse Vref calibration can be enabled/disabled using menuconfig. For ESP32s2, only Two Point values calibration and only ADC_WIDTH_BIT_13 is supported. The parameter default_vref is unused.

Return  
- ESP_ADC_CAL_VAL_EFUSE_VREF: eFuse Vref used for characterization
- ESP_ADC_CAL_VAL_EFUSE_TP: Two Point value used for characterization (only in Linear Mode)
- ESP_ADC_CAL_VAL_DEFAULT_VREF: Default Vref used for characterization

Parameters  
- [in] adc_num: ADC to characterize (ADC_UNIT_1 or ADC_UNIT_2)
- [in] atten: Attenuation to characterize
- [in] bit_width: Bit width configuration of ADC
- [in] default_vref: Default ADC reference voltage in mV (Only in ESP32, used if eFuse values is not available)
- [out] chars: Pointer to empty structure used to store ADC characteristics

uint32_t esp_adc_cal_raw_to_voltage(uint32_t adc_reading, const esp_adc_cal_characteristics_t *chars)

Convert an ADC reading to voltage in mV.

This function converts an ADC reading to a voltage in mV based on the ADC’s characteristics.

Note  Characteristics structure must be initialized before this function is called (call esp_adc_cal_characterize())

Return  Voltage in mV

Parameters  
- [in] adc_reading: ADC reading
- [in] chars: Pointer to initialized structure containing ADC characteristics

esp_err_t esp_adc_cal_get_voltage(adc_channel_t channel, const esp_adc_cal_characteristics_t *chars, uint32_t *voltage)

Reads an ADC and converts the reading to a voltage in mV.

This function reads an ADC then converts the raw reading to a voltage in mV based on the characteristics provided. The ADC that is read is also determined by the characteristics.

Note  The Characteristics structure must be initialized before this function is called (call esp_adc_cal_characterize())

Return  
- ESP_OK: ADC read and converted to mV
- ESP_ERR_INVALID_ARG: Error due to invalid arguments
- ESP_ERR_INVALID_STATE: Reading result is invalid. Try to read again.

Parameters  
- [in] channel: ADC Channel to read
- [in] chars: Pointer to initialized ADC characteristics structure
- [out] voltage: Pointer to store converted voltage

Structures  
struct esp_adc_cal_characteristics_t
Structure storing characteristics of an ADC.

Note  Call esp_adc_cal_characterize() to initialize the structure

Public Members  

adc_unit_t adc_num  
ADC number

adc_atten_t atten  
ADC attenuation
**adc_bits_width_t**
ADC bit width

```c
uint32_t coeff_a
```
Gradient of ADC-Voltage curve

```c
uint32_t coeff_b
```
Offset of ADC-Voltage curve

```c
uint32_t vref
```
Vref used by lookup table

```c
const uint32_t* low_curve
```
Pointer to low Vref curve of lookup table (NULL if unused)

```c
const uint32_t* high_curve
```
Pointer to high Vref curve of lookup table (NULL if unused)

```c
uint8_t version
```
ADC Calibration

---

**Enumerations**

```c
def esp_adc_cal_value_t
```
Type of calibration value used in characterization.

**Values:**

- `ESP_ADC_CAL_VAL_EFUSE_VREF = 0`
Characterization based on reference voltage stored in eFuse

- `ESP_ADC_CAL_VAL_EFUSE_TP = 1`
Characterization based on Two Point values stored in eFuse

- `ESP_ADC_CAL_VAL_DEFAULT_VREF = 2`
Characterization based on default reference voltage

- `ESP_ADC_CAL_VAL_EFUSE_TP_FIT = 3`
Characterization based on Two Point values and fitting curve coefficients stored in eFuse

- `ESP_ADC_CAL_VAL_MAX`

- `ESP_ADC_CAL_VAL_NOT_SUPPORTED = ESP_ADC_CAL_VAL_MAX`

---

**GPIO Lookup Macros**

**Header File**

- components/soc/esp32s3/include/soc/adc_channel.h

**Macros**

- ADC1_GPIO1_CHANNEL
- ADC1_CHANNEL_0_GPIO_NUM
- ADC1_GPIO2_CHANNEL
- ADC1_CHANNEL_1_GPIO_NUM
- ADC1_GPIO3_CHANNEL
- ADC1_CHANNEL_2_GPIO_NUM
- ADC1_GPIO4_CHANNEL
- ADC1_CHANNEL_3_GPIO_NUM
- ADC1_GPIO5_CHANNEL
ADC1_CHANNEL_4_GPIO_NUM
ADC1_GPIO6_CHANNEL
ADC1_CHANNEL_5_GPIO_NUM
ADC1_GPIO7_CHANNEL
ADC1_CHANNEL_6_GPIO_NUM
ADC1_GPIO8_CHANNEL
ADC1_CHANNEL_7_GPIO_NUM
ADC1_GPIO9_CHANNEL
ADC1_CHANNEL_8_GPIO_NUM
ADC1_GPIO10_CHANNEL
ADC1_CHANNEL_9_GPIO_NUM
ADC1_GPIO11_CHANNEL
ADC2_GPIO12_CHANNEL
ADC2_CHANNEL_0_GPIO_NUM
ADC2_GPIO13_CHANNEL
ADC2_CHANNEL_1_GPIO_NUM
ADC2_GPIO14_CHANNEL
ADC2_CHANNEL_2_GPIO_NUM
ADC2_GPIO15_CHANNEL
ADC2_CHANNEL_3_GPIO_NUM
ADC2_GPIO16_CHANNEL
ADC2_CHANNEL_4_GPIO_NUM
ADC2_GPIO17_CHANNEL
ADC2_CHANNEL_5_GPIO_NUM
ADC2_GPIO18_CHANNEL
ADC2_CHANNEL_6_GPIO_NUM
ADC2_GPIO19_CHANNEL
ADC2_CHANNEL_7_GPIO_NUM
ADC2_GPIO20_CHANNEL
ADC2_CHANNEL_8_GPIO_NUM
ADC2_CHANNEL_9_GPIO_NUM

### 2.3.2 GPIO & RTC GPIO

**Overview**

The ESP32-S3 chip features 45 physical GPIO pads. Some GPIO pads cannot be used or do not have the corresponding pin on the chip package. For more details, see *ESP32-S3 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX) [PDF]*. Each pad can be used as a general purpose I/O or can be connected to an internal peripheral signal.

The table below provides more information on pin usage, and please note the comments in the table for GPIOs with restrictions.
### GPIO Reference

<table>
<thead>
<tr>
<th>GPIO</th>
<th>Analog Function</th>
<th>RTC_GPIO</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO0</td>
<td>ADC1_CH0</td>
<td>RTC_GPIO0</td>
<td>Strapping pin</td>
</tr>
<tr>
<td>GPIO1</td>
<td>ADC1_CH1</td>
<td>RTC_GPIO1</td>
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<td>GPIO2</td>
<td>ADC1_CH2</td>
<td>RTC_GPIO2</td>
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<td>GPIO20</td>
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<td>RTC_GPIO20</td>
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<tr>
<td>GPIO22</td>
<td>SPI0/1</td>
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<td>GPIO23</td>
<td>SPI0/1</td>
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<td>GPIO26</td>
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<td>GPIO32</td>
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<td>GPIO44</td>
<td>SPI0/1</td>
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<tr>
<td>GPIO45</td>
<td>Strapping pin</td>
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<td>GPIO46</td>
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<td>GPIO47</td>
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</tr>
<tr>
<td>GPIO48</td>
<td>Strapping pin</td>
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</tbody>
</table>

**Note:**

- Strapping pin: GPIO0, GPIO3, GPIO45 and GPIO46 are strapping pins.
- SPI0/1: GPIO26-32 are usually used for SPI flash and PSRAM and not recommended for other uses. When using Octal Flash or Octal PSRAM or both, GPIO33−37 are connected to SPII04～SPII07 and SPIDQS. Therefore on ESP32-S3R8 / ESP32-S3R8V board GPIO33−37 are also not recommended for other uses.
- USB-JTAG: GPIO 19 and 20 are used by USB-JTAG by default. In order to use them as GPIOs, USB-JTAG will be disabled by the drivers.
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
- 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/include/driver/gpio.h

**Functions**

```c
esp_err_t gpio_config(const gpio_config_t *pGPIOConfig)

Configure GPIO's Mode, pull-up, PullDown, IntrType
```

**Return**

- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- pGPIOConfig: Pointer to GPIO configure struct

```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.

**Return** Always return ESP_OK.

**Parameters**

- gpio_num: GPIO number.

```c
esp_err_t gpio_set_intr_type (gpio_num_t gpio_num, gpio_int_type_t intr_type)

GPIO set interrupt trigger type.
```

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**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

```c
esp_err_t gpio_intr_enable (gpio_num_t gpio_num)

Enable GPIO module interrupt signal.
```

**Note** Please do not use the interrupt of GPIO36 and GPIO39 when using ADC or Wi-Fi with sleep mode enabled. Please refer to the comments of adc1_get_raw. Please refer to section 3.11 of ‘ECO_and_ Workarounds_for_Bugs_in_ESP32’ for the description of this issue. As a workaround, call adc_power_acquire() in the app. This will result in higher power consumption (by ~1mA), but will remove the glitches on GPIO36 and GPIO39.

**Return**

- ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number. If you want to enable an interrupt on e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);

```c
esp_err_t gpio_intr_disable(gpio_num_t gpio_num)
```
Disable GPIO module interrupt signal.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number. If you want to disable the interrupt of e.g. GPIO16, gpio_num should be GPIO_NUM_16 (16);

```c
esp_err_t gpio_set_level(gpio_num_t gpio_num, uint32_t level)
```
GPIO set output level.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO number error

**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

```c
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.

**Return**
- 0 the GPIO input level is 0
- 1 the GPIO input level is 1

**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);

```c
esp_err_t gpio_set_direction(gpio_num_t gpio_num, gpio_mode_t mode)
```
GPIO set direction.

Configure GPIO direction, such as output_only, input_only, output_and_input

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error

**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

```c
esp_err_t gpio_set_pull_mode(gpio_num_t gpio_num, gpio_pull_mode_t pull)
```
Configure GPIO pull-up/pull-down resistors.

Only pins that support both input & output have integrated pull-up and pull-down resistors. Input-only GPIOs 34-39 do not.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG : Parameter error

**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.
**esp_err_t gpio_wakeup_enable (gpio_num_t gpio_num, gpio_int_type_t intr_type)**

Enable GPIO wake-up function.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number.
- intr_type: GPIO wake-up type. Only GPIO_INTR_LOW_LEVEL or GPIO_INTR_HIGH_LEVEL can be used.

**esp_err_t gpio_wakeup_disable (gpio_num_t gpio_num)**

Disable GPIO wake-up function.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number

**esp_err_t gpio_isr_register (void (*fn) (void *)) 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.

**Return**
- 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.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number

**esp_err_t gpio_pullup_dis (gpio_num_t gpio_num)**

Disable pull-up on GPIO.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number

**esp_err_t gpio_pulldown_en (gpio_num_t gpio_num)**

Enable pull-down on GPIO.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- gpio_num: GPIO number
Parameters
- gpio_num: GPIO number

`esp_err_t gpio_pulldown_dis (gpio_num_t gpio_num)`

Disable pull-down on GPIO.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- gpio_num: GPIO number

`esp_err_t gpio_install_isr_service (int intr_alloc_flags)`

Install the driver’s GPIO 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.

Return
- 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

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.

`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.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE Wrong state, the ISR service has not been initialized.
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- gpio_num: GPIO number
- isr_handler: ISR handler function for the corresponding GPIO number.
- args: parameter for ISR handler.

`esp_err_t gpio_isr_handler_remove (gpio_num_t gpio_num)`

Remove ISR handler for the corresponding GPIO pin.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE Wrong state, the ISR service has not been initialized.
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- gpio_num: GPIO number

`esp_err_t gpio_set_drive_capability (gpio_num_t gpio_num, gpio_drive_cap_t strength)`

Set GPIO pad drive capability.
Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- **gpio_num**: GPIO number, only support output GPIOs
- **strength**: Drive capability of the pad

```c
esp_err_t gpio_get_drive_capability (gpio_num_t gpio_num, gpio_drive_cap_t *strength)
```

Get GPIO pad drive capability.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- **gpio_num**: GPIO number, only support output GPIOs
- **strength**: Pointer to accept drive capability of the pad

```c
esp_err_t gpio_hold_en (gpio_num_t gpio_num)
```

Enable gpio pad hold function.

The gpio pad hold function works in both input and output modes, but must be output-capable gpios. If pad hold enabled: in output mode: the output level of the pad will be force locked and can not be changed. in input mode: the input value read will not change, regardless the changes of input signal.

The state of digital gpio cannot be held during Deep-sleep, and it will resume the hold function when the chip wakes up from Deep-sleep. If the digital gpio also needs to be held during Deep-sleep, `gpio_deep_sleep_hold_en` should also be called.

Power down or call `gpio_hold_dis` will disable this function.

Return

- ESP_OK Success
- ESP_ERR_NOT_SUPPORTED Not support pad hold function

Parameters

- **gpio_num**: GPIO number, only support output-capable GPIOs

```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 hight level before calling `gpio_hold_dis`.

Return

- ESP_OK Success
- ESP_ERR_NOT_SUPPORTED Not support pad hold function

Parameters

- **gpio_num**: GPIO number, only support output-capable GPIOs

```c
void gpio_deep_sleep_hold_en (void)
```

Enable all digital gpio pad hold function during Deep-sleep.

When the chip is in Deep-sleep mode, all digital gpio will hold the state before sleep, and when the chip is woken up, the status of digital gpio will not be held. Note that the pad hold feature only works when the chip is in Deep-sleep mode, when not in sleep mode, the digital gpio state can be changed even you have called this function.

Power down or call `gpio_hold_dis` will disable this function, otherwise, the digital gpio hold feature works as long as the chip enter Deep-sleep.

```c
void gpio_deep_sleep_hold_dis (void)
```

Disable all digital gpio pad hold function during Deep-sleep.
**Chapter 2. API Reference**

void **gpio_iomux_in**(uint32_t gpio_num, uint32_t signal_idx)

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 pinto 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_force_hold_all(void)

Force hold digital and rtc gpio pad.

**Note** GPIO force hold, whether the chip in sleep mode or wakeup mode.

**esp_err_t** gpio_force_unhold_all(void)

Force unhold digital and rtc gpio pad.

**Note** GPIO force unhold, whether the chip in sleep mode or wakeup mode.

**esp_err_t** gpio_sleep_sel_en(gpio_num_t gpio_num)

Enable SLP_SEL to change GPIO status automatically in lightsleep.

**Return**

- ESP_OK Success

**Parameters**

- **gpio_num**: GPIO number of the pad.

**esp_err_t** gpio_sleep_sel_dis(gpio_num_t gpio_num)

Disable SLP_SEL to change GPIO status automatically in lightsleep.

**Return**

- ESP_OK Success

**Parameters**

- **gpio_num**: GPIO number of the pad.

**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

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG GPIO error

**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

**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.

Only pins that support both input & output have integrated pull-up and pull-down resistors. Input-only GPIOs 34-39 do not.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG : Parameter error

**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.

**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.

**Type Definitions**

```c
typedef intr_handle_t gpio_isr_handle_t
```

**Header File**

• `components/hal/include/hal/gpio_types.h`

**Structures**

```c
struct gpio_config_t  
```
Configuration parameters of GPIO pad for gpio_config function.

**Public Members**

```c
uint64_t pin_bit_mask  
```
GPIO pin: set with bit mask, each bit maps to a GPIO

```c
gpio_mode_t mode  
```
GPIO mode: set input/output mode

```c
gpio_pullup_t pull_up_en  
```
GPIO pull-up

```c
gpio_pulldown_t pull_down_en  
```
GPIO pull-down

```c
gpio_int_type_t intr_type  
```
GPIO interrupt type

**Macros**

`GPIO_SEL_0`  
Pin 0 selected

`GPIO_SEL_1`  
Pin 1 selected

`GPIO_SEL_2`  
Pin 2 selected

`GPIO_SEL_3`  
Pin 3 selected

`GPIO_SEL_4`  
Pin 4 selected

`GPIO_SEL_5`  
Pin 5 selected
GPIO_SEL_6
Pin 6 selected

GPIO_SEL_7
Pin 7 selected

GPIO_SEL_8
Pin 8 selected

GPIO_SEL_9
Pin 9 selected

GPIO_SEL_10
Pin 10 selected

GPIO_SEL_11
Pin 11 selected

GPIO_SEL_12
Pin 12 selected

GPIO_SEL_13
Pin 13 selected

GPIO_SEL_14
Pin 14 selected

GPIO_SEL_15
Pin 15 selected

GPIO_SEL_16
Pin 16 selected

GPIO_SEL_17
Pin 17 selected

GPIO_SEL_18
Pin 18 selected

GPIO_SEL_19
Pin 19 selected

GPIO_SEL_20
Pin 20 selected

GPIO_SEL_21
Pin 21 selected

GPIO_SEL_26
Pin 26 selected

GPIO_SEL_27
Pin 27 selected

GPIO_SEL_28
Pin 28 selected

GPIO_SEL_29
Pin 29 selected

GPIO_SEL_30
Pin 30 selected

GPIO_SEL_31
Pin 31 selected

GPIO_SEL_32
Pin 32 selected
GPIO_SEL_33
  Pin 33 selected
GPIO_SEL_34
  Pin 34 selected
GPIO_SEL_35
  Pin 35 selected
GPIO_SEL_36
  Pin 36 selected
GPIO_SEL_37
  Pin 37 selected
GPIO_SEL_38
  Pin 38 selected
GPIO_SEL_39
  Pin 39 selected
GPIO_SEL_40
  Pin 40 selected
GPIO_SEL_41
  Pin 41 selected
GPIO_SEL_42
  Pin 42 selected
GPIO_SEL_43
  Pin 43 selected
GPIO_SEL_44
  Pin 44 selected
GPIO_SEL_45
  Pin 45 selected
GPIO_SEL_46
  Pin 46 selected
GPIO_SEL_47
  Pin 47 selected
GPIO_SEL_48
  Pin 48 selected
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
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
**Type Definitions**

```c
typedef void (*gpio_isr_t)(void *)
```

**Enumerations**

```c
define gpio_port_t

Values:
- `GPIO_PORT_0` = 0

define gpio_num_t

Values:
- `GPIO_NUM_NC` = -1
  - Use to signal not connected to S/W
- `GPIO_NUM_0` = 0
  - GPIO0, input and output
- `GPIO_NUM_1` = 1
  - GPIO1, input and output
- `GPIO_NUM_2` = 2
  - GPIO2, input and output
- `GPIO_NUM_3` = 3
  - GPIO3, input and output
- `GPIO_NUM_4` = 4
  - GPIO4, input and output
- `GPIO_NUM_5` = 5
  - GPIO5, input and output
- `GPIO_NUM_6` = 6
  - GPIO6, input and output
- `GPIO_NUM_7` = 7
  - GPIO7, input and output
- `GPIO_NUM_8` = 8
  - GPIO8, input and output
- `GPIO_NUM_9` = 9
  - GPIO9, input and output
- `GPIO_NUM_10` = 10
  - GPIO10, input and output
- `GPIO_NUM_11` = 11
  - GPIO11, input and output
- `GPIO_NUM_12` = 12
  - GPIO12, input and output
- `GPIO_NUM_13` = 13
  - GPIO13, input and output
- `GPIO_NUM_14` = 14
  - GPIO14, input and output
- `GPIO_NUM_15` = 15
  - GPIO15, input and output
- `GPIO_NUM_16` = 16
  - GPIO16, input and output
```
GPIO_NUM_17 = 17
GPIO17, input and output

GPIO_NUM_18 = 18
GPIO18, input and output

GPIO_NUM_19 = 19
GPIO19, input and output

GPIO_NUM_20 = 20
GPIO20, input and output

GPIO_NUM_21 = 21
GPIO21, input and output

GPIO_NUM_26 = 26
GPIO26, input and output

GPIO_NUM_27 = 27
GPIO27, input and output

GPIO_NUM_28 = 28
GPIO28, input and output

GPIO_NUM_29 = 29
GPIO29, input and output

GPIO_NUM_30 = 30
GPIO30, input and output

GPIO_NUM_31 = 31
GPIO31, input and output

GPIO_NUM_32 = 32
GPIO32, input and output

GPIO_NUM_33 = 33
GPIO33, input and output

GPIO_NUM_34 = 34
GPIO34, input and output

GPIO_NUM_35 = 35
GPIO35, input and output

GPIO_NUM_36 = 36
GPIO36, input and output

GPIO_NUM_37 = 37
GPIO37, input and output

GPIO_NUM_38 = 38
GPIO38, input and output

GPIO_NUM_39 = 39
GPIO39, input and output

GPIO_NUM_40 = 40
GPIO40, input and output

GPIO_NUM_41 = 41
GPIO41, input and output

GPIO_NUM_42 = 42
GPIO42, input and output

GPIO_NUM_43 = 43
GPIO43, input and output
GPIO_NUM_44 = 44
  GPIO44, input and output

GPIO_NUM_45 = 45
  GPIO45, input and output

GPIO_NUM_46 = 46
  GPIO46, input and output

GPIO_NUM_47 = 47
  GPIO47, input and output

GPIO_NUM_48 = 48
  GPIO48, input and output

GPIO_NUM_MAX

enum gpio_int_type_t
  Values:

  GPIO_INTR_DISABLE = 0
    Disable GPIO interrupt

  GPIO_INTR_POSEDGE = 1
    GPIO interrupt type: rising edge

  GPIO_INTR_NEGEDGE = 2
    GPIO interrupt type: falling edge

  GPIO_INTR_ANYEDGE = 3
    GPIO interrupt type: both rising and falling edge

  GPIO_INTR_LOW_LEVEL = 4
    GPIO interrupt type: input low level trigger

  GPIO_INTR_HIGH_LEVEL = 5
    GPIO interrupt type: input high level trigger

GPIO_INTR_MAX

enum gpio_mode_t
  Values:

  GPIO_MODE_DISABLE = GPIO_MODE_DEF_DISABLE
    GPIO mode: disable input and output

  GPIO_MODE_INPUT = GPIO_MODE_DEF_INPUT
    GPIO mode: input only

  GPIO_MODE_OUTPUT = GPIO_MODE_DEF_OUTPUT
    GPIO mode: output only mode

  GPIO_MODE_OUTPUT_OD = ((GPIO_MODE_DEF_OUTPUT) | (GPIO_MODE_DEF_OD))
    GPIO mode: output only with open-drain mode

  GPIO_MODE_INPUT_OUTPUT_OD = ((GPIO_MODE_DEF_INPUT) | (GPIO_MODE_DEF_OUTPUT) | (GPIO_MODE_DEF_OD))
    GPIO mode: output and input with open-drain mode

  GPIO_MODE_INPUT_OUTPUT = ((GPIO_MODE_DEF_INPUT) | (GPIO_MODE_DEF_OUTPUT))
    GPIO mode: output and input mode

enum gpio_pullup_t
  Values:

  GPIO_PULLUP_DISABLE = 0x0
    Disable GPIO pull-up resistor

  GPIO_PULLUP_ENABLE = 0x1
    Enable GPIO pull-up resistor
enum gpio_pulldown_t
   Values:
   GPIO_PULLDOWN_DISABLE = 0x0
      Disable GPIO pull-down resistor
   GPIO_PULLDOWN_ENABLE = 0x1
      Enable GPIO pull-down resistor

enum gpio_pull_mode_t
   Values:
   GPIO_PULLUP_ONLY
      Pad pull up
   GPIO_PULLDOWN_ONLY
      Pad pull down
   GPIO_PULLUP_PULLDOWN
      Pad pull up + pull down
   GPIO_FLOATING
      Pad floating

enum gpio_drive_cap_t
   Values:
   GPIO_DRIVE_CAP_0 = 0
      Pad drive capability: weak
   GPIO_DRIVE_CAP_1 = 1
      Pad drive capability: stronger
   GPIO_DRIVE_CAP_2 = 2
      Pad drive capability: medium
   GPIO_DRIVE_CAP_DEFAULT = 2
      Pad drive capability: medium
   GPIO_DRIVE_CAP_3 = 3
      Pad drive capability: strongest
   GPIO_DRIVE_CAP_MAX

API Reference - RTC GPIO

Header File
   • components/driver/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.
   Return true if GPIO is valid for RTC GPIO use. false otherwise.
   Parameters
      • gpio_num: GPIO number

int rtc_io_number_get (gpio_num_t gpio_num)
   Get RTC IO index number by gpio number.
   Return >=0: Index of rtcio. -1 : The gpio is not rtcio.
   Parameters
      • gpio_num: GPIO number
Chapter 2. API Reference

```c
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.

Return
• ESP_OK success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)
```

```c
esp_err_t rtc_gpio_deinit (gpio_num_t gpio_num)
Init a GPIO as digital GPIO.

Return
• ESP_OK success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)
```

```c
uint32_t rtc_gpio_get_level (gpio_num_t gpio_num)
Get the RTC IO input level.

Return
• 1 High level
• 0 Low level
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)
```

```c
esp_err_t rtc_gpio_set_level (gpio_num_t gpio_num, uint32_t level)
Set the RTC IO output level.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)
• level: output level
```

```c
esp_err_t rtc_gpio_set_direction (gpio_num_t gpio_num, rtc_gpio_mode_t mode)
RT CGPIO set direction.

Configure RTC GPIO direction, such as output only, input only, output and input.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)
• mode: GPIO direction
```

```c
esp_err_t rtc_gpio_set_direction_in_sleep (gpio_num_t gpio_num, rtc_gpio_mode_t mode)
RT CGPIO 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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)
• mode: GPIO direction
```
```c
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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)

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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)

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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)

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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

Parameters
• gpio_num: GPIO number (e.g. GPIO_NUM_12)

esp_err_t rtc_gpio_set_drive_capability(gpio_num_t gpio_num, gpio_drive_cap_t strength)
Set RTC GPIO pad drive capability.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• gpio_num: GPIO number, only support output GPIOs
• strength: Drive capability of the pad

esp_err_t rtc_gpio_get_drive_capability(gpio_num_t gpio_num, gpio_drive_cap_t *strength)
Get RTC GPIO pad drive capability.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• gpio_num: GPIO number, only support output GPIOs
```
Chapter 2. API Reference

• strength: Pointer to accept drive capability of the pad

**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.

**Return**

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**

• gpio_num: GPIO number (e.g. GPIO_NUM_12)

**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.

**Return**

• ESP_OK Success
• ESP_ERR_INVALID_ARG GPIO is not an RTC IO

**Parameters**

• gpio_num: GPIO number (e.g. GPIO_NUM_12)

**esp_err_t rtc_gpio_isolate(gpio_num_t gpio_num)**

Helper function to disconnect internal circuits from an RTC IO. This function disables input, output, pullup, pulldown, and enables hold feature for an RTC IO. Use this function if an RTC IO needs to be disconnected from internal circuits in deep sleep, to minimize leakage current.

In particular, for ESP32-WROVER module, call rtc_gpio_isolate(GPIO_NUM_12) before entering deep sleep, to reduce deep sleep current.

**Return**

• ESP_OK on success
• ESP_ERR_INVALID_ARG if GPIO is not an RTC IO

**Parameters**

• gpio_num: GPIO number (e.g. GPIO_NUM_12).

**esp_err_t rtc_gpio_force_hold_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 EXf1 wakeup.

**esp_err_t rtc_gpio_force_hold_dis_all(void)**

Disable force hold signal for all RTC IOs.

**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.

**Return**

• 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.

**Parameters**

• gpio_num: GPIO number
• intr_type: Wakeup on high level (GPIO_INTR_HIGH_LEVEL) or low 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.
## 2.3.3 General Purpose Timer (GPTimer)

### Introduction

A general purpose timer is a hardware timer with high resolution and flexible alarm action. The behavior when the internal counter of a timer reaches a specific target value is called 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 time stamp at any time and any places
- Generate period alarms, trigger events periodically
- Generate one-shot alarm, respond in target time

### 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.
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.

Resource Allocation  Different ESP chip might have different number of independent timer groups, and within each group, there could also be several independent timers. Refer to the datasheet to find out how many hardware timers exist (usually described in the “General Purpose Timer” chapter).

From driver’s point of view, a GPTimer instance is represented by gptimer_handle_t. The driver behind will manage all available hardware resources in a pool, so that users don’t need to care about which timer and which group it belongs to.

To install a timer instance, there’s a configuration structure that needs to be given in advance: 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 Power management section.
- direction sets the counting direction of the timer, supported directions are listed in gptimer_count_direction_t, you can only pick one of them.
- resolution_hz sets the resolution of the internal counter. Each count step is equivalent to 1 / resolution_hz seconds.
- Optional 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, you should stop it by gptimer_stop() in advance or make sure it has not started yet by gptimer_start().

Creating a GPTimer Handle with Resolution of 1MHz

```c
#include <gptimer.h>

const gptimer_config_t timer_config = {
    .clk_src = GPTIMER_CLK_SRC_APB,
    .direction = GPTIMER_COUNT_UP,
    .resolution_hz = 1 * 1000 * 1000, // 1MHz, 1 tick = 1us
};

ESP_ERROR_CHECK(gptimer_new_timer(&timer_config, &gptimer));
```

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 hardware timer’s bit-width, 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 anytime.

Some ESP chip might only support a sub-set of the clocks, if an unsupported clock source is specified, you will get a runtime error during timer installation.
**Set Up Alarm Action**  
Most of the use cases of GPTimer 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, one should configure several members of `gptimer_alarm_config_t` based on how he takes use of the alarm event:

- **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, `alarm_count` and `reload_count` can’t be set to the same value when `auto_reload_on_alarm` is true, as keeping reload with a target alarm count is meaningless.
- **reload_count** sets the count value to be reloaded when the alarm event happens. This configuration only takes effect when `auto_reload_on_alarm` is set to true.
- **auto_reload_on_alarm** flag sets whether to enable the auto-reload feature. If enabled, the hardware timer will reload the value of `reload_count` into counter immediately when alarm event happens.

To make the alarm configurations take effect, one 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 crossed this value, the alarm will be triggered immediately.

**Register Event Callbacks**  
After the timer starts up, it can generate specific event (e.g. the “Alarm Event”) dynamically. If you have some function that should be called when event happens, you should hook your function to the interrupt service routine by calling `gptimer_register_event_callbacks()`. All supported event callbacks are listed in the `gptimer_event_callbacks_t`:

- **on_alarm** sets callback function for alarm event. As this function is called within the ISR context, user 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 `gptimer_alarm_cb_t`. One can save his own context to `gptimer_register_event_callbacks()` as well, via the parameter `user_data`. The user data will be directly passed to the callback functions.

**Start and Stop Timer**  
To start a timer means to enable its internal counter, it can only be achieved by calling `gptimer_start()`. The timer can be stopped at any time (even in the interrupt context) by `gptimer_stop()`. One thing should be kept in mind, calling of `gptimer_start()` should have the same times of calling `gptimer_stop()` before you delete the timer, otherwise the driver might be put in an undetermined state. For example, the timer might keep a Power Management lock, which in return increase the power consumption. Also see Power management section.

**Start Timer As a Wall Clock**

```c
ESP_ERROR_CHECK(gptimer_start(gptimer));
// Retrieve timestamp at anytime
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_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;

  // Continue with your code.
}
```

(continues on next page)
// Retrieve 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
// Don't 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
};
ESP_ERROR_CHECK(gptimer_register_event_callbacks(gptimer, &cbs, queue));
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 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_start(gptimer));
**Dynamic Alarm Update**  
Alarm value can be updated dynamically inside the ISR handler callback, by changing the `alarm_value` of `gptimer_alarm_event_data_t`. Then the alarm value will be updated after the callback function returns.

```c
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_data;
  // Retrieve 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;
}
```

**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 period of a GPTimer’s counting step and leading to inaccurate time keeping.

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 GPTimer instance that has selected `GPTIMER_CLK_SRC_APB` as its clock source, the driver will guarantee that the power management lock is acquired when the timer is started by `gptimer_start()`. Likewise, the driver releases the lock when `gptimer_stop()` is called for that timer. This requires that the `gptimer_start()` and `gptimer_stop()` should appear in pairs.

**IRAM Safe**  
By default, the GPTimer 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_GPTIMER_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 linked to PSRAM by accident)

`on_alarm` callback and the functions invoked by itself should also be placed in IRAM, users need to take care of them by themselves.
This will allow the interrupt to run while the cache is disabled but will come at the cost of increased IRAM consumption.

There’s another Kconfig option `CONFIG_GPTIMER_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:

- `gptimer_start()`
- `gptimer_stop()`
- `gptimer_get_raw_count()`
- `gptimer_set_raw_count()`
- `gptimer_set_alarm_action()`

**Thread Safety** The factory function `gptimer_new_timer()` is guaranteed to be thread safe by the driver, which means, user can call it from different RTOS tasks without protection by extra locks. Other functions that take the `gptimer_handle_t` as the first positional parameter, are not thread safe. The lifecycle of the gptimer handle is maintained by the user. So user should avoid calling them concurrently. If it has to, then one should introduce another mutex to prevent the gptimer handle being accessed concurrently.

### Application Examples

Typical use cases of GPTimer are listed in the example: `peripherals/timer_group/gptimer`.

### API Reference

#### Header File

- `components/driver/include/driver/gptimer.h`

#### Functions

**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** Once a timer is created, it is placed in the stopped state and will not start until `gptimer_start()` is called.

**Return**

- 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

**Parameters**

- [in] config: GPTimer configuration
- [out] ret_timer: Returned timer handle

**esp_err_t gptimer_del_timer(gptimer_handle_t timer)**

Delete the GPTimer handle.

**Note** A timer must be in a stop state before it can be deleted.

**Return**

- ESP_OK: Delete GPTimer successfully
- ESP_ERR_INVALID_ARG: Delete GPTimer failed because of invalid argument
- ESP_ERR_INVAL_STATE: Delete GPTimer failed because the timer has not stopped
- ESP_FAIL: Delete GPTimer failed because of other error

**Parameters**

- [in] timer: Timer handle created by `gptimer_new_timer()`
**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** This function is allowed to be executed when Cache is disabled, by enabling CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM

**Return**
- 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

**Parameters**
- [in] timer: Timer handle created by gptimer_new_timer()
- [in] value: Count value to be set

**esp_err_t gptimer_get_raw_count (gptimer_handle_t timer, uint64_t* value)**

Get GPTimer raw count value.

**Note** With the raw count value and the resolution set in the gptimer_config_t, you can convert the count value into seconds.

**Note** This function is allowed to run within ISR context

**Note** This function is allowed to be executed when Cache is disabled, by enabling CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM

**Return**
- 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

**Parameters**
- [in] timer: Timer handle created by gptimer_new_timer()
- [out] value: Returned GPTimer count value

**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** The user registered callbacks are expected to be runnable within ISR context

**Return**
- 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

**Parameters**
- [in] timer: Timer handle created by gptimer_new_timer()
- [in] cbs: Group of callback functions
- [in] user_data: User data, which will be passed to callback functions directly

**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

**Note** This function is allowed to be executed when Cache is disabled, by enabling CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM

**Return**
- 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

**Parameters**
- [in] timer: Timer handle created by gptimer_new_timer()
- [in] config: Alarm configuration, especially, set config to NULL means disabling the alarm function
**Chapter 2. API Reference**

### esp_err_t gptimer_start(gptimer_handle_t timer)

Start GPTimer.

**Note** This function is allowed to run within ISR context

**Note** This function is allowed to be executed when Cache is disabled, by enabling CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM

**Return**
- 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 in stop state
- ESP_FAIL: Start GPTimer failed because of other error

**Parameters**
- `[in]` timer: Timer handle created by gptimer_new_timer()

### esp_err_t gptimer_stop(gptimer_handle_t timer)

Stop GPTimer.

**Note** This function is allowed to run within ISR context

**Note** This function is allowed to be executed when Cache is disabled, by enabling CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM

**Return**
- 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 start state
- ESP_FAIL: Stop GPTimer failed because of other error

**Parameters**
- `[in]` timer: Timer handle created by gptimer_new_timer()

### 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

**struct gptimer_event_callbacks_t**

Group of supported GPTimer callbacks.

**Note** The callbacks are all running under ISR environment

**Public Members**

- `gptimer_alarm_cb_t on_alarm`
  - Timer alarm callback

**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 \((1 / \text{resolution}_hz)\) seconds

uint32_t intr_shared : 1
    Set true, the timer interrupt number can be shared with other peripherals

\textbf{struct gptimer_alarm_config_t}
    General Purpose Timer alarm configuration.

\textbf{Public Members}

uint64_t alarm_count
    Alarm target count value

uint64_t reload_count
    Alarm reload count value, effect only when \text{auto\_reload\_on\_alarm} is set to true

uint32_t auto_reload_on_alarm : 1
    Reload the count value by hardware, immediately at the alarm event

\textbf{Type Definitions}

typedef struct gptimer_t *gptimer_handle_t
    Type of General Purpose Timer handle.

typedef bool (*gptimer_alarm_cb_t)(gptimer_handle_t timer, const gptimer_alarm_event_data_t *edata, void *user_ctx)
    Timer alarm callback prototype.

\textbf{Return}
    Whether a high priority task has been waken up by this function

\textbf{Parameters}

- [in] timer: Timer handle created by \text{gptimer\_new\_timer}()
- [in] edata: Alarm event data, fed by driver
- [in] user_ctx: User data, passed from \text{gptimer\_register\_event\_callbacks}()

\textbf{Header File}

- components/hal/include/hal/timer_types.h

\textbf{Enumerations}

\textbf{enum gptimer_clock_source_t}
    GPTimer clock source.

\textbf{Note}
    The clock source listed here is not supported on all targets

\textbf{Note}
    User should select the clock source based on real requirements:

<table>
<thead>
<tr>
<th>GPTimer clock source</th>
<th>Features</th>
<th>Power Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPTIMER_CLK_SRC_APB</td>
<td>High resolution</td>
<td>ESP_PM_APB_FREQ_MAX lock</td>
</tr>
<tr>
<td>GPTIMER_CLK_SRC_XTAL</td>
<td>Medium resolution, high accuracy</td>
<td>No PM lock</td>
</tr>
</tbody>
</table>

\textbf{Values:}

- GPTIMER_CLK_SRC_APB
    Select APB as the source clock

- GPTIMER_CLK_SRC_XTAL
    Select XTAL as the source clock
Chapter 2. API Reference

2.3.4 Dedicated GPIO

Overview

The dedicated GPIO is designed for CPU interaction with GPIO matrix and IO MUX. Any GPIO that is configured as “dedicated” can be accessed by CPU instructions directly, which makes it easy to achieve a high GPIO flip speed, and simulate serial/parallel interface in a bit-banging way. As toggling a GPIO in this “CPU Dedicated” way costs few overhead, it would be great for cases like performance measurement using an oscilloscope.

Create/Destroy GPIO Bundle

A GPIO bundle is a group of GPIOs, which can be manipulated at the same time in one CPU cycle. The maximal number of GPIOs that a bundle can contain is limited by each CPU. What’s more, the GPIO bundle has a strong relevance to the CPU which it derives from. Any operations on the GPIO bundle should be put inside a task which is running on the same CPU core to the GPIO bundle belongs to. Likewise, only those ISRs who are installed on the same CPU core are allowed to do operations on that GPIO bundle.

Note: Dedicated GPIO is more of a CPU peripheral, so it has a strong relationship with CPU core. It’s highly recommended to install and operate GPIO bundle in a pin-to-core task. For example, if GPIOA is connected to CPU0, and the dedicated GPIO instruction is issued from CPU1, then it’s impossible to control GPIOA.

To install a GPIO bundle, one needs to call dedic_gpio_new_bundle() to allocate the software resources and connect the dedicated channels to user selected GPIOs. Configurations for a GPIO bundle are covered in dedic_gpio_bundle_config_t structure:

- gpio_array: An array that contains GPIO number.
- array_size: Element number of gpio_array.
- flags: Extra flags to control the behavior of GPIO Bundle.
  - in_en and out_en are used to select whether to enable the input and output function (note, they can be enabled together).
  - in_invert and out_invert are used to select whether to invert the GPIO signal.

The following code shows how to install a output only GPIO bundle:

```c
// configure GPIO
const int bundleA_gpios[] = {0, 1};
gpio_config_t io_conf = {
  .mode = GPIO_MODE_OUTPUT,
};
for (int i = 0; i < sizeof(bundleA_gpios) / sizeof(bundleA_gpios[0]); i++) {
  io_conf.pin_bit_mask = 1ULL << bundleA_gpios[i];
  gpio_config(&io_conf);
}
// Create bundleA, output only
dedic_gpio_bundle_handle_t bundleA = NULL;
dedic_gpio_bundle_config_t bundleA_config = {
  .gpio_array = bundleA_gpios,
}
```

(continues on next page)
array_size = sizeof(bundleA_gpios) / sizeof(bundleA_gpios[0]),
.flags = {
    .out_en = 1,
},
};
ESP_ERROR_CHECK(dedic_gpio_new_bundle(&bundleA_config, &bundleA));

To uninstall the GPIO bundle, one needs to call `dedic_gpio_del_bundle()`.

**Note:** `dedic_gpio_new_bundle()` doesn’t cover any GPIO pad configuration (e.g. pull up/down, drive ability, output/input enable), so before installing a dedicated GPIO bundle, you have to configure the GPIO separately using GPIO driver API (e.g. `gpio_config()`). For more information about GPIO driver, please refer to [GPIO API Reference](#).

### GPIO Bundle Operations

<table>
<thead>
<tr>
<th>Operations</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write to GPIOs in the bundle by mask</td>
<td><code>dedic_gpio_bundle_write()</code></td>
</tr>
<tr>
<td>Read the value that input to bundle</td>
<td><code>dedic_gpio_bundle_read_out()</code></td>
</tr>
<tr>
<td>Read the value that output from bundle</td>
<td><code>dedic_gpio_bundle_read_in()</code></td>
</tr>
</tbody>
</table>

**Note:** The functions above just wrap the customized instructions defined for ESP32-S3, for the details of those instructions, please refer to [ESP32-S3 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX)](PDF).

### Manipulate GPIOs by Writing Assembly Code

For advanced users, they can always manipulate the GPIOs by writing assembly code or invoking CPU Low Level APIs. The usual procedure could be:

1. Allocate a GPIO bundle: `dedic_gpio_new_bundle()`
2. Query the mask occupied by that bundle: `dedic_gpio_get_out_mask()` or/and `dedic_gpio_get_in_mask()`
3. Call CPU LL apis (e.g. `cpu_ll_write_dedic_gpio_mask`) or write assembly code with that mask
4. The fastest way of toggling IO is to use the dedicated “set/clear” instructions:

<table>
<thead>
<tr>
<th>CPU Arch</th>
<th>Set bits of GPIO</th>
<th>Clear bits of GPIO</th>
<th>Remarks</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xtensa</td>
<td>set_bit_gpio_out imm[7:0]</td>
<td>clr_bit_gpio_out imm[7:0]</td>
<td>immediate value width depends on the number of dedicated GPIO channels</td>
<td></td>
</tr>
<tr>
<td>RISC-V</td>
<td>csrsei rd, csr, imm[4:0]</td>
<td>csrsei rd, csr, imm[4:0]</td>
<td>can only control the lowest 4 GPIO channels</td>
<td></td>
</tr>
</tbody>
</table>

For details of supported dedicated GPIO instructions, please refer to [ESP32-S3 Technical Reference Manual > IO MUX and GPIO Matrix (GPIO, IO_MUX)](PDF). The supported dedicated CPU instructions are also wrapped inside `soc/cpu_ll.h` as helper inline functions.

**Note:** Writing assembly code in application could make your code hard to port between targets, because those customized instructions are not guaranteed to remain the same format on different targets.
Application Example

Matrix keyboard example based on dedicated GPIO: peripherals/gpio/matrix_keyboard.

API Reference

Header File

- components/driver/include/driver/dedic_gpio.h

Functions

dedicated_gpio_get_out_mask

```c
esp_err_t dedicated_gpio_get_out_mask(dedic_gpio_bundle_handle_t bundle, uint32_t* mask)
```

Get allocated channel mask.

**Return**

- ESP_OK: Get channel mask successfully
- ESP_ERR_INVALID_ARG: Get channel mask failed because of invalid argument
- ESP_FAIL: Get channel mask failed because of other error

**Note** Each bundle should have at least one mask (in or/and out), based on bundle configuration.

**Note** With the returned mask, user can directly invoke LL function like “cpu_pll_write_dedic_gpio_mask” or write assembly code with dedicated GPIO instructions, to get better performance on GPIO manipulation.

**Parameters**

- \[\text{in}\] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”
- \[\text{out}\] mask: Returned mask value for on specific direction (in or out)


dedicated_gpio_get_in_mask

```c
esp_err_t dedicated_gpio_get_in_mask(dedic_gpio_bundle_handle_t bundle, uint32_t* mask)
```

**Parameters**

- \[\text{in}\] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”
- \[\text{out}\] mask: Returned mask value for on specific direction (in or out)


dedicated_gpio_new_bundle

```c
esp_err_t dedicated_gpio_new_bundle(const dedic_gpio_bundle_config_t* config, dedic_gpio_bundle_handle_t* ret_bundle)
```

Create GPIO bundle and return the handle.

**Return**

- ESP_OK: Create GPIO bundle successfully
- ESP_ERR_INVALID_ARG: Create GPIO bundle failed because of invalid argument
- ESP_ERR_NO_MEM: Create GPIO bundle failed because of no capable memory
- ESP_ERR_NOT_FOUND: Create GPIO bundle failed because of no enough continuous dedicated channels
- ESP_FAIL: Create GPIO bundle failed because of other error

**Note** One has to enable at least input or output mode in “config” parameter.

**Parameters**

- \[\text{in}\] config: Configuration of GPIO bundle
- \[\text{out}\] ret_bundle: Returned handle of the new created GPIO bundle


dedicated_gpio_del_bundle

```c
esp_err_t dedicated_gpio_del_bundle(dedic_gpio_bundle_handle_t bundle)
```

Destory GPIO bundle.

**Return**

- ESP_OK: Destory GPIO bundle successfully
- ESP_ERR_INVALID_ARG: Destory GPIO bundle failed because of invalid argument
- ESP_FAIL: Destory GPIO bundle failed because of other error

**Parameters**

- \[\text{in}\] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”


dedicated_gpio_bundle_write

```c
void dedicated_gpio_bundle_write(dedic_gpio_bundle_handle_t bundle, uint32_t mask, uint32_t value)
```

Write value to GPIO bundle.

**Note** The mask is seen from the view of GPIO bundle. For example, bundleA contains [GPIO10, GPIO12, GPIO17], to set GPIO17 individually, the mask should be 0x04.

**Note** For performance reasons, this function doesn’t check the validity of any parameters, and is placed in IRAM.

**Parameters**

- \[\text{in}\] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”
- \[\text{out}\] mask: Mask used to write value
- \[\text{out}\] value: Value to write to GPIO bundle
Chapter 2. API Reference

- [in] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”
- [in] mask: Mask of the GPIOs to be written in the given bundle
- [in] value: Value to write to given GPIO bundle, low bit represents low member in the bundle

```c
uint32_t dedic_gpio_bundle_read_out (dedic_gpio_bundle_handle_t bundle)
```
Read the value that output from the given GPIO bundle.

**Return** Value that output from the GPIO bundle, low bit represents low member in the bundle

**Note** For performance reasons, this function doesn’t check the validity of any parameters, and is placed in IRAM.

**Parameters**
- [in] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”

```c
uint32_t dedic_gpio_bundle_read_in (dedic_gpio_bundle_handle_t bundle)
```
Read the value that input to the given GPIO bundle.

**Return** Value that input to the GPIO bundle, low bit represents low member in the bundle

**Note** For performance reasons, this function doesn’t check the validity of any parameters, and is placed in IRAM.

**Parameters**
- [in] bundle: Handle of GPIO bundle that returned from “dedic_gpio_new_bundle”

---

**Structures**

```c
struct dedic_gpio_bundle_config_t
```
Type of Dedicated GPIO bundle configuration.

**Public Members**

```c
const int *gpio_array
```
Array of GPIO numbers, gpio_array[0] ~ gpio_array[size-1] <=> low_dedic_channel_num ~ high_dedic_channel_num

```c
size_t array_size
```
Number of GPIOs in gpio_array

```c
unsigned int in_en : 1
```
Enable input

```c
unsigned int in_invert : 1
```
Invert input signal

```c
unsigned int out_en : 1
```
Enable output

```c
unsigned int out_invert : 1
```
Invert output signal

```c
struct dedic_gpio_bundle_config_t::[anonymous] flags
```
Flags to control specific behaviour of GPIO bundle

---

**Type Definitions**

```c
typedef struct dedic_gpio_bundle_t *dedic_gpio_bundle_handle_t
```
Type of Dedicated GPIO bundle.

---

### 2.3.5 Hash-based Message Authentication Code (HMAC)

The HMAC (Hash-based Message Authentication Code) module provides hardware acceleration for SHA256-HMAC generation using a key burned into an eFuse block. HMACs work with pre-shared secret keys and provide authenticity and integrity to a message.
Chapter 2. API Reference

For more detailed information on the application workflow and the HMAC calculation process, see ESP32-S3 Technical Reference Manual > HMAC Accelerator (HMAC) [PDF].

**Generalized Application Scheme**

Let there be two parties, A and B. They want to verify the authenticity and integrity of messages sent between each other. Before they can start sending messages, they need to exchange the secret key via a secure channel. To verify A’s messages, B can do the following:

- A calculates the HMAC of the message it wants to send.
- A sends the message and the HMAC to B.
- B calculates HMAC of the received message itself.
- B checks whether the received and calculated HMACs match. If they do match, the message is authentic.

However, the HMAC itself isn’t bound to this use case. It can also be used for challenge-response protocols supporting HMAC or as a key input for further security modules (see below), etc.

**HMAC on the ESP32-S3**

On the ESP32-S3, the HMAC module works with a secret key burnt into the eFuses. This eFuse key can be made completely inaccessible for any resources outside the cryptographic modules, thus avoiding key leakage.

Furthermore, the ESP32-S3 has three different application scenarios for its HMAC module:

1. HMAC is generated for software use
2. HMAC is used as a key for the Digital Signature (DS) module
3. HMAC is used for enabling the soft-disabled JTAG interface

The first mode is also called *Upstream* mode, while the last two modes are also called *Downstream* modes.

**eFuse Keys for HMAC**  Six physical eFuse blocks can be used as keys for the HMAC module: block 4 up to block 9. The enum `hmac_key_id_t` in the API maps them to `HMAC_KEY0 ... HMAC_KEY5`. Each key has a corresponding eFuse parameter `key purpose` determining for which of the three HMAC application scenarios (see below) the key may be used:

<table>
<thead>
<tr>
<th>Key Purpose</th>
<th>Application Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>HMAC generated for software use</td>
</tr>
<tr>
<td>7</td>
<td>HMAC used as a key for the Digital Signature (DS) module</td>
</tr>
<tr>
<td>6</td>
<td>HMAC used for enabling the soft-disabled JTAG interface</td>
</tr>
<tr>
<td>5</td>
<td>HMAC both as a key for the DS module and for enabling JTAG</td>
</tr>
</tbody>
</table>

This is to prevent the usage of a key for a different function than originally intended.

To calculate an HMAC, the software has to provide the ID of the key block containing the secret key as well as the `key purpose` (see ESP32-S3 Technical Reference Manual > eFuse Controller (eFuse) [PDF]). Before the HMAC key calculation, the HMAC module looks up the purpose of the provided key block. The calculation only proceeds if the provided key purpose matches the purpose stored in the eFuses of the key block provided by the ID.

**HMAC Generation for Software**  Key Purpose value: 8

In this case, the HMAC is given out to the software (e.g. to authenticate a message).

The API to calculate the HMAC is `esp_hmac_calculate()`. Only the message, message length and the eFuse key block ID have to be provided to that function. The rest, like setting the key purpose, is done automatically.
**HMAC for Digital Signature**  Key Purpose values: 7, 5

The HMAC can be used as a key derivation function to decrypt private key parameters which are used by the Digital Signature module. A standard message is used by the hardware in that case. The user only needs to provide the eFuse key block and purpose on the HMAC side (additional parameters are required for the Digital Signature component in that case). Neither the key nor the actual HMAC are ever exposed to outside the HMAC module and DS component. The calculation of the HMAC and its hand-over to the DS component happen internally.

For more details, see *ESP32-S3 Technical Reference Manual > Digital Signature (DS)* [PDF].

**HMAC for Enabling JTAG**  Key Purpose values: 6, 5

The third application is using the HMAC as a key to enable JTAG if it was soft-disabled before. Following is the procedure to re-enable the JTAG

**Setup**

1. Generate a 256-bit HMAC secret key to use for JTAG re-enable.
2. Write the key to an eFuse block with key purpose HMAC_DOWN_ALL (5) or HMAC_DOWN_JTAG (6).
   This can be done using the ets_efuse_write_key() function in the firmware or using esfuse.py from the host.
3. Configure the eFuse key block to be read protected using the esp_efuse_set_read_protect(), so that software cannot read back the value.
4. Burn the “soft JTAG disable” bit by esp_efuse_write_field_bit(ESP_EFUSE_SOFT_DIS_JTAG). This will permanently disable JTAG unless the correct key value is provided by software.

**JTAG enable**

1. The key to re-enable JTAG is the output of the HMAC-SHA256 function using the secret key in eFuse and 32 0x00 bytes as the message.
2. Pass this key value when calling the esp_hmac_jtag_enable() function from the firmware.
3. To re-disable JTAG in the firmware, reset the system or call esp_hmac_jtag_disable().

For more details, see *ESP32-S3 Technical Reference Manual > HMAC Accelerator (HMAC)* [PDF].

**Application Outline**

Following code is an outline of how to set an eFuse key and then use it to calculate an HMAC for software usage. We use ets_efuse_write_key to set physical key block 4 in the eFuse for the HMAC module together with its purpose. ETS_EFUSE_KEY_PURPOSE_HMAC_UP (8) means that this key can only be used for HMAC generation for software usage:

```c
#include "esp32s3/rom/efuse.h"

const uint8_t key_data[32] = { ... };

int ets_status = ets_efuse_write_key(ETS_EFUSE_BLOCK_KEY4, ETS_EFUSE_KEY_PURPOSE_HMAC_UP, key_data, sizeof(key_data));

if (ets_status == ESP_OK) {
    // written key
} else {
    // writing key failed, maybe written already
}
```

Now we can use the saved key to calculate an HMAC for software usage.

```c
#include "esp_hmac.h"

uint8_t hmac[32];

const char *message = "Hello, HMAC!";
```

(continues on next page)
const size_t msg_len = 12;

esp_err_t result = esp_hmac_calculate(HMAC_KEY4, message, msg_len, hmac);

if (result == ESP_OK) {
  // HMAC written to hmac now
} else {
  // failure calculating HMAC
}

API Reference

Header File

- components/esp_hw_support/include/soc/esp32s3/esp_hmac.h

Functions

**esp_err_t esp_hmac_calculate(hmac_key_id_t key_id, const void *message, size_t message_len, uint8_t *hmac)**

Calculate the HMAC of a given message.

Calculate the HMAC hmac of a given message message with length message_len. SHA256 is used for the calculation (fixed on ESP32S3).

**Note** Uses the HMAC peripheral in “upstream” mode.

**Return**
- ESP_OK, if the calculation was successful,
- ESP_ERR_INVALID_ARG if message or hmac is a nullptr or if key_id out of range
- ESP_FAIL, if the hmac calculation failed

**Parameters**
- key_id: Determines which of the 6 key blocks in the efuses should be used for the HMAC calculation. The corresponding purpose field of the key block in the efuse must be set to the HMAC upstream purpose value.
- message: the message for which to calculate the HMAC
- message_len: message length
- [out] hmac: the hmac result; the buffer behind the provided pointer must be 32 bytes long

**esp_err_t esp_hmac_jtag_enable(hmac_key_id_t key_id, const uint8_t *token)**

Use HMAC peripheral in Downstream mode to re-enable the JTAG, if it is not permanently disabled by HW. In downstream mode, HMAC calculations performed by peripheral are used internally and not provided back to user.

**Return**
- ESP_OK, if the calculation was successful, if the calculated HMAC value matches with provided token, JTAG will be re-enable otherwise JTAG will remain disabled. Return value does not indicate the JTAG status.
- ESP_FAIL, if the hmac calculation failed or JTAG is permanently disabled by EFUSE_HARD_DIS_JTAG eFuse parameter.
- ESP_ERR_INVALID_ARG, invalid input arguments

**Parameters**
- key_id: Determines which of the 6 key blocks in the efuses should be used for the HMAC calculation. The corresponding purpose field of the key block in the efuse must be set to HMAC downstream purpose.
- token: Pre calculated HMAC value of the 32-byte 0x00 using SHA-256 and the known private HMAC key. The key is already programmed to a eFuse key block. The key block number is provided as the first parameter to this function.

**esp_err_t esp_hmac_jtag_disable(void)**

Disable the JTAG which might be enabled using the HMAC downstream mode. This function just clears the
result generated by calling esp_hmac_jtag_enable() API.

**Return**

- ESP_OK return ESP_OK after writing the HMAC_SET_INVALIDATE_JTAG_REG with value 1.

**Enumerations**

```c
enum hmac_key_id_t
{
    HMAC_KEY0 = 0,
    HMAC_KEY1,
    HMAC_KEY2,
    HMAC_KEY3,
    HMAC_KEY4,
    HMAC_KEY5,
    HMAC_KEY_MAX
};
```

**2.3.6 Digital Signature (DS)**

The Digital Signature (DS) module provides hardware acceleration of signing messages based on RSA. It uses pre-encrypted parameters to calculate a signature. The parameters are encrypted using HMAC as a key-derivation function. In turn, the HMAC uses eFuses as input key. The whole process happens in hardware so that neither the decryption key for the RSA parameters nor the input key for the HMAC key derivation function can be seen by the software while calculating the signature.

For more detailed information on the hardware involved in signature calculation and the registers used, see *ESP32-S3 Technical Reference Manual > Digital Signature (DS)* [PDF].

**Private Key Parameters**

The private key parameters for the RSA signature are stored in flash. To prevent unauthorized access, they are AES-encrypted. The HMAC module is used as a key-derivation function to calculate the AES encryption key for the private key parameters. In turn, the HMAC module uses a key from the eFuses key block which can be read-protected to prevent unauthorized access as well.

Upon signature calculation invocation, the software only specifies which eFuse key to use, the corresponding eFuse key purpose, the location of the encrypted RSA parameters and the message.

**Key Generation**

Both the HMAC key and the RSA private key have to be created and stored before the DS peripheral can be used. This needs to be done in software on the ESP32-S3 or alternatively on a host. For this context, the IDF provides esp_efuse_write_block() to set the HMAC key and esp_hmac_calculate() to encrypt the private RSA key parameters.

You can find instructions on how to calculate and assemble the private key parameters in *ESP32-S3 Technical Reference Manual > Digital Signature (DS)* [PDF].
Signature Calculation with IDF

For more detailed information on the workflow and the registers used, see ESP32-S3 Technical Reference Manual > Digital Signature (DS) [PDF].

Three parameters need to be prepared to calculate the digital signature:

1. the eFuse key block ID which is used as key for the HMAC,
2. the location of the encrypted private key parameters,
3. and the message to be signed.

Since the signature calculation takes some time, there are two possible API versions to use in IDF. The first one is esp_ds_sign() and simply blocks until the calculation is finished. If software needs to do something else during the calculation, esp_ds_start_sign() can be called, followed by periodic calls to esp_ds_is_busy() to check when the calculation has finished. Once the calculation has finished, esp_ds_finish_sign() can be called to get the resulting signature.

The APIs esp_ds_sign() and esp_ds_start_sign() calculate a plain RSA signature with help of the DS peripheral. This signature needs to be converted to appropriate format for further use. For example, MbedTLS SSL stack supports PKCS#1 format. The API esp_ds_rsa_sign() can be used to obtain the signature directly in the PKCS#1 v1.5 format. It internally uses esp_ds_start_sign() and converts the signature into PKCS#1 v1.5 format.

Note: Note that this is only the basic DS building block, the message length is fixed. To create signatures of arbitrary messages, the input is normally a hash of the actual message, padded up to the required length. An API to do this is planned in the future.

Configure the DS peripheral for a TLS connection

The DS peripheral on ESP32-S3 chip must be configured before it can be used for a TLS connection. The configuration involves the following steps -

1. Randomly generate a 256 bit value called the Initialization Vector (IV).
2. Randomly generate a 256 bit value called the HMAC_KEY.
3. Calculate the encrypted private key parameters from the client private key (RSA) and the parameters generated in the above steps.
4. Then burn the 256 bit HMAC_KEY on the efuse, which can only be read by the DS peripheral.

For more details, see ESP32-S3 Technical Reference Manual > Digital Signature (DS) [PDF].

To configure the DS peripheral for development purposes, you can use the python script configure_ds.py. More details about the configure_ds.py script can be found at mqtt example README.

The encrypted private key parameters obtained after the DS peripheral configuration are then to be kept in flash. Furthermore, they are to be passed to the DS peripheral which makes use of those parameters for the Digital Signature operation. Non Volatile Storage can be used to store the encrypted private key parameters in flash. The script configure_ds.py creates an NVS partition for the encrypted private key parameters. Then the script flashes this partition onto the ESP32-S3. The application then needs to read the DS data from NVS, which can be done with the function esp_read_ds_data_from_nvs() in file ssl_ds/main/app_main.c

The process of initializing the DS peripheral and then performing the Digital Signature operation is done internally with help of ESP-TLS. Please refer to Digital Signature with ESP-TLS in ESP-TLS for more details. As mentioned in the ESP-TLS documentation, the application only needs to provide the encrypted private key parameters to the esp_tls context (as ds_data), which internally performs all necessary operations for initializing the DS peripheral and then performing the DS operation.

Example for SSL Mutual Authentication using DS

The example ssl_ds shows how to use the DS peripheral for mutual authentication. The example uses mqtt_client (Implemented through ESP-MQTT) to connect to broker test.mosquitto.org using ssl transport with mutual authenti-
API Reference

Header File

- components/esp_hw_support/include/soc/esp32s3/esp_ds.h

Functions

**esp_err_t esp_ds_sign**(const void *message, const esp_ds_data_t *data, hmac_key_id_t key_id, void **signature)

Sign the message.

This function is a wrapper around esp_ds_finish_sign() and esp_ds_start_sign(), so do not use them in parallel. It blocks until the signing is finished and then returns the signature.

The function calculates a plain RSA signature with help of the DS peripheral. The RSA encryption operation is as follows: \( Z = XY \mod M \) where, \( Z \) is the signature, \( X \) is the input message, \( Y \) and \( M \) are the RSA private key parameters.

**Note** This function locks the HMAC, SHA, AES and RSA components during its entire execution time.

**Return**

- ESP_OK if successful, the signature was written to the parameter signature.
- ESP_ERR_INVALID_ARG if one of the parameters is NULL or data->rsa_length is too long or 0
- ESP_ERR_HW_CRYPTO_DS_HMAC_FAIL if there was an HMAC failure during retrieval of the decryption key
- ESP_ERR_NO_MEM if there hasn’t been enough memory to allocate the context object
- ESP_ERR_HW_CRYPTO_DS_INVALID_KEY if there’s a problem with passing the HMAC key to the DS component
- ESP_ERR_HW_CRYPTO_DS_INVALID_DIGEST if the message digest didn’t match; the signature is invalid.
- ESP_ERR_HW_CRYPTO_DS_INVALID_PADDING if the message padding is incorrect, the signature can be read though since the message digest matches.

**Parameters**

- message: the message to be signed; its length should be (data->rsa_length + 1)*4 bytes
- data: the encrypted signing key data (AES encrypted RSA key + IV)
- key_id: the HMAC key ID determining the HMAC key of the HMAC which will be used to decrypt the signing key data
- signature: the destination of the signature, should be (data->rsa_length + 1)*4 bytes long

**esp_err_t esp_ds_start_sign**(const void *message, const esp_ds_data_t *data, hmac_key_id_t key_id, esp_ds_context_t **esp_ds_ctx)

Start the signing process.

This function yields a context object which needs to be passed to esp_ds_finish_sign() to finish the signing process.

The function calculates a plain RSA signature with help of the DS peripheral. The RSA encryption operation is as follows: \( Z = XY \mod M \) where, \( Z \) is the signature, \( X \) is the input message, \( Y \) and \( M \) are the RSA private key parameters.

**Note** This function locks the HMAC, SHA, AES and RSA components, so the user has to ensure to call esp_ds_finish_sign() in a timely manner.

**Return**

- ESP_OK if successful, the ds operation was started now and has to be finished with esp_ds_finish_sign()
- ESP_ERR_INVALID_ARG if one of the parameters is NULL or data->rsa_length is too long or 0
- ESP_ERR_HW_CRYPTO_DS_HMAC_FAIL if there was an HMAC failure during retrieval of the decryption key
- ESP_ERR_NO_MEM if there hasn’t been enough memory to allocate the context object
- ESP_ERR_HW_CRYPTO_DS_INVALID_KEY if there’s a problem with passing the HMAC key to the DS component
Parameters

- **message**: the message to be signed; its length should be `(data->rsa_length + 1)*4` bytes
- **data**: the encrypted signing key data (AES encrypted RSA key + IV)
- **key_id**: the HMAC key ID determining the HMAC key of the HMAC which will be used to decrypt the signing key data
- **esp_ds_ctx**: the context object which is needed for finishing the signing process later

bool esp_ds_is_busy (void)

Return true if the DS peripheral is busy, otherwise false.

**Note** Only valid if `esp_ds_start_sign()` was called before.

`esp_err_t esp_ds_finish_sign (void *signature, esp_ds_context_t *esp_ds_ctx)`

Finish the signing process.

**Return**

- ESP_OK if successful, the ds operation has been finished and the result is written to `signature`.
- ESP_ERR_INVALID_ARG if one of the parameters is NULL
- ESP_ERR_HW_CRYPTO_DS_INVALID_DIGEST if the message digest didn’t match; the signature is invalid.
- ESP_ERR_HW_CRYPTO_DS_INVALID_PADDING if the message padding is incorrect, the signature can be read though since the message digest matches.

Parameters

- **signature**: the destination of the signature, should be `(data->rsa_length + 1)*4` bytes long
- **esp_ds_ctx**: the context object retrieved by `esp_ds_start_sign()`

`esp_err_t esp_ds_encrypt_params (esp_ds_data_t *data, const void *iv, const esp_ds_p_data_t *p_data, const void *key)`

Encrypt the private key parameters.

**Return**

- ESP_OK if successful, the ds operation has been finished and the result is written to `signature`.
- ESP_ERR_INVALID_ARG if one of the parameters is NULL or `p_data->rsa_length` is too long

Parameters

- **data**: Output buffer to store encrypted data, suitable for later use generating signatures. The allocated memory must be in internal memory and word aligned since it’s filled by DMA. Both is asserted at run time.
- **iv**: Pointer to 16 byte IV buffer, will be copied into ‘data’. Should be randomly generated bytes each time.
- **p_data**: Pointer to input plain text key data. The expectation is this data will be deleted after this process is done and ‘data’ is stored.
- **key**: Pointer to 32 bytes of key data. Type determined by `key_type` parameter. The expectation is the corresponding HMAC key will be stored to efuse and then permanently erased.

Structures

**struct esp_digital_signature_data**

Encrypted private key data. Recommended to store in flash in this format.

**Note** This struct has to match to one from the ROM code! This documentation is mostly taken from there.

Public Members

derived from

**esp_digital_signature_length_t rsa_length**

RSA LENGTH register parameters (number of words in RSA key & operands, minus one).

Max value 127 (for RSA 4096).

This value must match the length field encrypted and stored in ‘c’, or invalid results will be returned. (The DS peripheral will always use the value in ‘c’, not this value, so an attacker can’t alter the DS peripheral results this way, it will just truncate or extend the message and the resulting signature in software.)
Note In IDF, the enum type length is the same as of type unsigned, so they can be used interchangably. See the ROM code for the original declaration of struct ets_ds_data_t.

```c
uint8_t iv[ESP_DS_IV_LEN]
IV value used to encrypt ‘c’

uint8_t[c][ESP_DS_C_LEN]
Encrypted Digital Signature parameters. Result of AES-CBC encryption of plaintext values. Includes an encrypted message digest.
```

```c
struct esp_ds_p_data_t
Plaintext parameters used by Digital Signature.
Not used for signing with DS peripheral, but can be encrypted in-device by calling esp_ds_encrypt_params()

Note This documentation is mostly taken from the ROM code.
```

Public Members

```c
uint32_t Y[(4096)/32]
RSA exponent.

uint32_t M[(4096)/32]
RSA modulus.

uint32_t Rb[(4096)/32]
RSA r inverse operand.

uint32_t M_prime
RSA M prime operand.

```

```c
dsp_digital_signature_length_t length
RSA length.
```

Macros

```c
ESP32S3_ERR_HW_CRYPTO_DS_HMAC_FAIL
HMAC peripheral problem

ESP32S3_ERR_HW_CRYPTO_DS_INVALID_KEY
given HMAC key isn’t correct, HMAC peripheral problem

ESP32S3_ERR_HW_CRYPTO_DS_INVALID_DIGEST
message digest check failed, result is invalid

ESP32S3_ERR_HW_CRYPTO_DS_INVALID_PADDING
padding check failed, but result is produced anyway and can be read

ESP_DS_IV_LEN

ESP_DS_C_LEN
```

Type Definitions

```c
typedef struct esp_ds_context esp_ds_context_t
Encrypted private key data. Recommended to store in flash in this format.

Note This struct has to match to one from the ROM code! This documentation is mostly taken from there.
```

Enumerations

```c
enum esp_digital_signature_length_t
Values:

ESP_DS_RSA_1024 = (1024 / 32) - 1
ESP_DS_RSA_2048 = (2048 / 32) - 1
```

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2.3.7 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-S3 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 - slave or master from `i2c_mode_t`
• Configure communication pins
  – Assign GPIO pins for SDA and SCL signals
  – Set whether to enable ESP32-S3’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
i2c_config_t config;
config.i2c_mode = I2C_MASTER;
config.sda_pin = GPIO_PIN(32);
config.scl_pin = GPIO_PIN(33);
config.sda_pullup = true;
config.scl_pullup = true;
config.clock_speed = 100000;
config.address_mode = I2C_ADDRESS_7BIT;
config.address = 0b1000000;
config.is_master = true;

i2c_param_config(1, &config);
```
```c
int i2c_master_port = 0;
i2c_config_t conf = {
    .mode = I2C_MODE_MASTER,
    .sda_io_num = I2C_MASTER_SDA_IO,       // select GPIO specific to your
    .sda_pullup_en = GPIO_PULLUP_ENABLE,   // select GPIO specific to your
    .scl_io_num = I2C_MASTER_SCL_IO,       // select GPIO specific to your
    .scl_pullup_en = GPIO_PULLUP_ENABLE,   // select GPIO specific to your
    .master.clk_speed = I2C_MASTER_FREQ_HZ, // select frequency specific to your
    // .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 GPIO specific to your
    .sda_pullup_en = GPIO_PULLUP_ENABLE,   // select GPIO specific to your
    .scl_io_num = I2C_SLAVE_SCL_IO,       // select GPIO specific to your
    .scl_pullup_en = GPIO_PULLUP_ENABLE,   // select GPIO specific to your
    .mode = I2C_MODE_SLAVE,
    .slave.addr_10bit_en = 0,
    .slave.addr = ESP_SLAVE_ADDR,        // address of your project
};
```

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>
<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>XTAL clock</td>
<td>40 MHz</td>
<td>2 MHz</td>
<td>/</td>
</tr>
<tr>
<td>RTC clock</td>
<td>20 MHz</td>
<td>1 MHz</td>
<td>I2C_SCLK_SRC_FLAG_AWARE_DFS, I2C_SCLK_SRC_FLAG_LIGHT_SLEEP</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-S3, 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.

### 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-S3 is ready to communicate with other I2C devices.

ESP32-S3’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.

![Fig. 5: I2C command link - master write example](image)

The following describes how a command link for a “master write” is set up and what comes inside:

1. Create a command link with `i2c_cmd_link_create()`.
   Then, populate it with the series of data to be sent to the slave:
   a) **Start bit**: `i2c_master_start()`
b) **Slave address** - `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 `i2c_master_write()`

d) **Stop bit** - `i2c_master_stop()`

Both functions `i2c_master_write_byte()` and `i2c_master_write()` have an additional argument specifying whether the master should ensure that it has received the ACK bit.

2. Trigger the execution of the command link by I2C controller by calling `i2c_master_cmd_begin()`. Once the execution is triggered, the command link cannot be modified.

3. After the commands are transmitted, release the resources used by the command link by calling `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 `i2c_master_write(...)` functions but with `i2c_master_read_byte()` and/or `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 `(ESP_SLAVE_ADDR << 1) | I2C_MASTER_WRITE` and looks as follows:

```
i2c_master_write_byte(cmd, (ESP_SLAVE_ADDR << 1) | I2C_MASTER_WRITE, ACK_EN);
```

Likewise, the command link to read from the slave looks as follows:

```
i2c_master_write_byte(cmd, (ESP_SLAVE_ADDR << 1) | I2C_MASTER_READ, ACK_EN);
```

**Communication as Slave** After installing the I2C driver, ESP32-S3 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. The frequency of APB is specified in `I2C_APB_CLK_FREQ`.

<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.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-S3’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*.

**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.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 master and slave example: `peripherals/i2c`.

**API Reference**

**Header File**

- `components/driver/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** 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 cannot access the psmem (if psmem is enabled) in interrupt handle function when cache is disabled.

  **Return**

  - ESP_OK Success
  - ESP_ERR_INVALID_ARG Parameter error
  - ESP_FAIL Driver installation error

  **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.

- `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.

  **Return**

  - ESP_OK Success
  - ESP_ERR_INVALID_ARG Parameter error

  **Parameters**

  - `i2c_num`: I2C port to delete

- `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.

  **Return**

  - ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- i2c_num: I2C port to configure
- i2c_conf: Pointer to the I2C configuration

```c
esp_err_t i2c_reset_tx_fifo(i2c_port_t i2c_num)
```
reset I2C tx hardware fifo

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- i2c_num: I2C port number

```c
esp_err_t i2c_reset_rx_fifo(i2c_port_t i2c_num)
```
reset I2C rx fifo

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- i2c_num: I2C port number

```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.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**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

```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.

**Return**
- 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.

**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.

```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.

**Return**
- 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.

**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.

```c
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.

**Return**
- 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.

**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.

```c
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 to not 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).

**Return** 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.

**Parameters**
- buffer: Buffer to use for commands allocations
- size: Size in bytes of the buffer

```c
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.

**Return** 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.

Return
- 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

Parameters
- cmd_handle: I2C commands list

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.

Return
- 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

Parameters
- cmd_handle: I2C commands list
- data: Byte to send on the port
- ack_en: Enable ACK signal

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.

Return
- 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

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

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.

Return
- 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

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

`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. This function shall only be called in I2C master mode. Call `i2c_master_cmd_begin()` to send all queued commands.

Return
• 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

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

`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.

Return
• 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

Parameters
• cmd_handle: I2C commands list

`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 APIs are not thread-safe, if you want to use one I2C port in different tasks, you need to take care of the multi-thread issue. This function shall only be called in I2C master mode.

Return
• 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.

Parameters
• i2c_num: I2C port number
• cmd_handle: I2C commands list
• ticks_to_wait: Maximum ticks to wait before issuing a timeout.

`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.

Return
• ESP_FAIL (-1) Parameter error
• Other (>=0) The number of data bytes pushed to the I2C slave buffer.

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.

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.

Return
• ESP_FAIL (-1) Parameter error
• Others (>=0) The number of data bytes read from I2C slave buffer.

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

esp_err_t i2c_set_period (i2c_port_t i2c_num, int high_period, int low_period)
Set I2C master clock period.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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

esp_err_t i2c_get_period (i2c_port_t i2c_num, int *high_period, int *low_period)
Get I2C master clock period.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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

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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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.

esp_err_t i2c_filter_disable (i2c_port_t i2c_num)
Disable filter on I2C bus.
Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2c_num: I2C port number

`esp_err_t i2c_set_start_timing(i2c_port_t i2c_num, int setup_time, int hold_time)`
set I2C master start signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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.

`esp_err_t i2c_get_start_timing(i2c_port_t i2c_num, int *setup_time, int *hold_time)`
get I2C master start signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2c_num: I2C port number
• setup_time: pointer to get setup time
• hold_time: pointer to get hold time

`esp_err_t i2c_set_stop_timing(i2c_port_t i2c_num, int setup_time, int hold_time)`
set I2C master stop signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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.

`esp_err_t i2c_get_stop_timing(i2c_port_t i2c_num, int *setup_time, int *hold_time)`
get I2C master stop signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• i2c_num: I2C port number
• setup_time: pointer to get setup time.
• hold_time: pointer to get hold time.

`esp_err_t i2c_set_data_timing(i2c_port_t i2c_num, int sample_time, int hold_time)`
set I2C data signal timing

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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.
• hold_time: clock number I2C used to hold the data after the falling-edge of SCL, it’s a 10-bit value

```c
esp_err_t i2c_get_data_timing(i2c_port_t i2c_num, int *sample_time, int *hold_time)
```

get I2C data signal timing

Return

• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• i2c_num: I2C port number
• sample_time: pointer to get sample time
• hold_time: pointer to get hold time

```c
esp_err_t i2c_set_timeout(i2c_port_t i2c_num, int timeout)
```

set I2C timeout value

Return

• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• i2c_num: I2C port number
• timeout: timeout value for I2C bus (unit: APB 80Mhz clock cycle)

```c
esp_err_t i2c_get_timeout(i2c_port_t i2c_num, int *timeout)
```

get I2C timeout value

Return

• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• i2c_num: I2C port number
• timeout: pointer to get timeout value

```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

Return

• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• i2c_num: I2C port number
• tx_trans_mode: I2C sending data mode
• rx_trans_mode: I2C receiving data mode

```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

Return

• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

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

Structures

```c
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

### I2C_NUM_MAX
I2C port max

### I2C_NUM_0
I2C port 0

### I2C_NUM_1
I2C port 1

### 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

**Macros**

`I2C_CLK_FREQ_MAX`
Use the highest speed that is available for the clock source picked by clk_flags.

**Type Definitions**

```c
typedef int i2c_port_t
I2C port number, can be I2C_NUM_0 ~ (I2C_NUM_MAX-1).
```

**Enumerations**

```c
def type i2c_mode_t
Values:

I2C_MODE_SLAVE = 0
I2C slave mode

I2C_MODE_MASTER
I2C master mode

I2C_MODE_MAX
```

```c
def type i2c_rw_t
Values:

I2C_MASTER_WRITE = 0
I2C write data

I2C_MASTER_READ
I2C read data
```

```c
def type i2c_trans_mode_t
Values:

I2C_DATA_MODE_MSB_FIRST = 0
I2C data msb first

I2C_DATA_MODE_LSB_FIRST = 1
I2C data lsb first

I2C_DATA_MODE_MAX
```

```c
def type i2c_addr_mode_t
Values:

I2C_ADDR_BIT_7 = 0
I2C 7bit address for slave mode
```
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`I2C_ADDR_BIT_10`
I2C 10bit address for slave mode

`I2C_ADDR_BIT_MAX`

`enum i2c_ack_type_t`
Values:
- `I2C_MASTER_ACK = 0x0`
  I2C ack for each byte read
- `I2C_MASTER_NACK = 0x1`
  I2C nack for each byte read
- `I2C_MASTER_LAST_NACK = 0x2`
  I2C nack for the last byte

`I2C_MASTER_ACK_MAX`

`enum i2c_sclk_t`
I2C clock source, sorting from smallest to largest, place them in order. This can be expanded in the future use.
Values:
- `I2C_SCLK_DEFAULT = 0`
  I2C source clock not selected
- `I2C_SCLK_XTAL`
  I2C source clock from XTAL, 40M
- `I2C_SCLK_RTC`
  I2C source clock from 8M RTC, 8M
- `I2C_SCLK_MAX`

2.3.8 Inter-IC Sound (I2S)

**Overview**

I2S (Inter-IC Sound) is a serial, synchronous communication protocol that is usually used for transmitting audio data between two digital audio devices.

ESP32-S3 contains two I2S peripheral(s). These peripherals can be configured to input and output sample data via the I2S driver.

An I2S bus consists of the following lines:
- Master clock line (operational)
- Bit clock line
- Channel select line
- Serial data line

Each I2S controller has the following features that can be configured using the I2S driver:
- Operation as system master or slave
- Capable of acting as transmitter or receiver
- DMA controller that allows for streaming sample data without requiring the CPU to copy each data sample

Each controller can operate in half-duplex communication mode. Thus, the two controllers can be combined to establish full-duplex communication.

**Functional Overview**

**Installing the Driver** Install the I2S driver by calling the function `i2s_driver_install` and passing the following arguments:
Chapter 2. API Reference

- Port number
- The structure `i2s_config_t` with defined communication parameters
- Event queue size and handle

Once `cpp:func`i2s_driver_install` returns `ESP_OK`, it means I2S has started.

Configuration example:

```c
static const int i2s_num = 0; // i2s port number

i2s_config_t i2s_config = {
    .mode = I2S_MODE_MASTER | I2S_MODE_TX,
    .sample_rate = 44100,
    .bits_per_sample = I2S_BITS_PER_SAMPLE_16BIT,
    .channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT,
    .communication_format = I2S_COMM_FORMAT_STAND_I2S,
    .tx_desc_auto_clear = false,
    .dma_desc_num = 8,
    .dma_frame_num = 64,
    .bits_per_chan = I2S_BITS_PER_SAMPLE_16BIT
};

i2s_driver_install(I2S_NUM, &i2s_config, 0, NULL);
```

**Setting Communication Pins** Once the driver is installed, configure physical GPIO pins to which signals will be routed. For this, call the function `cpp:func`i2s_set_pin` and pass the following arguments to it:

- Port number
- The structure `i2s_pin_config_t` defining the GPIO pin numbers to which the driver should route the MCK, BCK, WS, DATA out, and DATA in signals. If you want to keep a currently allocated pin number for a specific signal, or if this signal is unused, then pass the macro `I2S_PIN_NO_CHANGE`. See the example below.

**Note:** MCK only takes effect in `I2S_MODE_MASTER` mode.

```c
static const i2s_pin_config_t pin_config = {
    .mck_io_num = 0,
    .bck_io_num = 4,
    .ws_io_num = 5,
    .data_out_num = 18,
    .data_in_num = I2S_PIN_NO_CHANGE
};

i2s_set_pin(i2s_num, &pin_config);
```

**Running I2S Communication** To perform a transmission:

- Prepare the data for sending
- Call the function `i2s_write()` and pass the data buffer address and data length to it

The function will write the data to the DMA Tx buffer, and then the data will be transmitted automatically.

```c
i2s_write(I2S_NUM, samples_data, ((bits+8)/16)*SAMPLE_PER_CYCLE*4, &i2s_bytes_write, 100);
```

To retrieve received data, use the function `i2s_read()`. It will retrieve the data from the DMA Rx buffer, once the data is received by the I2S controller.

```c
i2s_read(I2S_NUM, data_recv, ((bits+8)/16)*SAMPLE_PER_CYCLE*4, &i2s_bytes_read, 100);
```
You can temporarily stop the I2S driver by calling the function `i2s_stop()`, which will disable the I2S Tx/Rx units until the function `i2s_start()` is called. If the function `cpp:func`i2s_driver_install` is used, the driver will start up automatically eliminating the need to call `i2s_start()`.

**Deleting the Driver** If the established communication is no longer required, the driver can be removed to free allocated resources by calling `i2s_driver_uninstall()`.

**Application Example**

A code example for the I2S driver can be found in the directory `peripherals/i2s`.

In addition, there is a short configuration examples for the I2S driver.

**I2S configuration** Example for general usage.

```c
#include "driver/i2s.h"

static const int i2s_num = 0; // I2S port number
static const i2s_config_t i2s_config = {
    .mode = I2S_MODE_MASTER | I2S_MODE_TX,
    .sample_rate = 44100,
    .bits_per_sample = I2S_BITS_PER_SAMPLE_16BIT,
    .channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT,
    .communication_format = I2S_COMM_FORMAT_STAND_I2S
    .tx_desc_auto_clear = false,
    .dma_desc_num = 8,
    .dma_frame_num = 64
};

static const i2s_pin_config_t pin_config = {
    .bck_io_num = 4,
    .ws_io_num = 5,
    .data_out_num = 18,
    .data_in_num = I2S_PIN_NO_CHANGE
};
i2s_driver_install(i2s_num, &i2s_config, 0, NULL); // install and start i2s driver
i2s_set_pin(i2s_num, &pin_config);
...
// You can reset parameters by calling 'i2s_set_clk'
/*
 * The low 16 bits are the valid data bits in one chan and the high 16 bits are
 * the total bits in one chan. If high 16 bits is smaller than low 16 bits, it will
 * be set to a same value as low 16 bits.
 */
static const uint32_t bits_cfg = (I2S_BITS_PER_CHAN_32BIT << 16) | I2S_BITS_PER_SAMPLE_16BIT;
i2s_set_clk(i2s_num, 22050, bits_cfg, I2S_CHANNEL_STEREO);
...
i2s_driver_uninstall(i2s_num); // stop & destroy i2s driver
```

I2S on ESP32-S3 support TDM mode, up to 16 channels are available in TDM mode. If you want to use TDM mode, set field `channel_format` of `i2s_config_t` to `I2S_CHANNEL_FMT_MULTIPLE`. Then enable the channels by setting `chan_mask` using masks in `i2s_channel_t`, the number of active channels and total channels will be calculate automatically. Also you can set a particular total channel number for it, but it shouldn’t be smaller than the largest channel you use.
If active channels are discrete, the inactive channels within total channels will be filled by a constant automatically. But if `skip_msk` is enabled, these inactive channels will be skiped.

```c
#include "driver/i2s.h"

static const int i2s_num = 0; // i2s port number

i2s_config_t i2s_config = {
    .mode = I2S_MODE_MASTER | I2S_MODE_TX,
    .sample_rate = 44100,
    .bits_per_sample = I2S_BITS_PER_SAMPLE_16BIT,
    .channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT,
    .communication_format = I2S_COMM_FORMAT_STAND_I2S
    .tx_desc_auto_clear = false,
    .dma_desc_num = 8,
    .dma_frame_num = 64,
    .chan_mask = I2S_TDM_ACTIVE_CH0 | I2S_TDM_ACTIVE_CH2
};

static const i2s_pin_config_t pin_config = {
    .bck_io_num = 4,
    .ws_io_num = 5,
    .data_out_num = 18,
    .data_in_num = I2S_PIN_NO_CHANGE
};

i2s_driver_install(i2s_num, &i2s_config, 0, NULL); //install and start i2s driver
i2s_set_pin(i2s_num, &pin_config);

... /* You can reset parameters by calling 'i2s_set_clk' */
  /* The low 16 bits are the valid data bits in one chan and the high 16 bits are
  * the total bits in one chan. If high 16 bits is smaller than low 16 bits, it will
  * be set to a same value as low 16 bits.
  */

uint32_t bits_cfg = (I2S_BITS_PER_CHAN_32BIT << 16) | I2S_BITS_PER_SAMPLE_16BIT;
i2s_set_clk(i2s_port_t i2s_num, 22050, bits_cfg, I2S_TDM_ACTIVE_CH0 | I2S_TDM_ACTIVE_CH1); // set clock
...

i2s_driver_uninstall(i2s_num); //stop & destroy i2s driver
```

**Application Notes** If you are using a high sample rate like more than 48 kHz or see the data being lost, the following information might help.

Considering different applications have different requirements, `dma_desc_num` and `dma_frame_num` are made public. Here is the detailed explanation to these two fields:

- **`dma_desc_num`**: The total number of descriptors used by I2S DMA to receive/transmit data. A descriptor includes some information such as buffer address, the address of the next descriptor, and the buffer length. Since one descriptor points to one buffer, therefore, `dma_desc_num` can be interpreted as the total number of DMA buffers used to store data from DMA interrupt. Notice that these buffers are internal to `i2s_read()` and descriptors are created automatically inside of the I2S driver. Users only need to set the buffer number while the length is derived from the parameter described below.

- **`dma_frame_num`**: The number of frames for one-time sampling. The frame here means the total data from all the channels in one WS cycle. For example, if two channels in stereo mode (i.e., `channel_format` is set to `I2S_CHANNEL_FMT_RIGHT_LEFT`) are active, and each channel transfers 32 bits (i.e., `bits_per_sample` is set to `I2S_BITS_PER_CHAN_32BIT`), then the total number of bytes of a frame is `channel_format * bits_per_sample = 2 * 32 / 8 = 8` bytes. For example, we assume that the current `dma_frame_num` is 100, then the length of the DMA buffer is `8 * 100 = 800` bytes. Note
that the length of an internal DMA buffer shouldn’t be greater than 4092.

When the data received by DMA reach the size of internal DMA buffer, a receive interrupt is triggered, and an internal message queue will transport this buffer to `i2s_read()`. The main task of `i2s_read()` is to copy the data in the internal DMA buffer into the user given buffer. Since the internal DMA buffer is usually not equal to the user given buffer size, there are two cases:

- If the size of internal DMA buffers is smaller than the user given buffer size, `i2s_read()` will consume several internal DMA buffers to fill up the user given buffer. If the message queue of DMA buffer is not long enough, `i2s_read()` will be blocked on receive message queue until getting enough data. You can estimate the time `i2s_read()` function is blocked by the formula block_time (sec) = (given_buffer_size) / (sample_rate * channel_num * channel_bytes). If we place `i2s_read()` in a while together with other functions we should also consider the time the loop execution is blocked by the other functions before `i2s_read()` is executed again. It is not allowed to exceed the max_wait_time (sec) = ((dma_desc_num - 1) * dma_buffer_size) / (sample_rate), otherwise the internal message queue will overflow and in consequence some data will be lost.

- If the DMA buffer size is greater than the user given buffer size, it means `i2s_read()` would need to be called in a loop several times to take all the data, the max_wait_time may be exceeded, and the message queue overflow is likely to happen. Therefore it is quite risky to use a small user buffer for data receiving.

Here are a couple of tips when the sample rate is high:

1. Increasing `dma_frame_num` can help to reduce the I2S DMA interrupt frequency;
2. Increasing `dma_desc_num` can help to allow a longer max_wait_time to be spent by the other functions in the loop containing `i2s_read();`

   ```c
   while (1) {
      ... // Other operations (e.g. Waiting on a semaphore)
      i2s_read(I2S_NUM, user_given_buffer, user_given_buffer_size, &i2s_bytes_read, 100);
      ... // Other operations (e.g. Sending the data to another thread...
      // Avoid any data processing here.)
   }
   ```

3. Increasing the size of the buffer internal to `i2s_read()` can help to increase the max_wait_time. When you process I2S data (like storing the data to an SD card) in another thread, the time spent in processing thread for one loop should not exceed the max_wait_time otherwise some data will be lost. So if the processing of the received data received is rather slow, please allow `i2s_read()` a big internal buffer for storing the read data;
4. Allocating at least two user given buffers can improve the data receipt efficiency. One buffer can continue to receive data while the other one is under processing. But we have to guarantee the buffer that is going to read data is not under processing in the other thread. We can use a semaphore or another lock to avoid overwriting the data in the buffer while it is still under processing:

   ```c
   uint8_t **user_given_buffers = (uint8_t **)calloc(buffer_num, sizeof(uint8_t *));
   // Don’t forget to check if user_given_buffers is NULL here
   for (int i = 0; i < buffer_num; i++) {
      user_given_buffers[i] = (uint8_t *)calloc(user_given_buffer_size, sizeof(uint8_t *));
      // Don’t forget to check if user_given_buffers[i] is NULL here
   }
   int cnt = 0;
   while (1) {
      ... // Other operations (e.g. Waiting on a semaphore)
      i2s_read(I2S_NUM, user_given_buffer[cnt], user_given_buffer_size, &i2s_bytes_read, 100);
      ... // Other operations (e.g. Sending the data to another thread...
      // Avoid any data processing here.)
      cnt++;
      cnt %= buffer_num;
   }
   ```
5. Increasing the priority of the thread that contains `i2s_read()` can help the data in the message queue to be taken more timely.

To check whether there are data lost, you can offer an event queue handler to the driver during installation:

```c
QueueHandle_t evt_que;
i2s_driver_install(i2s_num, &i2s_config, 10, &evt_que);
```

You will receive `I2S_EVENT_RX_Q_OVF` event when there are data lost.

### API Reference

#### Header File

- components/driver/include/driver/i2s.h

#### Functions

**esp_err_t i2s_set_pin(i2s_port_t i2s_num, const i2s_pin_config_t *pin)**

Set I2S pin number.

Inside the pin configuration structure, set I2S_PIN_NO_CHANGE for any pin where the current configuration should not be changed.

**Note** The I2S peripheral output signals can be connected to multiple GPIO pads. However, the I2S peripheral input signal can only be connected to one GPIO pad.

**Parameters**

- `i2s_num`: I2S port number
- `pin`: I2S Pin structure, or NULL to set 2-channel 8-bit internal DAC pin configuration (GPIO25 & GPIO26)

**Note** if `*pin` is set as NULL, this function will initialize both of the built-in DAC channels by default. if you don’t want this to happen and you want to initialize only one of the DAC channels, you can call `i2s_set_dac_mode` instead.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL IO error

**esp_err_t i2s_set_pdm_rx_down_sample(i2s_port_t i2s_num, i2s_pdm_dsr_t downsampling)**

Set PDM mode down-sample rate In PDM RX mode, there would be 2 rounds of downsampling process in hardware. In the first downsampling process, the sampling number can be 16 or 8. In the second downsampling process, the sampling number is fixed as 8. So the clock frequency in PDM RX mode would be `(fpcm * 64)` or `(fpcm * 128)` accordingly.

**Note** After calling this function, it would call `i2s_set_clk` inside to update the clock frequency. Please call this function after I2S driver has been initialized.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM Out of memory

**Parameters**

- `i2s_num`: I2S port number
- `downsampling`: I2S RX down sample rate for PDM mode.

**esp_err_t i2s_set_pdm_tx_up_sample(i2s_port_t i2s_num, const i2s_pdm_tx_upsample_cfg_t *upsample_cfg)**

Set TX PDM mode up-sample rate.

**Note** If you have set PDM mode while calling ‘`i2s_driver_install`’, default PDM TX upsample parameters have already been set, no need to call this function again if you don’t have to change the default configuration.

**Return**
Chapter 2. API Reference

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM Out of memory

Parameters
- i2s_num: I2S port number
- upsample_cfg: Set I2S PDM upsample rate configuration

```c
esp_err_t i2s_driver_install(i2s_port_t i2s_num, const i2s_config_t *i2s_config, int queue_size, void *i2s_queue)
```

Install and start I2S driver.

This function must be called before any I2S driver read/write operations.

Parameters
- i2s_num: I2S port number
- i2s_config: I2S configurations - see i2s_config_t struct
- queue_size: I2S event queue size/depth.
- i2s_queue: I2S event queue handle, if set NULL, driver will not use an event queue.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM Out of memory
- ESP_ERR_INVALID_STATE Current I2S port is in use

```c
esp_err_t i2s_driver_uninstall(i2s_port_t i2s_num)
```

Uninstall I2S driver.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_INVALID_STATE I2S port has been uninstalled by others (e.g. LCD i80)

Parameters
- i2s_num: I2S port number

```c
esp_err_t i2s_write(i2s_port_t i2s_num, const void *src, size_t size, size_t *bytes_written, TickType_t ticks_to_wait)
```

Write data to I2S DMA transmit buffer.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- i2s_num: I2S port number
- src: Source address to write from
- size: Size of data in bytes
- [out] bytes_written: Number of bytes written, if timeout, the result will be less than the size passed in.
- ticks_to_wait: TX buffer wait timeout in RTOS ticks. If this many ticks pass without space becoming available in the DMA transmit buffer, then the function will return (note that if the data is written to the DMA buffer in pieces, the overall operation may still take longer than this timeout.) Pass portMAX_DELAY for no timeout.

```c
esp_err_t i2s_write_expanded(i2s_port_t i2s_num, const void *src, size_t size_t src_bits, size_t aim_bits, size_t *bytes_written, TickType_t ticks_to_wait)
```

Write data to I2S DMA transmit buffer while expanding the number of bits per sample. For example, expanding 16-bit PCM to 32-bit PCM.

Format of the data in source buffer is determined by the I2S configuration (see i2s_config_t).

Parameters
- i2s_num: I2S port number
- src: Source address to write from
- size: Size of data in bytes
Chapter 2. API Reference

- **src_bits**: Source audio bit
- **aim_bits**: Bit wanted, no more than 32, and must be greater than src_bits
- **[out] bytes_written**: Number of bytes written, if timeout, the result will be less than the size passed in.
- **ticks_to_wait**: TX buffer wait timeout in RTOS ticks. If this many ticks pass without space becoming available in the DMA transmit buffer, then the function will return (note that if the data is written to the DMA buffer in pieces, the overall operation may still take longer than this timeout.) Pass portMAX_DELAY for no timeout.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t i2s_read(i2s_port_t i2s_num, void *dest, size_t size, size_t *bytes_read, TickType_t ticks_to_wait)
```

Read data from I2S DMA receive buffer.

**Note** If the built-in ADC mode is enabled, we should call i2s_adc_enable and i2s_adc_disable around the whole reading process, to prevent the data getting corrupted.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- i2s_num: I2S port number
- dest: Destination address to read into
- size: Size of data in bytes
- [out] bytes_read: Number of bytes read, if timeout, bytes read will be less than the size passed in.
- ticks_to_wait: RX buffer wait timeout in RTOS ticks. If this many ticks pass without bytes becoming available in the DMA receive buffer, then the function will return (note that if data is read from the DMA buffer in pieces, the overall operation may still take longer than this timeout.) Pass portMAX_DELAY for no timeout.

```c
esp_err_t i2s_set_sample_rates(i2s_port_t i2s_num, uint32_t rate)
```

Set sample rate used for I2S RX and TX.

The bit clock rate is determined by the sample rate and i2s_config_t configuration parameters (number of channels, bits_per_sample).

\[
\text{bit\_clock} = \text{rate} \times (\text{number of channels}) \times \text{bits\_per\_sample}
\]

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM Out of memory

**Parameters**

- i2s_num: I2S port number
- rate: I2S sample rate (ex: 8000, 44100…)

```c
esp_err_t i2s_stop(i2s_port_t i2s_num)
```

Stop I2S driver.

There is no need to call i2s_stop() before calling i2s_driver_uninstall().

Disables I2S TX/RX, until i2s_start() is called.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- i2s_num: I2S port number

```c
esp_err_t i2s_start(i2s_port_t i2s_num)
```

Start I2S driver.
It is not necessary to call this function after `i2s_driver_install()` (it is started automatically), however it is necessary to call it after `i2s_stop()`.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `i2s_num`: I2S port number

```c
esp_err_t i2s_zero_dma_buffer (i2s_port_t i2s_num)
```
Zero the contents of the TX DMA buffer.

Pushes zero-byte samples into the TX DMA buffer, until it is full.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `i2s_num`: I2S port number

```c
esp_err_t i2s_pcm_config (i2s_port_t i2s_num, const i2s_pcm_cfg_t *pcm_cfg)
```
Configure I2S a/u-law decompressor or compressor.

**Note**
This function should be called after i2s driver installed. Only take effective when the i2s ‘communication_format’ is set to ‘I2S_COMM_FORMAT_STAND_PCM_SHORT’ or ‘I2S_COMM_FORMAT_STAND_PCM_LONG’.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `i2s_num`: I2S port number
- `pcm_cfg`: including mode selection and a/u-law decompress or compress configuration parameter

```c
esp_err_t i2s_set_clk (i2s_port_t i2s_num, uint32_t rate, uint32_t bits_cfg, i2s_channel_t ch)
```
Set clock & bit width used for I2S RX and TX.

Similar to `i2s_set_sample_rates()`, but also sets bit width.

1. stop i2s;
2. calculate mclk, bck, bck_factor
3. malloc dma buffer;
4. start i2s

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM Out of memory

**Parameters**
- `i2s_num`: I2S port number
- `rate`: I2S sample rate (ex: 8000, 44100…)
- `bits_cfg`: I2S bits configuration the low 16 bits is for data bits per sample in one channel (see ‘i2s_bits_per_sample_t’) the high 16 bits is for total bits in one channel (see ‘i2s_bits_per_chan_t’) high 16bits =0 means same as the bits per sample.
- `ch`: I2S channel, (I2S_CHANNEL_MONO, I2S_CHANNEL_STEREO or specific channel in TDM mode)

```c
float i2s_get_clk (i2s_port_t i2s_num)
```
get clock set on particular port number.

**Return**
- actual clock set by i2s driver

**Parameters**
- `i2s_num`: I2S port number
Structures

struct i2s_pcm_cfg_t
I2S PCM configuration.

Public Members

i2s_pcm_compress_t pcm_type
I2SPCM a/u-law decompress or compress type

struct i2s_pdm_tx_upsample_cfg_t
I2S PDM up-sample rate configuration.

Note TX PDM can only be set to the following two upsampling rate configurations:
1: fp = 960, fs = sample_rate / 100, in this case, Fpdm = 128*48000
2: fp = 960, fs = 480, in this case, Fpdm = 128*Fpcm
= 128*sample_rate If the pdm receiver do not care the pdm serial clock, it’s recommended set Fpdm
= 128*48000. Otherwise, the second configuration should be applied.

Public Members

int sample_rate
I2SPDM sample rate

int fp
I2SPDM TX upsampling paramater. Normally it should be set to 960

int fs
I2SPDM TX upsampling paramater. When it is set to 480, the pdm clock frequency Fpdm = 128 *
sample_rate, when it is set to sample_rate / 100. Fpdm will be fixed to 128*48000

struct i2s_pin_config_t
I2S pin number for i2s_set_pin.

Public Members

int mck_io_num
MCK in out pin. Note that ESP32 supports setting MCK on GPIO0/GPIO1/GPIO3 only

int bck_io_num
BCK in out pin

int ws_io_num
WS in out pin

int data_out_num
DATA out pin

int data_in_num
DATA in pin

struct i2s_driver_config_t
I2S driver configuration parameters.

Public Members

i2s_mode_t mode
I2S work mode

uint32_t sample_rate
I2S sample rate

i2s_bits_per_sample_t bits_per_sample
I2S sample bits in one channel
**i2s_channel_fmt_t**

I2S channel format.

**i2s_comm_format_t**

I2S communication format

**int 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

**int dma_desc_num**

The total number of descriptors used by I2S DMA to receive/transmit data

**int dma_buf_count**

This is an alias to ‘dma_desc_num’ for backward compatibility

**int dma_frame_num**

Number of frames for one-time sampling. The frame here means the total data from all the channels in a WS cycle

**int dma_buf_len**

This is an alias to ‘dma_frame_num’ for backward compatibility

**bool use_apll**

I2S using APPLL as main I2S clock, enable it to get accurate clock

**bool tx_desc_auto_clear**

I2S auto clear tx descriptor if there is underflow condition (helps in avoiding noise in case of data unavailability)

**int fixed_mclk**

I2S using fixed MCLK output. If use_apll = true and fixed_mclk > 0, then the clock output for i2s is fixed and equal to the fixed_mclk value. If fixed_mclk set, mclk_multiple won’t take effect

**i2s_mclk_multiple_t/mclk_multiple**

The multiple of I2S master clock(MCLK) to sample rate

**i2s_bits_per_chan_t/bits_per_chan**

I2S total bits in one channel, only take effect when larger than ‘bits_per_sample’, default ‘0’ means equal to ‘bits_per_sample’

**i2s_channel_t/chan_mask**

I2S active channel bit mask. set value in i2s_channel_t to enable specific channel, the bit map of active channel can not exceed (0x1<<total_chan).

**uint32_t/total_chan**

I2S Total number of channels. If it is smaller than the biggest active channel number, it will be set to this number automatically.

**bool left_align**

Set to enable left alignment

**bool big_edin**

Set to enable big edin

**bool bit_order_msb**

Set to enable msb order

**bool skip_msk**

Set to enable skip mask. If it is enabled, only the data of the enabled channels will be sent, otherwise all data stored in DMA TX buffer will be sent

**struct i2s_event_t**

Event structure used in I2S event queue.
Public Members

i2s_event_type_t type
I2S event type

size_t size
I2S data size for I2S_DATA event

Macros

I2S_PIN_NO_CHANGE
Use in i2s_pin_config_t for pins which should not be changed

I2S_PDM_DEFAULT_UPSAMPLE_CONFIG(rate)
Default I2S PDM Up-Sampling Rate configuration.

Type Definitions

typedef i2s_driver_config_t i2s_config_t
typedef intr_handle_t i2s_isr_handle_t

Enumerations

enum i2s_port_t
I2S port number, the max port number is (I2S_NUM_MAX -1).

Values:

I2S_NUM_0 = 0
I2S port 0

I2S_NUM_1 = 1
I2S port 1

I2S_NUM_MAX
I2S port max

enum i2s_event_type_t
I2S event queue types.

Values:

I2S_EVENT_DMA_ERROR

I2S_EVENT_TX_DONE
I2S DMA finish sent 1 buffer

I2S_EVENT_RX_DONE
I2S DMA finish received 1 buffer

I2S_EVENT_TX_Q_OVF
I2S DMA sent queue overflow

I2S_EVENT_RX_Q_OVF
I2S DMA receive queue overflow

I2S_EVENT_MAX
I2S event max index

Header File

- components/hal/include/hal/i2s_types.h
Enumerations

**enum i2s_bits_per_sample_t**

I2S bit width per sample.

Values:

- **I2S_BITS_PER_SAMPLE_8BIT** = 8
  - data bit-width: 8
- **I2S_BITS_PER_SAMPLE_16BIT** = 16
  - data bit-width: 16
- **I2S_BITS_PER_SAMPLE_24BIT** = 24
  - data bit-width: 24
- **I2S_BITS_PER_SAMPLE_32BIT** = 32
  - data bit-width: 32

**enum i2s_bits_per_chan_t**

I2S bit width per chan.

Values:

- **I2S_BITS_PER_CHAN_DEFAULT** = 0
  - channel bit-width equals to data bit-width
- **I2S_BITS_PER_CHAN_8BIT** = (8)
  - channel bit-width: 8
- **I2S_BITS_PER_CHAN_16BIT** = (16)
  - channel bit-width: 16
- **I2S_BITS_PER_CHAN_24BIT** = (24)
  - channel bit-width: 24
- **I2S_BITS_PER_CHAN_32BIT** = (32)
  - channel bit-width: 32

**enum i2s_channel_t**

I2S channel.

Values:

- **I2S_CHANNEL_MONO** = (0x01 << 31) | 0x03
  - I2S channel (mono), two channel enabled. In this mode, you only need to send one channel data but the fifo will copy same data for another channel automatically, then both channels will transmit same data. The highest bit is for differentiating I2S_CHANNEL_STEREO since they both use two channels
- **I2S_CHANNEL_STEREO** = 0x03
  - I2S channel (stereo), two channel enabled. In this mode, two channels will transmit different data.
- **I2S_TDM_ACTIVE_CH0** = (0x1 << 0)
  - I2S channel 0 enabled
- **I2S_TDM_ACTIVE_CH1** = (0x1 << 1)
  - I2S channel 1 enabled
- **I2S_TDM_ACTIVE_CH2** = (0x1 << 2)
  - I2S channel 2 enabled
- **I2S_TDM_ACTIVE_CH3** = (0x1 << 3)
  - I2S channel 3 enabled
- **I2S_TDM_ACTIVE_CH4** = (0x1 << 4)
  - I2S channel 4 enabled
- **I2S_TDM_ACTIVE_CH5** = (0x1 << 5)
  - I2S channel 5 enabled
I2S_TDM_ACTIVE_CH6 = (0x1 << 6)
I2S channel 6 enabled

I2S_TDM_ACTIVE_CH7 = (0x1 << 7)
I2S channel 7 enabled

I2S_TDM_ACTIVE_CH8 = (0x1 << 8)
I2S channel 8 enabled

I2S_TDM_ACTIVE_CH9 = (0x1 << 9)
I2S channel 9 enabled

I2S_TDM_ACTIVE_CH10 = (0x1 << 10)
I2S channel 10 enabled

I2S_TDM_ACTIVE_CH11 = (0x1 << 11)
I2S channel 11 enabled

I2S_TDM_ACTIVE_CH12 = (0x1 << 12)
I2S channel 12 enabled

I2S_TDM_ACTIVE_CH13 = (0x1 << 13)
I2S channel 13 enabled

I2S_TDM_ACTIVE_CH14 = (0x1 << 14)
I2S channel 14 enabled

I2S_TDM_ACTIVE_CH15 = (0x1 << 15)
I2S channel 15 enabled

enum i2s_comm_format_t
I2S communication standard format.

Values:

I2S_COMM_FORMAT_STAND_I2S = 0x01
I2S communication I2S Philips standard, data launch at second BCK

I2S_COMM_FORMAT_STAND_MSB = 0x02
I2S communication MSB alignment standard, data launch at first BCK

I2S_COMM_FORMAT_STAND_PCM_SHORT = 0x04
PCM Short standard, also known as DSP mode. The period of synchronization signal (WS) is 1 bck cycle.

I2S_COMM_FORMAT_STAND_PCM_LONG = 0x0C
PCM Long standard. The period of synchronization signal (WS) is channel_bit*bck cycles.

I2S_COMM_FORMAT_STAND_MAX
standard max

I2S_COMM_FORMAT_I2S = 0x01
I2S communication format I2S, correspond to I2S_COMM_FORMAT_STAND_I2S

I2S_COMM_FORMAT_I2S_MSB = 0x01
I2S format MSB, (I2S_COMM_FORMAT_I2S \| I2S_COMM_FORMAT_I2S_MSB) correspond to I2S_COMM_FORMAT_STAND_I2S

I2S_COMM_FORMAT_I2S_LSB = 0x02
I2S format LSB, (I2S_COMM_FORMAT_I2S \| I2S_COMM_FORMAT_I2S_LSB) correspond to I2S_COMM_FORMAT_STAND_MSB

I2S_COMM_FORMAT_PCM = 0x04
I2S communication format PCM, correspond to I2S_COMM_FORMAT_STAND_PCM_SHORT

I2S_COMM_FORMAT_PCM_SHORT = 0x04
PCM Short, (I2S_COMM_FORMAT_PCM \| I2S_COMM_FORMAT_PCM_SHORT) correspond to I2S_COMM_FORMAT_STAND_PCM_SHORT
I2S_COMM_FORMAT_PCM_LONG = 0x08

PCM Long, (I2S_COMM_FORMAT_PCM | I2S_COMM_FORMAT_PCM_LONG) correspond to
I2S_COMM_FORMAT_STAND_PCM_LONG

enum i2s_channel_fmt_t
I2S channel format type.

Values:

I2S_CHANNEL_FMT_RIGHT_LEFT
Separated left and right channel

I2S_CHANNEL_FMT_ALL_RIGHT
Load right channel data in both two channels

I2S_CHANNEL_FMT_ALL_LEFT
Load left channel data in both two channels

I2S_CHANNEL_FMT_ONLY_RIGHT
Only load data in right channel (mono mode)

I2S_CHANNEL_FMT_ONLY_LEFT
Only load data in left channel (mono mode)

I2S_CHANNEL_FMT_MULTIPLE
More than two channels are used

enum i2s_mode_t
I2S Mode.

Values:

I2S_MODE_MASTER = (0x1 << 0)
Master mode

I2S_MODE_SLAVE = (0x1 << 1)
Slave mode

I2S_MODE_TX = (0x1 << 2)
TX mode

I2S_MODE_RX = (0x1 << 3)
RX mode

I2S_MODE_PDM = (0x1 << 6)
I2S PDM mode

enum i2s_clock_src_t
I2S source clock.

Values:

I2S_CLK_D2CLK = 0
Clock from PLL_D2_CLK(160M)

enum i2s_mclk_multiple_t
The multiple of mclk to sample rate.

Values:

I2S_MCLK_MULTIPLE_DEFAULT = 0
Default value, mclk = sample_rate * 256

I2S_MCLK_MULTIPLE_128 = 128
mclk = sample_rate * 128

I2S_MCLK_MULTIPLE_256 = 256
mclk = sample_rate * 256
\[ I2S_{\text{MCLK\_MULTIPLE\_384}} = 384 \]
\[ \text{mclk} = \text{sample\_rate} \times 384 \]

**enum i2s_pcm_compress_t**  
A/U-law decompress or compress configuration.

*Values:*

- **I2S_PCM_DISABLE = 0**  
  Disable A/U law decompress or compress
- **I2S_PCM_A_DECOMPRESS**  
  A-law decompress
- **I2S_PCM_A_COMPRESS**  
  A-law compress
- **I2S_PCM_U_DECOMPRESS**  
  U-law decompress
- **I2S_PCM_U_COMPRESS**  
  U-law compress

**enum i2s_pdm_dsr_t**  
I2S PDM RX downsample mode.

*Values:*

- **I2S_PDM_DSR_8S = 0**  
  Downsampling number is 8 for PDM RX mode
- **I2S_PDM_DSR_16S**  
  Downsampling number is 16 for PDM RX mode
- **I2S_PDM_DSR_MAX**

**enum i2s_pdm_sig_scale_t**

*Values:*

- **I2S_PDM_SIG_SCALING_DIV_2 = 0**  
  I2S TX PDM sigmadelta signal scaling: /2
- **I2S_PDM_SIG_SCALING_MUL_1**  
  I2S TX PDM sigmadelta signal scaling: x1
- **I2S_PDM_SIG_SCALING_MUL_2 = 2**  
  I2S TX PDM sigmadelta signal scaling: x2
- **I2S_PDM_SIG_SCALING_MUL_4 = 3**  
  I2S TX PDM sigmadelta signal scaling: x4

## 2.3.9 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 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, the LCD panel allocation functions are mainly grouped into the following categories:
Chapter 2. API Reference

- **RGB LCD panel** - is simply based on a group of specific synchronous signals indicating where to start and stop a frame.
- **Controller based LCD panel** involves multiple steps to get a panel handle, like bus allocation, IO device registration and controller driver install.

After we get the LCD handle, the remaining LCD operations are the same for different LCD interfaces and vendors.

### Application Example

LCD examples are located under: `peripherals/lcd`:

- Jpeg decoding and LCD display - `peripherals/lcd/tjpgd`
- i80 controller based LCD and LVGL animation UI - `peripherals/lcd/i80_controller`
- GC9A01 user customized driver and dash board UI - `peripherals/lcd/gc9a01`
- RGB panel example with scatter chart UI - `peripherals/lcd/rgb_panel`
- I2C interfaced OLED display scrolling text - `peripherals/lcd/i2c_oled`

### API Reference

#### Header File

- `components/hal/include/hal/lcd_types.h`

#### Enumerations

**enum lcd_clock_source_t**

LCD clock source.

<table>
<thead>
<tr>
<th>LCD clock source</th>
<th>Features</th>
<th>Power Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCD_CLK_SRC_PLL160M</td>
<td>High resolution</td>
<td>ESP_PM_APB_FREQ_MAX lock</td>
</tr>
<tr>
<td>LCD_CLK_SRC_PLL240M</td>
<td>High resolution</td>
<td>ESP_PM_APB_FREQ_MAX lock</td>
</tr>
<tr>
<td>LCD_CLK_SRC_APLL</td>
<td>Configurable resolution</td>
<td>ESP_PM_NO_LIGHT_SLEEP lock</td>
</tr>
<tr>
<td>LCD_CLK_SRC_XTAL</td>
<td>Medium resolution</td>
<td>No PM lock</td>
</tr>
</tbody>
</table>

**Values**:

- **LCD_CLK_SRC_PLL160M**
  Select PLL160M as the source clock
- **LCD_CLK_SRC_PLL240M**
  Select PLL240M as the source clock
- **LCD_CLK_SRC_APLL**
  Select APLL as the source clock
- **LCD_CLK_SRC_XTAL**
  Select XTAL as the source clock

#### Header File

- `components/esp_lcd/include/esp_lcd_types.h`

#### Type Definitions

```c
typedef struct esp_lcd_panel_io_t *esp_lcd_panel_io_handle_t
Type of LCD panel IO handle
```

```c
typedef struct esp_lcd_panel_t *esp_lcd_panel_handle_t
Type of LCD panel handle
```
Chapter 2. API Reference

Enumerations

```c
enum esp_lcd_color_space_t

   {ESP_LCD_COLOR_SPACE_RGB,  // Color space: RGB
    ESP_LCD_COLOR_SPACE_BGR,  // Color space: BGR
    ESP_LCD_COLOR_SPACE_MONOCHROME // Color space: monochrome
   };
```

Header File

- `components/esp_lcd/include/esp_lcd_panel_io.h`

Functions

```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).

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**

- [in] `io`: LCD panel IO handle, which is created by other factory API like `esp_lcd_new_panel_io_spi()`
- [in] `lcd_cmd`: The specific LCD command
- [in] `param`: Buffer that holds the command specific parameters, set to NULL if no parameter is needed for the command
- [in] `param_size`: Size of `param` in memory, in bytes, set to zero if no parameter is needed for the command

```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()`.

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**

- [in] `io`: LCD panel IO handle, which is created by factory API like `esp_lcd_new_panel_io_spi()`
- [in] `lcd_cmd`: The specific LCD command
- [in] `color`: Buffer that holds the RGB color data
- [in] `color_size`: Size of `color` in memory, in bytes

```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)

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_OK on success

Parameters
• [in] io: LCD panel IO handle, which is created by factory API like esp_lcd_new_panel_io_spi()

\[
\text{esp_err_t esp_lcd_new_panel_io_spi}(\text{esp_lcd_spi_bus_handle_t \ bus, const esp_lcd_panel_io_spi_config_t \ *io_config, esp_lcd_panel_io_handle_t \ *ret_io})
\]

Create LCD panel IO handle, for SPI interface.

Return
• ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_ERR_NO_MEM if out of memory
• ESP_OK on success

Parameters
• [in] bus: SPI bus handle
• [in] io_config: IO configuration, for SPI interface
• [out] ret_io: Returned IO handle

\[
\text{esp_err_t esp_lcd_new_panel_io_i2c}(\text{esp_lcd_i2c_bus_handle_t \ bus, const esp_lcd_panel_io_i2c_config_t \ *io_config, esp_lcd_panel_io_handle_t \ *ret_io})
\]

Create LCD panel IO handle, for I2C interface.

Return
• ESP_ERR_INVALID_ARG if parameter is invalid
• ESP_ERR_NO_MEM if out of memory
• ESP_OK on success

Parameters
• [in] bus: I2C bus handle
• [in] io_config: IO configuration, for I2C interface
• [out] ret_io: Returned IO handle

\[
\text{esp_err_t esp_lcd_new_i80_bus}(\text{const esp_lcd_i80_bus_config_t \ *bus_config, esp_lcd_i80_bus_handle_t \ *ret_bus})
\]

Create Intel 8080 bus handle.

Return
• 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

Parameters
• [in] bus_config: Bus configuration
• [out] ret_bus: Returned bus handle

\[
\text{esp_err_t esp_lcd_del_i80_bus}(\text{esp_lcd_i80_bus_handle_t \ bus})
\]

Destory Intel 8080 bus handle.

Return
• 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

Parameters
• [in] bus: Intel 8080 bus handle, created by esp_lcd_new_i80_bus()

\[
\text{esp_err_t esp_lcd_new_panel_io_i80}(\text{esp_lcd_i80_bus_handle_t \ bus, const esp_lcd_panel_io_i80_config_t \ *io_config, esp_lcd_panel_io_handle_t \ *ret_io})
\]

Create LCD panel IO, for Intel 8080 interface.

Return
• 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

Parameters
• [in] bus: Intel 8080 bus handle, created by esp_lcd_new_i80_bus()
• [in] io_config: IO configuration, for i80 interface
• [out] ret_io: Returned panel IO handle

Structures
struct esp_lcd_panel_io_event_data_t
Type of LCD panel IO event data.
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 not controlled by manually pulling high/low GPIO
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

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

int lcd_cmd_bits
  Bit-width of LCD command
int lcd_param_bits
  Bit-width of LCD parameter
unsigned int dc_as_cmd_phase : 1
  D/C line value is encoded into SPI transaction command phase
unsigned int dc_low_on_data : 1
  If this flag is enabled, DC line = 0 means transfer data, DC line = 1 means transfer command; vice versa
unsigned int octal_mode : 1
  Transmit with octal mode (8 data lines), this mode is used to simulate Intel 8080 timing

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

int lcd_cmd_bits
Bit-width of LCD command

int lcd_param_bits
Bit-width of LCD parameter

unsigned int dc_low_on_data : 1
If this flag is enabled, DC line = 0 means transfer data, DC line = 1 means transfer command; vice versa

struct esp_lcd_panel_io_color_trans_done_cb_t
Callback invoked when color data was transferred done

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[(16)]
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_i80_bus_config_t
LCD Intel 8080 bus configuration structure.

Public Members

int cs_gpio_num
GPIO used for CS line, set to -1 will declaim exclusively use of I80 bus

unsigned int 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 : 1
    Level of DC line in IDLE phase

unsigned int dc_cmd_level : 1
    Level of DC line in CMD phase

unsigned int dc_dummy_level : 1
    Level of DC line in DUMMY phase

unsigned int dc_data_level : 1
    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 : 1
    If set, a high level of CS line will select the device, otherwise, CS line is low level active

unsigned int reverse_color_bits : 1
    Reverse the data bits, D[N:0] -> D[0:N]

unsigned int swap_color_bytes : 1
    Swap adjacent two color bytes

unsigned int pclk_active_neg : 1
    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 : 1
    The WR signal (a.k.a the PCLK) stays at low level in IDLE phase

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)

Declare the prototype of the function that will be invoked when panel IO finishes transferring color data.

Return Whether a high priority task has been waken up by this function

Parameters

• [in] panel_io: LCD panel IO handle, which is created by factory API like esp_lcd_new_panel_io_spi()
• [in] edata: Panel IO event data, fed by driver
• [in] user_ctx: User data, passed from esp_lcd_panel_io_xxx_config_t

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()`.

Return
- **ESP_OK** on success

Parameters
- **[in]** `panel`: LCD panel handle, which is created by other factory API like `esp_lcd_new_panel_st7789()`.

**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()`.

Return
- **ESP_OK** on success

Parameters
- **[in]** `panel`: LCD panel handle, which is created by other factory API like `esp_lcd_new_panel_st7789()`.

**esp_err_t esp_lcd_panel_del (esp_lcd_panel_handle_t panel)**
Deinitialize the LCD panel.

Return
- **ESP_OK** on success

Parameters
- **[in]** `panel`: LCD panel handle, which is created by other factory API like `esp_lcd_new_panel_st7789()`.

**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.

Return
- **ESP_OK** on success

Parameters
- **[in]** `panel`: LCD panel handle, which is created by other factory API like `esp_lcd_new_panel_st7789()`.
- **[in]** `x_start`: Start index on x-axis (x_start included)
- **[in]** `y_start`: Start index on y-axis (y_start included)
- **[in]** `x_end`: End index on x-axis (x_end not included)
- **[in]** `y_end`: End index on y-axis (y_end not included)
- **[in]** `color_data`: RGB color data that will be dumped to the specific window range.

**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.

Return
- **ESP_OK** on success
- **ESP_ERR_NOT_SUPPORTED** if this function is not supported by the panel

Parameters
- **[in]** `panel`: LCD panel handle, which is created by other factory API like `esp_lcd_new_panel_st7789()`.
- **[in]** `mirror_x`: Whether the panel will be mirrored about the x axis
- **[in]** `mirror_y`: Whether the panel will be mirrored about the y axis

**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.

Return
- **ESP_OK** on success
- **ESP_ERR_NOT_SUPPORTED** if this function is not supported by the panel

Parameters
- **[in]** `panel`: LCD panel handle, which is created by other factory API like `esp_lcd_new_panel_st7789()`.
- **[in]** `swap_axes`: Whether the panel will be swapped x and y axis.
• ESP_OK on success
• ESP_ERR_NOT_SUPPORTED if this function is not supported by the panel

**Parameters**
- [in] panel: LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- [in] swap_axes: Whether to swap the x and y axis

```
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.

**Return**
- ESP_OK on success

**Parameters**
- [in] panel: LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- [in] x_gap: Extra gap on x axis, in pixels
- [in] y_gap: Extra gap on y axis, in pixels

```
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)

**Return**
- ESP_OK on success

**Parameters**
- [in] panel: LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- [in] invert_color_data: Whether to invert the color data

```
esp_err_t esp_lcd_panel_disp_off(esp_lcd_panel_handle_t panel, bool off)
```

Turn off the display.

**Return**
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if this function is not supported by the panel

**Parameters**
- [in] panel: LCD panel handle, which is created by other factory API like esp_lcd_new_panel_st7789()
- [in] off: Whether to turn off the screen

**Header File**
- components/esp_lcd/include/esp_lcd_panel_rgb.h

**Functions**

```
esp_err_t esp_lcd_new_rgb_panel(const esp_lcd_rgb_panel_config_t *rgb_panel_config, esp_lcd_panel_handle_t *ret_panel)
```

Create RGB LCD panel.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_NO_MEM if out of memory
- ESP_ERR_NOT_FOUND if no free RGB panel is available
- ESP_OK on success

**Parameters**
- rgb_panel_config: RGB panel configuration
- ret_panel: Returned LCD panel handle
Structures

```c
struct esp_lcd_rgb_timing_t
```

LCD RGB timing structure.

Diagram of the timing structure.
Public Members

unsigned int \texttt{pclk\_hz}
Frequency of pixel clock

unsigned int \texttt{h\_res}
Horizontal resolution, i.e. the number of pixels in a line

unsigned int \texttt{v\_res}
Vertical resolution, i.e. the number of lines in the frame

unsigned int \texttt{hsync\_pulse\_width}
Horizontal sync width, unit: PCLK period

unsigned int \texttt{hsync\_back\_porch}
Horizontal back porch, number of PCLK between hsync and start of line active data

unsigned int \texttt{hsync\_front\_porch}
Horizontal front porch, number of PCLK between the end of active data and the next hsync

unsigned int \texttt{vsync\_pulse\_width}
Vertical sync width, unit: number of lines

unsigned int \texttt{vsync\_back\_porch}
Vertical back porch, number of invalid lines between vsync and start of frame

unsigned int \texttt{vsync\_front\_porch}
Vertical front porch, number of invalid lines between then end of frame and the next vsync

unsigned int \texttt{hsync\_idle\_low} : 1
The hsync signal is low in IDLE state

unsigned int \texttt{vsync\_idle\_low} : 1
The vsync signal is low in IDLE state

unsigned int \texttt{de\_idle\_high} : 1
The de signal is high in IDLE state

unsigned int \texttt{pclk\_active\_neg} : 1
Whether the display data is clocked out at the falling edge of PCLK

unsigned int \texttt{pclk\_idle\_high} : 1
The PCLK stays at high level in IDLE phase

\textbf{struct esp\_lcd\_rgb\_panel\_event\_data\_t}
Type of RGB LCD panel event data.

\textbf{struct esp\_lcd\_rgb\_panel\_config\_t}
LCD RGB panel configuration structure.

Public Members

\texttt{lcd\_clock\_source\_t clk\_src}
Clock source for the RGB LCD peripheral

\texttt{esp\_lcd\_rgb\_timing\_t timings}
RGB timing parameters

\texttt{size\_t data\_width}
Number of data lines

\texttt{size\_t sram\_trans\_align}
Alignment for framebuffer that allocated in SRAM

\texttt{size\_t psram\_trans\_align}
Alignment for framebuffer that allocated in PSRAM
int hsync_gpio_num
   GPIO used for HSYNC signal

int vsync_gpio_num
   GPIO used for VSYNC signal

int de_gpio_num
   GPIO used for DE signal, set to -1 if it’s not used

int pclk_gpio_num
   GPIO used for PCLK signal

int data_gpio_nums[(16)]
   GPIOs used for data lines

int disp_gpio_num
   GPIO used for display control signal, set to -1 if it’s not used

esp_lcd_rgb_panel_frame_trans_done_cb_t on_frame_trans_done
   Callback invoked when one frame buffer has transferred done

void *user_ctx
   User data which would be passed to on_frame_trans_done’s user_ctx

unsigned int disp_active_low : 1
   If this flag is enabled, a low level of display control signal can turn the screen on; vice versa

unsigned int relax_on_idle : 1
   If this flag is enabled, the host won’t refresh the LCD if nothing changed in host’s frame buffer (this is useful for LCD with built-in GRAM)

unsigned int fb_in_psram : 1
   If this flag is enabled, the frame buffer will be allocated from PSRAM preferentially

Type Definitions

typedef bool (*esp_lcd_rgb_panel_frame_trans_done_cb_t)(esp_lcd_panel_handle_t panel, esp_lcd_rgb_panel_event_data_t *edata, void *user_ctx)

Declare the prototype of the function that will be invoked when panel IO finishes transferring color data.

Return
   Whether a high priority task has been waken up by this function

Parameters
   • [in] panel: LCD panel handle, returned from esp_lcd_new_rgb_panel
   • [in] edata: Panel event data, fed by driver
   • [in] user_ctx: User data, passed from esp_lcd_rgb_panel_config_t

Header File

   • components/esp_lcd/include/esp_lcd_panel_vendor.h

Functions

esp_err_t esp_lcd_new_panel_st7789(const esp_lcd_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.

Return
   • ESP_ERR_INVALID_ARG if parameter is invalid
   • ESP_ERR_NO_MEM if out of memory
   • ESP_OK on success

Parameters
   • [in] io: LCD panel IO handle
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- [in] panel_dev_config: general panel device configuration
- [out] ret_panel: Returned LCD panel handle

```c
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.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_NO_MEM if out of memory
- ESP_OK on success

**Parameters**
- [in] io: LCD panel IO handle
- [in] panel_dev_config: general panel device configuration
- [out] ret_panel: Returned LCD panel handle

```c
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.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_NO_MEM if out of memory
- ESP_OK on success

**Parameters**
- [in] io: LCD panel IO handle
- [in] panel_dev_config: general panel device configuration
- [out] ret_panel: Returned LCD panel handle

**Structures**

```c
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

```c
esp_lcd_color_space_t color_space
```

Set the color space used by the LCD panel

- unsigned int bits_per_pixel
  - Color depth, in bpp

- unsigned int reset_active_high : 1
  - Setting this if the panel reset is high level active

2.3.10 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.

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 is done in three steps. Note that unlike ESP32, ESP32-S3 only supports configuring channels in “low speed” mode.

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.

![Fig. 7: Key Settings of LED PWM Controller’s API](image)

**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 (value must be `LEDC_LOW_SPEED_MODE`)
- Timer number `ledc_timer_t`
- PWM signal frequency
- Resolution of PWM duty
- Source clock `ledc_clk_config_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>
<thead>
<tr>
<th>Clock name</th>
<th>Clock freq</th>
<th>Clock capabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>APB_CLK</td>
<td>80 MHz</td>
<td>/</td>
</tr>
<tr>
<td>RTC20M_CLK</td>
<td>~20 MHz</td>
<td>Dynamic Frequency Scaling compatible, Light sleep compatible</td>
</tr>
<tr>
<td>XTAL_CLK</td>
<td>40 MHz</td>
<td>Dynamic Frequency Scaling compatible</td>
</tr>
</tbody>
</table>
Chapter 2. API Reference

**Note:** For ESP32-S3, all timers share one clock source. In other words, it is impossible to use different clock sources for different timers.

**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()`. 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 are 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.

**Note:** All the timers and channels in the ESP32-S3’s LED PWM Controller only support low speed mode. Any change of PWM settings must be explicitly triggered by software (see below).

**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 $(2^{*duty\_resolution}) - 1$. 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 or is stopped. `ledc_fade_stop()` has to be called to stop a fade that is in progress.

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.

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()`.

**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-S3 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--
    reducing 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--
    increasing 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.
Chapter 2. API Reference

Application Example

The LEDC change duty cycle and fading control example: peripherals/ledc/ledc_fade.
The LEDC basic example: peripherals/ledc/ledc_basic.

API Reference

Header File

- components/driver/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.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `ledc_conf`: Pointer of LEDC channel configure struct

`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.

Return

- 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.

Parameters

- `timer_conf`: Pointer of LEDC timer configure struct

`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

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

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

`esp_err_t ledc_set_pin(int gpio_num, ledc_mode_t speed_mode, ledc_channel_t ledc_channel)`

Set LEDC output gpio.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

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
**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.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**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.

**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)

**Return**
- 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.

**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

**uint32_t ledc_get_freq (ledc_mode_t speed_mode, ledc_timer_t timer_num)**

LEDC get channel frequency (Hz)

**Return**
- 0 error
- Others Current LEDC frequency

**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

**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.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**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)

**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.

**Return**
- LEDC_ERR_VAL if parameter error
- Others Current hpoint value of LEDC channel

**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

```c
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.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**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 \([0, (2^{**duty_resolution}) - 1]\)

```c
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.

**Return**
- LEDC_ERR_DUTY if parameter error
- Others Current LEDC duty

**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 \([0, (2^{**duty_resolution}) - 1]\)

```c
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 ledc_update_duty function, the function can take effect.

**Note** For ESP32, hardware does not support any duty change while a fade operation is running on that channel. Other duty operations will have to wait until the fade operation has finished.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**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

```c
esp_err_t ledc_isr_register (void (*fn) 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.

**Return**
- ESP_OK Success
• ESP_ERR_INVALID_ARG Function pointer error.

**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 (ORed) 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.

```c
esp_err_t ledc_timer_set (ledc_mode_t speed_mode, ledc_timer_t timer_sel, uint32_t clock_divider, uint32_t duty_resolution, ledc_clk_src_t clk_src)
```

Configure LEDC settings.

**Return**
- (-1) Parameter error
- Other Current LEDC duty

**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.

```c
esp_err_t ledc_timer_rst (ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Reset LEDC timer.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**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

```c
esp_err_t ledc_timer_pause (ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Pause LEDC timer counter.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**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

```c
esp_err_t ledc_timer_resume (ledc_mode_t speed_mode, ledc_timer_t timer_sel)
```

Resume LEDC timer.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**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

```c
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.

**Return**
Chapter 2. API Reference

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**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

```c
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.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

**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

```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.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

**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).

```c
esp_err_t ledc_fade_func_install(int intr_alloc_flags)
```

Install LEDC fade function. This function will occupy interrupt of LEDC module.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function already installed.
Chapter 2. API Reference

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.

```c
void ledc_fade_func_uninstall (void)
```

Uninstall LEDC fade function.

```c
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.

**Return**

• ESP_OK Success
• ESP_ERR_INVALID_STATE Fade function not installed.
• ESP_ERR_INVALID_ARG Parameter error.

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.

```c
esp_err_t ledc_fade_stop (ledc_mode_t speed_mode, ledc_channel_t channel)
```

Stop LEDC fading. Duty of the channel will stay at its present value.

**Note**  
This API can be called if a new fixed duty or a new fade want to be set while the last fade operation is still running in progress.

**Note**  
Call this API will abort the fading operation only if it was started by calling `ledc_fade_start` with `LEDC_FADE_NO_WAIT` mode.

**Note**  
If a fade was started with `LEDC_FADE_WAIT_DONE` mode, calling this API afterwards is no use in stopping the fade. Fade will continue until it reaches the target duty.

**Return**

• ESP_OK Success
• ESP_ERR_INVALID_STATE Fade function not installed.
• ESP_ERR_INVALID_ARG Parameter error.

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

```c
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)

```c
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.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

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]
- fade_mode: choose blocking or non-blocking mode

```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.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

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

```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.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success
- ESP_ERR_INVALID_STATE Fade function not installed.
- ESP_FAIL Fade function init error

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
- cbs: Group of LEDC callback functions
- user_arg: user registered data for the callback function

Structures

```c
struct ledc_channel_config_t
```

Configuration parameters of LEDC channel for ledc_channel_config function.
Public Members

```c
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 - 7)

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 - 3)

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 0xfffff

unsigned int output_invert : 1
    Enable (1) or disable (0) gpio output invert

struct ledc_channel_config_t::[anonymous] flags
    LEDC flags

struct ledc_timer_config_t
    Configuration parameters of LEDC Timer timer for ledc_timer_config function.
```

Public Members

```c
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_bit_t bit_num
    Deprecated in ESP-IDF 3.0. This is an alias to ‘duty_resolution’ for backward compatibility with ESP-IDF 2.1

ledc_timer_t timer_num
    The timer source of channel (0 - 3)

uint32_t freq_hz
    LEDC timer frequency (Hz)

ledc_clkCfg_t clk_cfg
    Configure LEDC source clock. For low speed channels and high speed channels, you can specify the source clock using LEDC_USE_REF_TICK, LEDC_USE_APB_CLK or LEDC_AUTO_CLK. For low speed channels, you can also specify the source clock using LEDC_USE_RTC8M_CLK, in this case, all low speed channel’s source clock must be RTC8M_CLK

struct ledc_cb_param_t
    LEDC callback parameter.
```

Public Members

```c
ledc_cb_event_t event
    Event name
```
Chapter 2. API Reference

```c
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

lede_cb_t fade_cb
        LEDC fade_end callback function

Macros

LEDC_APB_CLK_HZ
LEDC_REF_CLK_HZ
LEDC_ERR_DUTY
LEDC_ERR_VAL

Type Definitions

typedef intr_handle_t ledc_isr_handle_t

typedef bool (*lede_cb_t)(const ledc_cb_param_t *param, void *user_arg)
        Type of LEDC event callback.

Parameters

        • param: LEDC callback parameter
        • user_arg: User registered data

Enumerations

enum ledc_cb_event_t
        LEDC callback event type.

Values:

        LEDC_FADE_END_EVT
        LEDC fade end event

Header File

• components/hal/include/hal/ledc_types.h

Enumerations

enum ledc_mode_t
        Values:

        LEDC_LOW_SPEED_MODE
        LEDC low speed speed_mode

        LEDC_SPEED_MODE_MAX
        LEDC speed limit

enum ledc_intr_type_t
        Values:
```
Chapter 2. API Reference

```c
LED_INTR_DISABLE = 0
    Disable LEDC interrupt
LED_INTR_FADE_END
    Enable LEDC interrupt
LED_INTR_MAX
```

`enum ledc_duty_direction_t`

*Values:*

- **LEDC_DUTY_DIR_DECREASE = 0**
  LEDC duty decrease direction
- **LEDC_DUTY_DIR_INCREASE = 1**
  LEDC duty increase direction
- **LEDC_DUTY_DIR_MAX**

`enum ledc_slow_clk_sel_t`

*Values:*

- **LEDC_SLOW_CLK_RTC8M = 0**
  LEDC low speed timer clock source is 8MHz RTC clock
- **LEDC_SLOW_CLK_APB**
  LEDC low speed timer clock source is 80MHz APB clock
- **LEDC_SLOW_CLK_XTAL**
  LEDC low speed timer clock source XTAL clock

`enum ledc_clk_cfg_t`

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.

*Values:*

- **LEDC_AUTO_CLK = 0**
  The driver will automatically select the source clock (REF_TICK or APB) based on the giving resolution and duty parameter when init the timer
- **LEDC_USE_APB_CLK**
  LEDC timer select APB clock as source clock
- **LEDC_USE_RTC8M_CLK**
  LEDC timer select RTC8M_CLK as source clock. Only for low speed channels and this parameter must be the same for all low speed channels
- **LEDC_USE_XTAL_CLK**
  LEDC timer select XTAL clock as source clock

`enum ledc_clk_src_t`

*Values:*

- **LEDC_APB_CLK = LEDC_USE_APB_CLK**
  LEDC timer clock divided from APB clock (80Mhz)
- **LEDC_SCLK = LEDC_USE_APB_CLK**
  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:*

- **LEDC_TIMER_0 = 0**
  LEDC timer 0
```
Chapter 2. API Reference

```c
enum ledc_channel_t
Values:
LEDC_CHANNEL_0 = 0
LEDC_CHANNEL_1
LEDC_CHANNEL_2
LEDC_CHANNEL_3
LEDC_CHANNEL_4
LEDC_CHANNEL_5
LEDC_CHANNEL_6
LEDC_CHANNEL_7
LEDC_CHANNEL_MAX
```

```c
enum ledc_timer_bit_t
Values:
LEDC_TIMER_1_BIT = 1
LEDC_TIMER_2_BIT
LEDC_TIMER_3_BIT
LEDC_TIMER_4_BIT
LEDC_TIMER_5_BIT
LEDC_TIMER_6_BIT
LEDC_TIMER_7_BIT
LEDC_TIMER_8_BIT
LEDC_TIMER_9_BIT
```

LED_C.Timer 1
LED_C.timer 2
LED_C.timer 3
LED_C_TIMER_MAX
Chapter 2. API Reference

LEDC_TIMER_10_BIT
LEDC PWM duty resolution of 10 bits

LEDC_TIMER_11_BIT
LEDC PWM duty resolution of 11 bits

LEDC_TIMER_12_BIT
LEDC PWM duty resolution of 12 bits

LEDC_TIMER_13_BIT
LEDC PWM duty resolution of 13 bits

LEDC_TIMER_14_BIT
LEDC PWM duty resolution of 14 bits

LEDC_TIMER_BIT_MAX

enum ledc_fade_mode_t
Values:

LEDC_FADE_NO_WAIT = 0
LEDC fade function will return immediately

LEDC_FADE_WAIT_DONE
LEDC fade function will block until fading to the target duty

LEDC_FADE_MAX

2.3.11 Motor Control Pulse Width Modulator (MCPWM)

ESP32-S3 has two MCPWM units which can be used to control different types of motors. Each unit has three pairs of PWM outputs.

More detailed block diagram of the MCPWM unit is shown below. Each A/B pair may be clocked by any one of the three timers Timer 0, 1 and 2. The same timer may be used to clock more than one pair of PWM outputs. Each unit is also able to collect inputs such as SYNC SIGNALS, detect FAULT SIGNALS like motor overcurrent or overvoltage, as well as obtain feedback with CAPTURE SIGNALS on e.g. a rotor position.

Description of this API starts with configuration of MCPWM’s Timer and Generator submodules to provide the basic motor control functionality. Then it discusses more advanced submodules and functionalities of a Fault Handler, signal Capture and Carrier.
Chapter 2. API Reference

Fig. 9: MCPWM Block Diagram

Contents

- **Configure** a basic functionality of the outputs
- **Operate** the outputs to drive a motor
- **Adjust** how the motor is driven
- **Synchronize** sync timers to work together
- **Capture** external signals to provide additional control over the outputs
- Use **Fault Handler** to detect and manage faults
- Add a higher frequency **Carrier**, if output signals are passed through an isolation transformer
- Extra configuration of **Resolution**.

Configure

The scope of configuration depends on the motor type, in particular how many outputs and inputs are required, and what will be the sequence of signals to drive the motor.

In this case we will describe a simple configuration to control a brushed DC motor that is using only some of the available MCPWM’s resources. An example circuit is shown below. It includes a **H-Bridge** to switch polarization of a voltage applied to the motor (M) and to provide sufficient current to drive it.

Configuration covers the following steps:

1. Selection of a MCPWM unit that will be used to drive the motor. There are two units available on-board of ESP32-S3 and enumerated in `mcpwm_unit_t`.
2. Initialization of two GPIOs as output signals within selected unit by calling `mcpwm_gpio_init()`. The two output signals are typically used to command the motor to rotate right or left. All available signal options are listed in `mcpwm_io_signals_t`. To set more than a single pin at a time, use function `mcpwm_set_pin()` together with `mcpwm_pin_config_t`.
3. Selection of a timer. There are three timers available within the unit. The timers are listed in `mcpwm_timer_t`. 
4. Setting of the timer frequency and initial duty within `mcpwm_config_t` structure.
5. Setting timer resolution if necessary, by calling `mcpwm_group_set_resolution()` and `mcpwm_timer_set_resolution()`.
6. Calling of `mcpwm_init()` with the above parameters to make the configuration effective.

**Operate**

To operate a motor connected to the MCPWM unit, e.g. turn it left or right, or vary the speed, we should apply some control signals to the unit’s outputs. The outputs are organized into three pairs. Within a pair they are labeled “A” and “B” and each driven by a submodule called an “Generator”. To provide a PWM signal, the Operator itself, which contains two Generators, should be clocked by one of three available Timers. To make the API simpler, each Timer is automatically associated by the API to drive an Operator of the same index, e.g. Timer 0 is associated with Operator 0.

There are the following basic ways to control the outputs:

- We can drive particular signal steady high or steady low with function `mcpwm_set_signal_high()` or `mcpwm_set_signal_low()`. This will make the motor to turn with a maximum speed or stop. Depending on selected output A or B the motor will rotate either right or left.
- Another option is to drive the outputs with the PWM signal by calling `mcpwm_start()` or `mcpwm_stop()`. The motor speed will be proportional to the PWM duty.
- To vary PWM’s duty call `mcpwm_set_duty()` and provide the duty value in %. Optionally, you may call `mcpwm_set_duty_in_us()`, if you prefer to set the duty in microseconds. Checking of currently set value is possible by calling `mcpwm_get_duty()`. Phase of the PWM signal may be altered by calling `mcpwm_set_duty_type()`. The duty is set individually for each A and B output using `mcpwm_generator_t` in specific function calls. The duty value refers either to high or low output signal duration. This is configured when calling `mcpwm_init()`, as discussed in section **Configure**, and selecting one of options from `mcpwm_duty_type_t`.

**Note:** Call function `mcpwm_set_duty_type()` every time after `mcpwm_set_signal_high()` or `mcpwm_set_signal_low()` to resume with previously set duty cycle.
Adjust

There are couple of ways to adjust a signal on the outputs and changing how the motor operates.

- Set specific PWM frequency by calling `mcpwm_set_frequency()`. This may be required to adjust to electrical or mechanical characteristics of particular motor and driver. To check what frequency is set, use function `mcpwm_get_frequency()`.
- Introduce a dead time between outputs A and B when they are changing the state to reverse direction of the motor rotation. This is to make up for on/off switching delay of the motor driver FETs. The dead time options are defined in `mcpwm_deadtime_type_t` and enabled by calling `mcpwm_deadtime_enable()`. To disable this functionality call `mcpwm_deadtime_disable()`.
- Synchronize outputs of operator submodules, e.g. to get raising edge of PWM0A/B and PWM1A/B to start exactly at the same time, or shift them between each other by a given phase. Synchronization is triggered by SYNC SIGNALS shown on the block diagram of the MCPWM above, and defined in `mcpwm_sync_signal_t`. To attach the signal to a GPIO call `mcpwm_gpio_init()`. You can then enable synchronization with function `mcpwm_sync_configure()`. As input parameters provide MCPWM unit, timer to synchronize, the synchronization signal and a phase to delay the timer.

**Note:** Synchronization signals are referred to using two different enumerations. First one `mcpwm_io_signals_t` is used together with function `mcpwm_gpio_init()` when selecting a GPIO as the signal input source. The second one `mcpwm_sync_signal_t` is used when enabling or disabling synchronization with `mcpwm_sync_configure()` or `mcpwm_sync_disable()`.

- Vary the pattern of the A/B output signals by getting MCPWM counters to count up, down and up/down (automatically changing the count direction). Respective configuration is done when calling `mcpwm_init()`, as discussed in section Configure, and selecting one of counter types from `mcpwm_counter_type_t`. For explanation of how A/B PWM output signals are generated, see ESP32-S3 Technical Reference Manual > Motor Control PWM (MCPWM) [PDF].

Synchronize

Each PWM timer has a synchronization input and a synchronization output. The synchronization input can be selected from other timers’ synchronization outputs or GPIO signals via the GPIO matrix. Timer’s synchronization signal can be generated from either the input sync signal or when the count value reaches peak/zero. Thus, the PWM timers can be chained together with their phase-locked. During synchronization, the PWM timer clock prescaler will reset its counter in order to synchronize the PWM timer clock.

The functionality is enabled in following steps:

1. Make sure the PWM timer and operator are already configured so that sync will inherit its config (count mode, freq and duty).
2. Enabling sync input of the timer by invoking `mcpwm_sync_configure()`, selecting desired signal input from `mcpwm_sync_signal_t`, and setting the desired phase range from 0 to 999 which is mapped to 0%~99.9%. 0 means zero phase is applied and output is fired at the same time. And selecting desired counting direction.
3. Enabling one of sync event source from another timer or from external GPIO input.

To sync with another timer:

Enabling sync output of another timer by invoking `mcpwm_set_timer_sync_output()` and selecting desired event to generate sync output from `mcpwm_timer_sync_trigger_t`.

To sync with GPIO positive edge input (negative edge requires `mcpwm_sync_invert_gpio_synchro()`):

Configuring GPIOs to act as the sync signal inputs by calling functions `mcpwm_gpio_init()` or `mcpwm_set_pin()`, which were described in section Configure.

It’s normal condition that chained sync signal may have tens or even hundreds of nanoseconds of delay between each timer output due to hardware limitation. To sync two timers accurately it is required to have the third timer occupied to produce sync event that can be consumed parallel by other two timer, so that those two timer will have
no delay between each other but have the same delay between the timer which provides events. Another solution is introducing an external GPIO event source so that all three timers can be synced together with no delay.

Software sync event which triggered on one timer can be propagated to other timers on ESP32-S3, which can be used as a tricky way to get all three timers synced without any extra requirement.

```c
// configure timer0 as trigger source
mcpwm_set_timer_sync_output(MCPWM_UNIT_0, MCPWM_TIMER_0, MCPWM_SWSYNC_SOURCE_,
  &SYNCIN);
mcpwm_sync_config_t sync_conf = {
  .sync_sig = MCPWM_SELECT_TIMER0_SYNC,
  .timer_val = 0,
  .count_direction = MCPWM_TIMER_DIRECTION_UP,
};
mcpwm_sync_configure(TARGET_MCPWM_UNIT, MCPWM_TIMER_0, &sync_conf);
mcpwm_sync_configure(TARGET_MCPWM_UNIT, MCPWM_TIMER_1, &sync_conf);
mcpwm_sync_configure(TARGET_MCPWM_UNIT, MCPWM_TIMER_2, &sync_conf);
// then send soft sync event to timer0
mcpwm_timer_trigger_soft_sync(MCPWM_UNIT_0, MCPWM_TIMER_0);
```

If not required anymore, the capture functionality may be disabled with `mcpwm_sync_disable()`.

**Capture**

One of requirements of BLDC (Brushless DC, see figure below) motor control is sensing of the rotor position. To facilitate this task each MCPWM unit provides three sensing inputs together with dedicated hardware. The hardware is able to detect the input signal’s edge and measure time between signals. As result the control software is simpler and the CPU power may be used for other tasks.

![Fig. 11: Example of Brushless DC Motor Control with MCPWM](image)

The capture functionality may be used for other types of motors or tasks. The functionality is enabled in two steps:

1. Configuration of GPIOs to act as the capture signal inputs by calling functions `mcpwm_gpio_init()` or `mcpwm_set_pin()`, that were described in section Configure.
2. Enabling of the functionality itself by invoking `mcpwm_capture_enable_channel()`, selecting desired signal input from `mcpwm_capture_channel_id_t`, setting the signal edge, signal count prescaler and user callback within `mcpwm_capture_config_t`.

Within the second step above a 32-bit capture timer is enabled. The timer runs continuously driven by the APB clock. The clock frequency is typically 80 MHz. On each capture event the capture timer’s value is stored in timestamp register that may be then checked by calling `mcpwm_capture_signal_get_value()`. The edge of the last signal may be checked with `mcpwm_capture_signal_get_edge()`. Those data are also provided inside callback function as event data `cap_event_data_t`.

If not required anymore, the capture functionality may be disabled with `mcpwm_capture_disable_channel()`.

Capture prescale is different from other modules as it is applied to the input signal, not the timer source. Prescaler has maintained its own level state with the initial value set to low and is detecting the positive edge of the input signal to change its internal state. That means if two pairs of positive and negative edges are passed to input, the prescaler’s internal state will change twice. ISR will report on this internal state change, not the input signal. For example, setting prescale to 2 will generate ISR callback on each positive edge of input if both edge is selected via `mcpwm_capture_config_t`. Or each 2 positive edges of input if only one edge is selected though `mcpwm_capture_config_t`.

**Fault Handler**

Each unit of the MCPWM is able to sense external signals with information about failure of the motor, the motor driver or any other device connected to the MCPWM. There are three fault inputs per unit that may be routed to user selectable GPIOs. The MCPWM may be configured to perform one of four predefined actions on A/B outputs when a fault signal is received:

- lock current state of the output
- set the output low
- set the output high
- toggle the output

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.

The fault handler functionality is enabled in two steps:

1. Configuration of GPIOs to act as fault signal inputs. This is done in analogous way as described for capture signals in section above. It includes setting the signal level to trigger the fault as defined in `mcpwm_fault_input_level_t`.
2. Initialization of the fault handler by calling either `mcpwm_fault_set_oneshot_mode()` or `mcpwm_fault_set_cyc_mode()`. These functions set the mode that MCPWM should operate once fault signal becomes inactive. There are two modes possible:

- State of MCPWM unit will be locked until reset - `mcpwm_fault_set_oneshot_mode()`.
- The MCPWM will resume operation once fault signal becoming inactive - `mcpwm_fault_set_cyc_mode()`.

The function call parameters include selection of one of three fault inputs defined in `mcpwm_fault_signal_t` and specific action on outputs A and B defined in `mcpwm_action_on_pwmxa_t` and `mcpwm_action_on_pwmxb_t`.

Particular fault signal may be disabled at the runtime by calling `mcpwm_fault_deinit()`.

**Carrier**

The MCPWM has a carrier submodule used if galvanic isolation from the motor driver is required by passing the A/B output signals through transformers. Any of A and B 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 use the carrier submodule, it should be first initialized by calling `mcpwm_carrier_init()`. The carrier parameters are defined in `mcpwm_carrier_config_t` structure invoked within the function call. Then the carrier functionality may be enabled by calling `mcpwm_carrier_enable()`.

The carrier parameters may be then altered at a runtime by calling dedicated functions to change individual fields of the `mcpwm_carrier_config_t` structure, like `mcpwm_carrier_set_period()`, `mcpwm_carrier_set_duty_cycle()`, `mcpwm_carrier_output_invert()`, etc.

This includes enabling and setting duration of the first pulse of the carrier with `mcpwm_carrier_oneshot_mode_enable()`. For more details, see ESP32-S3 Technical Reference Manual > Motor Control PWM (MCPWM) > PWM Carrier Submodule [PDF].

To disable carrier functionality call `mcpwm_carrier_disable()`.

**Interrupts**

Registering of the MCPWM interrupt handler is possible by calling `mcpwm_isr_register()`. Note if `mcpwm_capture_enable_channel()` is used then a default ISR routine will be installed hence please do not call this function to register any more.

**Resolution**

The default resolution for MCPWM group and MCPWM timer are configured to 10MHz and 1MHz in `mcpwm_init()`, which might be not enough for some applications. The driver also provides two APIs that can be used to override the default resolution: `mcpwm_group_set_resolution()` and `mcpwm_timer_set_resolution()`.

Note that, these two APIs won’t update the frequency and duty automatically, to achieve that, one has to call `mcpwm_set_frequency()` and `mcpwm_set_duty()` accordingly.

To get PWM pulse that is below 15Hz, please set the resolution to a lower value. For high frequency PWM with limited step range, please set them with higher value.

**Application Example**

MCPWM example are located under: `peripherals/mcpwm`:

- Control of BLDC (brushless DC) motor with hall sensor feedback - `peripherals/mcpwm/mcpwm_bldc_hall_control`
- Brushed DC motor control - `peripherals/mcpwm/mcpwm_bdc_speed_control`
- Servo motor control - `peripherals/mcpwm/mcpwm_servo_control`
- HC-SR04 sensor with capture - `peripherals/mcpwm/mcpwm_capture_hc_sr04`

**API Reference**

**Header File**

- `components/hal/include/hal/mcpwm_types.h`

**Enumerations**

```c
enum mcpwm_timer_direction_t
{
    MCPWM_TIMER_DIRECTION_UP = 0,
    MCPWM_TIMER_DIRECTION_DOWN = 1,
};
```

Values:

- `MCPWM_TIMER_DIRECTION_UP`: Counting direction: Increase
- `MCPWM_TIMER_DIRECTION_DOWN`: Counting direction: Decrease
enum mcpwm_timer_event_t
Values:

MCPWM TIMER EVENT ZERO
MCPWM timer counts to zero

MCPWM TIMER EVENT PEAK
MCPWM timer counts to peak

def mcpwm_timer_event_t

enum mcpwm_timer_count_mode_t
Values:

MCPWM TIMER COUNT MODE PAUSE
MCPWM timer paused

MCPWM TIMER COUNT MODE UP
MCPWM timer counting up

MCPWM TIMER COUNT MODE DOWN
MCPWM timer counting down

MCPWM TIMER COUNT MODE UP DOWN
MCPWM timer counting up and down

def mcpwm_timer_count_mode_t

def mcpwm_timer_execute_cmd_t

enum mcpwm_timer_execute_cmd_t
Values:

MCPWM TIMER STOP AT ZERO
MCPWM timer stops when counting to zero

MCPWM TIMER STOP AT PEAK
MCPWM timer stops when counting to peak

MCPWM TIMER START NO STOP
MCPWM timer starts counting

MCPWM TIMER START STOP AT ZERO
MCPWM timer starts counting and stops when counting to zero

MCPWM TIMER START STOP AT PEAK
MCPWM timer starts counting and stops when counting to peak

def mcpwm_timer_execute_cmd_t

def mcpwm_generator_action_t

enum mcpwm_generator_action_t
Values:

MCPWM GEN ACTION KEEP
Generator action: Keep the same level

MCPWM GEN ACTION LOW
Generator action: Force to low level

MCPWM GEN ACTION HIGH
Generator action: Force to high level

MCPWM GEN ACTION_TOGGLE
Generator action: Toggle level

def mcpwm_generator_action_t

def mcpwm_trip_type_t

enum mcpwm_trip_type_t
Values:

MCPWM TRIP TYPE CBC
CBC trip type, shut down the operator cycle by cycle

MCPWM TRIP TYPE OST
OST trip type, shut down the operator in one shot

def mcpwm_trip_type_t
Chapter 2. API Reference

Header File
- components/driver/include/driver/mcpwm.h

Functions

```c
esp_err_t mcpwm_gpio_init(mcpwm_unit_t mcpwm_num, mcpwm_io_signals_t io_signal, int gpio_num)
```

This function initializes each gpio signal for MCPWM.

**Note** This function initializes one gpio at a time.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- io_signal: set MCPWM signals, each MCPWM unit has 6 output(MCPWMXA, MCPWMXB) and 9 input(SYNC_X, FAULT_X, CAP_X) ‘X’ is timer_num(0-2)
- gpio_num: set this to configure gpio for MCPWM, if you want to use gpio16, gpio_num = 16

```c
esp_err_t mcpwm_set_pin(mcpwm_unit_t mcpwm_num, const mcpwm_pin_config_t *mcpwm_pin)
```

Initialize MCPWM gpio structure.

**Note** This function initialize a group of MCPWM GPIOs at a time.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- mcpwm_pin: MCPWM pin structure

```c
esp_err_t mcpwm_init(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, const mcpwm_config_t *mcpwm_conf)
```

Initialize MCPWM parameters.

**Note** The default resolution configured for MCPWM group and timer are 160M / 16 = 10M and 10M / 10 = 1M The default resolution can be changed by calling mcpwm_group_set_resolution() and mcpwm_timer_set_resolution(), before calling this function.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers.
- mcpwm_conf: configure structure mcpwm_config_t

```c
esp_err_t mcpwm_group_set_resolution(mcpwm_unit_t mcpwm_num, unsigned long int resolution)
```

Set resolution of the MCPWM group.

**Note** This will override default resolution of group(=10,000,000). This WILL NOT automatically update frequency and duty. Call mcpwm_set_frequency() and mcpwm_set_duty() manually to set them back.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- resolution: set expected frequency resolution

```c
esp_err_t mcpwm_timer_set_resolution(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, unsigned long int resolution)
```

Set resolution of each timer.

**Note** This WILL override default resolution of timer(=1,000,000). This WILL NOT automatically update frequency and duty. Call mcpwm_set_frequency() and mcpwm_set_duty() manually to set them back.
Chapter 2. API Reference

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- resolution: set expected frequency resolution

```c
esp_err_t mcpwm_set_frequency(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, uint32_t frequency)
```
Set frequency(in Hz) of MCPWM timer.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- frequency: set the frequency in Hz of each timer

```c
esp_err_t mcpwm_set_duty(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_generator_t gen, float duty)
```
Set duty cycle of each operator(MCPWMXA/MCPWMXB)

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- gen: set the generator(MCPWMXA/MCPWMXB), ‘X’ is operator number selected
- duty: set duty cycle in % (i.e for 62.3% duty cycle, duty = 62.3) of each operator

```c
esp_err_t mcpwm_set_duty_in_us(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_generator_t gen, uint32_t duty_in_us)
```
Set duty cycle of each operator(MCPWMXA/MCPWMXB) in us.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- gen: set the generator(MCPWMXA/MCPWMXB), ‘X’ is operator number selected
- duty_in_us: set duty value in microseconds of each operator

```c
esp_err_t mcpwm_set_duty_type(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_generator_t gen, mcpwm_duty_type_t duty_type)
```
Set duty either active high or active low(out of phase/inverted)

Note: Call this function every time after mcpwm_set_signal_high or mcpwm_set_signal_low to resume with previously set duty cycle

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- gen: set the generator(MCPWMXA/MCPWMXB), ‘X’ is operator number selected
- duty_type: set active low or active high duty type

```c
uint32_t mcpwm_get_frequency(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
```
Get frequency of timer.
Chapter 2. API Reference

Return
• frequency of timer

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

float mcpwm_get_duty(const mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_operator_t gen)
Get duty cycle of each operator.

Return
• duty cycle in % of each operator(56.7 means duty is 56.7%)

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• gen: set the generator(MCPWMXA/MCPWMXB), ‘x’ is operator number selected

uint32_t mcpwm_get_duty_in_us(const mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_operator_t gen)
Get duty cycle of each operator in us.

Return
• duty cycle in us of each operator

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• gen: set the generator(MCPWMXA/MCPWMXB), ‘x’ is operator number selected

esp_err_t mcpwm_set_signal_high(const mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_generator_t gen)
Use this function to set MCPWM signal high.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• gen: set the generator(MCPWMXA/MCPWMXB), ‘x’ is timer number selected

esp_err_t mcpwm_set_signal_low(const mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_generator_t gen)
Use this function to set MCPWM signal low.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• gen: set the generator(MCPWMXA/MCPWMXB), ‘x’ is timer number selected

esp_err_t mcpwm_start(const mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
Start MCPWM signal on timer ‘x’.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

esp_err_t mcpwm_stop(const mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
Start MCPWM signal on timer ‘x’.
Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `mcpwm_num`: set MCPWM unit(0-1)
- `timer_num`: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

```c
esp_err_t mcpwm_carrier_init(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, const mcpwm_carrier_config_t *carrier_conf)
```

Initialize carrier configuration.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `mcpwm_num`: set MCPWM unit(0-1)
- `timer_num`: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- `carrier_conf`: configure structure `mcpwm_carrier_config_t`

```c
esp_err_t mcpwm_carrier_enable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
```

Enable MCPWM carrier submodule, for respective timer.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `mcpwm_num`: set MCPWM unit(0-1)
- `timer_num`: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

```c
esp_err_t mcpwm_carrier_disable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)
```

Disable MCPWM carrier submodule, for respective timer.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `mcpwm_num`: set MCPWM unit(0-1)
- `timer_num`: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

```c
esp_err_t mcpwm_carrier_set_period(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, uint8_t carrier_period)
```

Set period of carrier.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `mcpwm_num`: set MCPWM unit(0-1)
- `timer_num`: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- `carrier_period`: set the carrier period of each timer, carrier period = (carrier_period + 1)*800ns (carrier_period <= 15)

```c
esp_err_t mcpwm_carrier_set_duty_cycle(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, uint8_t carrier_duty)
```

Set duty_cycle of carrier.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `mcpwm_num`: set MCPWM unit(0-1)
- `timer_num`: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- `carrier_duty`: set duty_cycle of carrier , carrier duty cycle = carrier_duty*12.5% (chop_duty <= 7)
Chapter 2. API Reference

```
esp_err_t mcpwm_carrier_oneshot_mode_enable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, uint8_t pulse_width)

Enable and set width of first pulse in carrier oneshot mode.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• pulse_width: set pulse width of first pulse in oneshot mode, width = (carrier period)*(pulse_width + 1) (pulse_width <= 15)

esp_err_t mcpwm_carrier_oneshot_mode_disable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)

Disable oneshot mode, width of first pulse = carrier period.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

esp_err_t mcpwm_carrier_output_invert(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_carrier_out_ivt_t carrier_ivt_mode)

Enable or disable carrier output inversion.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• carrier_ivt_mode: enable or disable carrier output inversion

esp_err_t mcpwm_deadtime_enable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_deadtime_type_t dt_mode, uint32_t red, uint32_t fed)

Enable and initialize deadtime for each MCPWM timer.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
• dt_mode: set deadtime mode
• red: set rising edge delay = red*100ns
• fed: set rising edge delay = fed*100ns

esp_err_t mcpwm_deadtime_disable(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)

Disable deadtime on MCPWM timer.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• mcpwm_num: set MCPWM unit(0-1)
• timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

esp_err_t mcpwm_fault_init(mcpwm_unit_t mcpwm_num, mcpwm_fault_input_level_t input_level, mcpwm_fault_signal_t fault_sig)

Initialize fault submodule, currently low level triggering is not supported.
```
Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- fault_sig: set the fault pin, which needs to be enabled
- input_level: set fault signal level, which will cause fault to occur

```c
esp_err_t mcpwm_fault_set_oneshot_mode(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_fault_signal_t fault_sig, mcpwm_output_action_t action_on_pwmxa, mcpwm_output_action_t action_on_pwmxb)
```

Set oneshot mode on fault detection, once fault occur in oneshot mode reset is required to resume MCPWM signals.

Note currently low level triggering is not supported

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- fault_sig: set the fault pin, which needs to be enabled for oneshot mode
- action_on_pwmxa: action to be taken on MCPWMXA when fault occurs, either no change or high or low or toggle
- action_on_pwmxb: action to be taken on MCPWMXB when fault occurs, either no change or high or low or toggle

```c
esp_err_t mcpwm_fault_set_cyc_mode(mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_fault_signal_t fault_sig, mcpwm_output_action_t action_on_pwmxa, mcpwm_output_action_t action_on_pwmxb)
```

Set cycle-by-cycle mode on fault detection, once fault occur in cyc mode MCPWM signal resumes as soon as fault signal becomes inactive.

Note currently low level triggering is not supported

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- fault_sig: set the fault pin, which needs to be enabled for cyc mode
- action_on_pwmxa: action to be taken on MCPWMXA when fault occurs, either no change or high or low or toggle
- action_on_pwmxb: action to be taken on MCPWMXB when fault occurs, either no change or high or low or toggle

```c
esp_err_t mcpwm_fault_deinit(mcpwm_unit_t mcpwm_num, mcpwm_fault_signal_t fault_sig)
```

Disable fault signal.

Return

- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- mcpwm_num: set MCPWM unit(0-1)
- fault_sig: fault pin, which needs to be disabled

```c
esp_err_t mcpwm_capture_enable(mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap_sig, mcpwm_capture_on_edge_t cap_edge, uint32_t num_of_pulse)
```

Initialize capture submodule.
Note: Enabling capture feature would also enable the capture interrupt event, users have to register an interrupt handler by `mcpwm_isr_register`, and in there, query the capture data.

Note: The capture timer uses APB_CLK (typically 80MHz) as the count source.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `cap_edge`: set capture edge, BIT(0) - negative edge, BIT(1) - positive edge
- `cap_sig`: capture pin, which needs to be enabled
- `num_of_pulse`: Input capture signal prescaling, ranges from 0 to 255, representing prescaling from 1 to 256.

```c
esp_err_t mcpwm_capture_disable(mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap_sig)
```
Disable capture signal.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `cap_sig`: capture pin, which needs to be disabled

```c
esp_err_t mcpwm_capture_enable_channel(mcpwm_unit_t mcpwm_num, mcpwm_capture_channel_id_t cap_channel, const mcpwm_capture_config_t *cap_conf)
```
Enable capture channel.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `cap_channel`: capture channel, which needs to be enabled
- `cap_conf`: capture channel configuration

```c
esp_err_t mcpwm_capture_disable_channel(mcpwm_unit_t mcpwm_num, mcpwm_capture_channel_id_t cap_channel)
```
Disable capture channel.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `cap_channel`: capture channel, which needs to be disabled

```c
uint32_t mcpwm_capture_signal_get_value(mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap_sig)
```
Get capture value.

**Return** Captured value

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `cap_sig`: capture channel on which value is to be measured

```c
uint32_t mcpwm_capture_signal_get_edge(mcpwm_unit_t mcpwm_num, mcpwm_capture_signal_t cap_sig)
```
Get edge of capture signal.

**Return** Capture signal edge: 1 - positive edge, 2 - negative edge

**Parameters**
- `mcpwm_num`: set MCPWM unit(0-1)
- `cap_sig`: capture channel of whose edge is to be determined
**esp_err_t mcpwm_sync_enable** (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_sync_signal_t sync_sig, uint32_t phase_val)

Initializes sync submodule and sets the signal that will cause the timer be loaded with pre-defined value.

**Note** Count direction is undefined within this API

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- sync_sig: set the synchronization input signal
- phase_val: phase value in 1/1000 (for 86.7%, phase_val = 867) which timer moves to on sync signal

**esp_err_t mcpwm_sync_configure** (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, const mcpwm_sync_config_t *sync_conf)

Initialize sync submodule and sets the signal that will cause the timer be loaded with pre-defined value.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- sync_conf: sync configuration on this timer

**esp_err_t mcpwm_sync_disable** (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)

Disable sync submodule on given timer.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers

**esp_err_t mcpwm_set_timer_sync_output** (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num, mcpwm_timer_sync_trigger_t trigger)

Set sync output on given timer Configures what event triggers MCPWM timer to output a sync signal.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- mcpwm_num: set MCPWM unit(0-1)
- timer_num: set timer number(0-2) of MCPWM, each MCPWM unit has 3 timers
- trigger: set the trigger that will cause the timer to generate a software sync signal. Specifically, MCPWM_SWSYNC_SOURCE_DISABLED will disable the timer from generating sync signal.

**esp_err_t mcpwm_timer_trigger_soft_sync** (mcpwm_unit_t mcpwm_num, mcpwm_timer_t timer_num)

Trigger a software sync event and sends it to a specific timer.

**Note** This software sync event will have the same effect as hw one, except that:
- On esp32s3 the soft sync event can be routed to its output if MCPWM_SWSYNC.getSource.SYNCCIN is selected via mcpwm_set_timer_sync_output()
- On esp32 there is no such behavior and soft sync event will only take effect on this timer and can not be propagated to others.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Function pointer error.

**Parameters**
Chapter 2. API Reference

- `mcpwm_num`: set MCPWM unit (0-1)
- `timer_num`: set timer number (0-2) of MCPWM, each MCPWM unit has 3 timers

```c
esp_err_t mcpwm_sync_invert_gpio_synchro(mcpwm_unit_t mcpwm_num, mcpwm_sync_signal_t sync_sig, bool invert)
```

Set external GPIO sync input inverter.

**Return**
- `ESP_OK` Success
- `ESP_ERR_INVALID_ARG` Function pointer error.

**Parameters**
- `mcpwm_num`: set MCPWM unit (0-1)
- `sync_sig`: set sync signal of MCPWM, only supports GPIO sync signal
- `invert`: whether GPIO sync source input is inverted (to get negative edge trigger)

```c
esp_err_t mcpwm_isr_register(mcpwm_unit_t mcpwm_num, void(*fn)(void*), void *arg, int intr_alloc_flags, intr_handle_t *handle)
```

Register MCPWM interrupt handler, the handler is an ISR. The handler will be attached to the same CPU core that this function is running on.

**Return**
- `ESP_OK` Success
- `ESP_ERR_INVALID_ARG` Function pointer error.

**Parameters**
- `mcpwm_num`: set MCPWM unit (0-1)
- `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.

**Structures**

```c
struct mcpwm_pin_config_t
```

pin number for MCPWM

**Public Members**

- `int mcpwm0a_out_num` MCPWM0A out pin
- `int mcpwm0b_out_num` MCPWM0A out pin
- `int mcpwm1a_out_num` MCPWM0A out pin
- `int mcpwm1b_out_num` MCPWM0A out pin
- `int mcpwm2a_out_num` MCPWM0A out pin
- `int mcpwm2b_out_num` MCPWM0A out pin
- `int mcpwm_sync0_in_num` SYNC0 in pin
- `int mcpwm_sync1_in_num` SYNC1 in pin
- `int mcpwm_sync2_in_num` SYNC2 in pin
Chapter 2. API Reference

```c
int mcpwm_fault0_in_num
FAULT0 in pin
int mcpwm_fault1_in_num
FAULT1 in pin
int mcpwm_fault2_in_num
FAULT2 in pin
int mcpwm_cap0_in_num
CAP0 in pin
int mcpwm_cap1_in_num
CAP1 in pin
int mcpwm_cap2_in_num
CAP2 in pin

struct cap_event_data_t
event data that will be passed into ISR callback
```

Public Members

```c
mcpwm_capture_on_edge_t cap_edge
Which signal edge is detected

uint32_t cap_value
Corresponding timestamp when event occurs. Clock rate = APB(usually 80M)
```

```c
struct mcpwm_config_t
MCPWM config structure.
```

Public Members

```c
uint32_t frequency
Set frequency of MCPWM in Hz
float cmpr_a
Set % duty cycle for operator a(MCPWMXA), i.e for 62.3% duty cycle, duty_a = 62.3
float cmpr_b
Set % duty cycle for operator b(MCPWMXB), i.e for 48% duty cycle, duty_b = 48.0
mcpwm_duty_type_t duty_mode
Set type of duty cycle
mcpwm_counter_type_t counter_mode
Set type of MCPWM counter
```

```c
struct mcpwm_carrier_config_t
MCPWM carrier configuration structure.
```

Public Members

```c
uint8_t carrier_period
Set carrier period = (carrier_period + 1)*800ns, carrier_period should be < 16
uint8_t carrier_duty
Set carrier duty cycle, carrier_duty should be less than 8 (increment every 12.5%)
uint8_t pulse_width_in_os
Set pulse width of first pulse in one shot mode = (carrier period)*(pulse_width_in_os + 1), should be less then 16
```
Chapter 2. API Reference

```c
mcpwm_carrier_os_t carrier_os_mode
   Enable or disable carrier oneshot mode

mcpwm_carrier_out_ivt_t carrier_ivt_mode
   Invert output of carrier
```

```c
def struct mcpwm_capture_config_t
   MCPWM config capture structure.

Public Members

mcpwm_capture_on_edge_t cap_edge
   Set capture edge

uint32_t cap_prescale
   Prescale of capture signal, ranging from 1 to 256

cap_isr_cb_t capture_cb
   User defined capture event callback, running under interrupt context

void *user_data
   User defined ISR callback function args
```

```c
def struct mcpwm_sync_config_t
   MCPWM config sync structure.

Public Members

mcpwm_sync_signal_t sync_sig
   Set sync input signal that will cause timer to sync

uint32_t timer_val
   Counter value to be set after sync, in 0 ~ 999, unit: 1 / 1000 * peak
```

```c
mcpwm_timer_direction_t count_direction
   Counting direction to be set after sync
```

**Macros**

MCPWM_OPR_A
MCPWM_OPR_B
MCPWM_OPR_MAX
MCPWM_SELCT_SYNC0
MCPWM_SELCT_SYNC1
MCPWM_SELCT_SYNC2
MCPWM_NO_CHANGE_IN_MCPWMXA
MCPWM_FORCE_MCPWMXA_LOW
MCPWM_FORCE_MCPWMXA_HIGH
MCPWM_TOG_MCPWMXA
MCPWM_NO_CHANGE_IN_MCPWMB
MCPWM_FORCE_MCPWMB_LOW
MCPWM_FORCE_MCPWMB_HIGH
MCPWM_TOG_MCPWMB
```
Type Definitions

typedef mcpwm_generator_t mcpwm_operator_t

typedef mcpwm_output_action_t mcpwm_action_on_pwmxa_t

typedef mcpwm_output_action_t mcpwm_action_on_pwmxb_t

typedef mcpwm_capture_signal_t mcpwm_capture_channel_id_t

MCPWM capture channel ID alias.

typedef bool (*cap_isr_cb_t)(mcpwm_unit_t mcpwm, mcpwm_capture_channel_id_t cap_channel,
                          const cap_event_data_t *edata, void *user_data)

Type of capture event callback.

Note Since this an ISR callback so do not do anything that may block and call APIs that is designed to be used within ISR (usually has ‘_ISR’ postfix)

Return Whether a task switch is needed after the callback function returns, this is usually due to the callback wakes up some high priority task.

Parameters

• mcpwm: MCPWM unit (0-1)
• cap_channel: capture channel ID
• edata: Capture event data, contains capture edge and capture value, fed by the driver
• user_data: User registered data, passed from mcpwm_capture_config_t

Enumerations

enum mcpwm_io_signals_t

IO signals for the MCPWM.

- 6 MCPWM output pins that generate PWM signals
- 3 MCPWM fault input pins to detect faults like overcurrent, overvoltage, etc.
- 3 MCPWM sync input pins to synchronize MCPWM outputs signals
- 3 MCPWM capture input pins to gather feedback from controlled motors, using e.g. hall sensors

Values:

MCPWM0A = 0
PWM0A output pin

MCPWM0B
PWM0B output pin

MCPWM1A
PWM1A output pin

MCPWM1B
PWM1B output pin

MCPWM2A
PWM2A output pin

MCPWM2B
PWM2B output pin

MCPWM_SYNC_0
SYNC0 input pin

MCPWM_SYNC_1
SYNC1 input pin

MCPWM_SYNC_2
SYNC2 input pin

MCPWM_FAULT_0
FAULT0 input pin
MCPWM_FAULT_1
FAULT1 input pin

MCPWM_FAULT_2
FAULT2 input pin

MCPWM_CAP_0 = 84
CAP0 input pin

MCPWM_CAP_1
CAP1 input pin

MCPWM_CAP_2
CAP2 input pin

def mcpwm_unit_t
Select MCPWM unit.
Values:

MCPWM_UNIT_0
MCPWM unit0 selected

MCPWM_UNIT_1
MCPWM unit1 selected

MCPWM_UNIT_MAX
Max number of MCPWM units

def mcpwm_timer_t
Select MCPWM timer.
Values:

MCPWM_TIMER_0
Select MCPWM timer0

MCPWM_TIMER_1
Select MCPWM timer1

MCPWM_TIMER_2
Select MCPWM timer2

MCPWM_TIMER_MAX
Max number of timers in a unit

def mcpwm_generator_t
Select MCPWM operator.
Values:

MCPWM_GEN_A
Select MCPWMXA, where ‘X’ is operator number

MCPWM_GEN_B
Select MCPWMXB, where ‘X’ is operator number

MCPWM_GEN_MAX
Num of generators to each operator of MCPWM

def mcpwm_carrier_os_t
MCPWM carrier oneshot mode, in this mode the width of the first pulse of carrier can be programmed.
Values:

MCPWM_ONESHOT_MODE_DIS
Enable oneshot mode

MCPWM_ONESHOT_MODE_EN
Disable oneshot mode
enum mcpwm_carrier_out_ivt_t
MCPWM carrier output inversion, high frequency carrier signal active with MCPWM signal is high.

Values:
MCPWM_CARRIER_OUT_IVT_DIS
Enable carrier output inversion
MCPWM_CARRIER_OUT_IVT_EN
Disable carrier output inversion

denum mcpwm_fault_signal_t
MCPWM select fault signal input.

Values:
MCPWM_SELECT_F0
Select F0 as input
MCPWM_SELECT_F1
Select F1 as input
MCPWM_SELECT_F2
Select F2 as input

denum mcpwm_sync_signal_t
MCPWM select sync signal input.

Values:
MCPWM_SELECT_NO_INPUT
No sync input selected
MCPWM_SELECT_TIMER0_SYNC
Select software sync signal from timer0 as input
MCPWM_SELECT_TIMER1_SYNC
Select software sync signal from timer1 as input
MCPWM_SELECT_TIMER2_SYNC
Select software sync signal from timer2 as input
MCPWM_SELECT_GPIO_SYNC0
Select GPIO SYNC0 as input
MCPWM_SELECT_GPIO_SYNC1
Select GPIO SYNC1 as input
MCPWM_SELECT_GPIO_SYNC2
Select GPIO SYNC2 as input

denum mcpwm_timer_sync_trigger_t
MCPWM timer sync event trigger.

Values:
MCPWM_SWSYNC_SOURCE_SYNCIN
the input sync signal will be routed to its sync output path
MCPWM_SWSYNC_SOURCE_TZ
sync signal generated when timer counts to zero
MCPWM_SWSYNC_SOURCE_TEP
sync signal generated when timer counts to peak
MCPWM_SWSYNC_SOURCE_DISABLED
timer does not generate sync signals
### enum mcpwm_fault_input_level_t
MCPWM select triggering level of fault signal.

**Values:**
- **MCPWM_LOW_LEVEL_TGR**
  Fault condition occurs when fault input signal goes from high to low
- **MCPWM_HIGH_LEVEL_TGR**
  Fault condition occurs when fault input signal goes low to high

### enum mcpwm_capture_on_edge_t
MCPWM select capture starts from which edge.

**Values:**
- **MCPWM_NEG_EDGE** = BIT(0)
  Capture the negative edge
- **MCPWM_POS_EDGE** = BIT(1)
  Capture the positive edge
- **MCPWM_BOTH_EDGE** = BIT(1) | BIT(0)
  Capture both edges

### enum mcpwm_intr_t
Interrupt masks for MCPWM capture.

**Values:**
- **MCPWM_LL_INTR_CAP0** = BIT(27)
  Capture 0 happened.
- **MCPWM_LL_INTR_CAP1** = BIT(28)
  Capture 1 happened.
- **MCPWM_LL_INTR_CAP2** = BIT(29)
  Capture 2 happened.

### enum mcpwm_counter_type_t
Select type of MCPWM counter.

**Values:**
- **MCPWM_FREEZE_COUNTER**
  Counter freeze
- **MCPWM_UP_COUNTER**
  For asymmetric MCPWM
- **MCPWM_DOWN_COUNTER**
  For asymmetric MCPWM
- **MCPWM_UP_DOWN_COUNTER**
  For symmetric MCPWM, frequency is half of MCPWM frequency set
- **MCPWM_COUNTER_MAX**
  Maximum counter mode

### enum mcpwm_duty_type_t
Select type of MCPWM duty cycle mode.

**Values:**
- **MCPWM_DUTY_MODE_0** = 0
  Active high duty, i.e. duty cycle proportional to high time for asymmetric MCPWM
- **MCPWM_DUTY_MODE_1**
  Active low duty, i.e. duty cycle proportional to low time for asymmetric MCPWM, out of phase(inverted) MCPWM
Chapter 2. API Reference

MCPWM_HAL_GENERATOR_MODE_FORCE_LOW
MCPWM_HAL_GENERATOR_MODE_FORCE_HIGH
MCPWM_DUTY_MODE_MAX

Num of duty cycle modes

def mcpwm_deadtime_type_t
MCPWM deadtime types, used to generate deadtime, RED refers to rising edge delay and FED refers to falling edge delay.
Values:

MCPWM_DEADTIME_BYPASS = 0
Bypass the deadtime

MCPWM_BYPASS_RED
MCPWMXA Out = MCPWMXA In with no delay, MCPWMXB Out = MCPWMXA In with falling edge delay

MCPWM_BYPASS_FED
MCPWMXA Out = MCPWMXA In with rising edge delay, MCPWMXB Out = MCPWMXB In with no delay

MCPWM_ACTIVE_HIGH_MODE
MCPWMXA Out = MCPWMXA In with rising edge delay, MCPWMXB Out = MCPWMXA In with falling edge delay

MCPWM_ACTIVE_LOW_MODE
MCPWMXA Out = MCPWMXA In with compliment of rising edge delay, MCPWMXB Out = MCPWMXA In with compliment of falling edge delay

MCPWM_ACTIVE_HIGH_COMPLIMENT_MODE
MCPWMXA Out = MCPWMXA In with rising edge delay, MCPWMXB = MCPWMXA In with compliment of falling edge delay

MCPWM_ACTIVE_LOW_COMPLIMENT_MODE
MCPWMXA Out = MCPWMXA In with compliment of rising edge delay, MCPWMXB Out = MCPWMXA In with falling edge delay

MCPWM_ACTIVE_RED_FED_FROM_PWMXA
MCPWMXA Out = MCPWMXB Out = MCPWMXA In with rising edge delay as well as falling edge delay

MCPWM_ACTIVE_RED_FED_FROM_PWMXB
MCPWMXA Out = MCPWMXB Out = MCPWMXB In with rising edge delay as well as falling edge delay

MCPWM_DEADTIME_TYPE_MAX
Maximum number of supported dead time modes

def mcpwm_output_action_t
MCPWM select action to be taken on the output when event happens.
Values:

MCPWM_ACTION_NO_CHANGE = 0
No change in the output

MCPWM_ACTION_FORCE_LOW
Make output low

MCPWM_ACTION_FORCE_HIGH
Make output high

MCPWM_ACTION_TOGGLE
Make output toggle
```c
enum mcpwm_capture_signal_t

MCPWM_SELECT_CAP0
    Select CAP0 as input

MCPWM_SELECT_CAP1
    Select CAP1 as input

MCPWM_SELECT_CAP2
    Select CAP2 as input
```

2.3.12 Pulse Counter (PCNT)

Introduction

The PCNT (Pulse Counter) module is designed to count the number of rising and/or falling edges of an input signal. Each pulse counter unit has a 16-bit signed counter register and two channels that can be configured to either increment or decrement the counter. Each channel has a signal input that accepts signal edges to be detected, as well as a control input that can be used to enable or disable the signal input. The inputs have optional filters that can be used to discard unwanted glitches in the signal.

Functionality Overview

Description of functionality of this API has been broken down into four sections:

- **Configuration** - describes counter’s configuration parameters and how to setup the counter.
- **Operating the Counter** - provides information on control functions to pause, measure and clear the counter.
- **Filtering Pulses** - describes options to filtering pulses and the counter control signals.
- **Using Interrupts** - presents how to trigger interrupts on specific states of the counter.

Configuration

The PCNT module has 8 independent counting “units” numbered from 0 to 7. In the API they are referred to using `pcnt_unit_t`. Each unit has two independent channels numbered as 0 and 1 and specified with `pcnt_channel_t`.

The configuration is provided separately per unit’s channel using `pcnt_config_t` and covers:

- The unit and the channel number this configuration refers to.
- GPIO numbers of the pulse input and the pulse gate input.
- Two pairs of parameters: `pcnt_ctrl_mode_t` and `pcnt_count_mode_t` to define how the counter reacts depending on the status of control signal and how counting is done positive / negative edge of the pulses.
- Two limit values (minimum / maximum) that are used to establish watchpoints and trigger interrupts when the pulse count is meeting particular limit.

Setting up of particular channel is then done by calling a function `pcnt_unit_config()` with above `pcnt_config_t` as the input parameter.

To disable the pulse or the control input pin in configuration, provide `PCNT_PIN_NOT_USED` instead of the GPIO number.

Operating the Counter

After doing setup with `pcnt_unit_config()`, the counter immediately starts to operate. The accumulated pulse count can be checked by calling `pcnt_get_counter_value()`.
There are couple of functions that allow to control the counter’s operation: `pcnt_counter_pause()`, `pcnt_counter_resume()` and `pcnt_counter_clear()`.

It is also possible to dynamically change the previously set up counter modes with `pcnt_unit_config()` by calling `pcnt_set_mode()`.

If desired, the pulse input pin and the control input pin may be changed “on the fly” using `pcnt_set_pin()`.

To disable particular input provide as a function parameter `PCNT_PIN_NOT_USED` instead of the GPIO number.

**Note:** For the counter not to miss any pulses, the pulse duration should be longer than one APB_CLK cycle (12.5 ns). The pulses are sampled on the edges of the APB_CLK clock and may be missed, if fall between the edges. This applies to counter operation with or without a filter.

### Filtering Pulses

The PCNT unit features filters on each of the pulse and control inputs, adding the option to ignore short glitches in the signals.

The length of ignored pulses is provided in APB_CLK clock cycles by calling `pcnt_set_filter_value()`. The current filter setting may be checked with `pcnt_get_filter_value()`. The APB_CLK clock is running at 80 MHz.

The filter is put into operation / suspended by calling `pcnt_filter_enable()` / `pcnt_filter_disable()`.

### Using Interrupts

There are five counter state watch events, defined in `pcnt_evt_type_t`, that are able to trigger an interrupt. The event happens on the pulse counter reaching specific values:

- Minimum or maximum count values: `counter_l_lim` or `counter_h_lim` provided in `pcnt_config_t` as discussed in Configuration
- Threshold 0 or Threshold 1 values set using function `pcnt_set_event_value()`.
- Pulse count = 0

To register, enable or disable an interrupt to service the above events, call `pcnt_isr_register()`, `pcnt_intr_enable()`, and `pcnt_intr_disable()`. To enable or disable events on reaching threshold values, you will also need to call functions `pcnt_event_enable()` and `pcnt_event_disable()`.

In order to check what are the threshold values currently set, use function `pcnt_get_event_value()`.

### Application Example

- Pulse counter with control signal and event interrupt example: `peripherals/pcnt/pulse_count_event`.
- Parse the signal generated from rotary encoder: `peripherals/pcnt/rotary_encoder`.

### API Reference

#### Header File

- `components/driver/include/driver/pcnt.h`

#### Functions

```c
esp_err_t pcnt_unit_config(const pcnt_config_t *pcnt_config)
```

Configure Pulse Counter unit.
This function will disable three events: PCNT_EVT_L_LIM, PCNT_EVT_H_LIM, PCNT_EVT_ZERO.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE_pct_count_driver_already_initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- pcnt_config: Pointer of Pulse Counter unit configure parameter

\textit{esp_err_t} \textbf{pcnt_get_counter_value} (\textit{pcnt_unit_t} \textit{pcnt_unit}, int16_t \*\textit{count})
Get pulse counter value.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE_pct_count_driver_has_not_been_initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \textit{pcnt_unit}: Pulse Counter unit number
- \textit{count}: Pointer to accept counter value

\textit{esp_err_t} \textbf{pcnt_counter_pause} (\textit{pcnt_unit_t} \textit{pcnt_unit})
Pause PCNT counter of PCNT unit.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE_pct_count_driver_has_not_been_initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \textit{pcnt_unit}: PCNT unit number

\textit{esp_err_t} \textbf{pcnt_counter_resume} (\textit{pcnt_unit_t} \textit{pcnt_unit})
Resume counting for PCNT counter.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE_pct_count_driver_has_not_been_initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \textit{pcnt_unit}: PCNT unit number, select from \textit{pcnt_unit_t}

\textit{esp_err_t} \textbf{pcnt_counter_clear} (\textit{pcnt_unit_t} \textit{pcnt_unit})
Clear and reset PCNT counter value to zero.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE_pct_count_driver_has_not_been_initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \textit{pcnt_unit}: PCNT unit number, select from \textit{pcnt_unit_t}

\textit{esp_err_t} \textbf{pcnt_intr_enable} (\textit{pcnt_unit_t} \textit{pcnt_unit})
Enable PCNT interrupt for PCNT unit.

Note Each Pulse counter unit has five watch point events that share the same interrupt. Configure events with\textit{pcnt_event_enable()} and \textit{pcnt_event_disable()}.

Return
- ESP_OK Success
- ESP_ERR_INVALID_STATE_pct_count_driver_has_not_been_initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters
- \textit{pcnt_unit}: PCNT unit number

\textit{esp_err_t} \textbf{pcnt_intr_disable} (\textit{pcnt_unit_t} \textit{pcnt_unit})
Disable PCNT interrupt for PCNT unit.
Return

• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• pcnt_unit: PCNT unit number

`esp_err_t pcnt_event_enable(pcnt_unit_t unit, pcnt_evt_type_t evt_type)`

Enable PCNT event of PCNT unit.

Return

• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• unit: PCNT unit number
• evt_type: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).

`esp_err_t pcnt_event_disable(pcnt_unit_t unit, pcnt_evt_type_t evt_type)`

Disable PCNT event of PCNT unit.

Return

• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• unit: PCNT unit number
• evt_type: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).

`esp_err_t pcnt_set_event_value(pcnt_unit_t unit, pcnt_evt_type_t evt_type, int16_t value)`

Set PCNT event value of PCNT unit.

Return

• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• unit: PCNT unit number
• evt_type: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).
• value: Counter value for PCNT event

`esp_err_t pcnt_get_event_value(pcnt_unit_t unit, pcnt_evt_type_t evt_type, int16_t* value)`

Get PCNT event value of PCNT unit.

Return

• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
• ESP_ERR_INVALID_ARG Parameter error

Parameters

• unit: PCNT unit number
• evt_type: Watch point event type. All enabled events share the same interrupt (one interrupt per pulse counter unit).
• value: Pointer to accept counter value for PCNT event

`esp_err_t pcnt_get_event_status(pcnt_unit_t unit, uint32_t* status)`

Get PCNT event status of PCNT unit.

Return

• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
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- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- unit: PCNT unit number
- status: Pointer to accept event status word

`esp_err_t pcnt_isr_unregister (pcnt_isr_handle_t handle)`
Unregister PCNT interrupt handler (registered by `pcnt_isr_register`), the handler is an ISR. The handler will be attached to the same CPU core that this function is running on. If the interrupt service is registered by `pcnt_isr_service_install`, please call `pcnt_isr_service_uninstall` instead.

**Return**
- ESP_OK Success
- ESP_ERR_NOT_FOUND Can not find the interrupt that matches the flags.
- ESP_ERR_INVALID_ARG Function pointer error

**Parameters**
- handle: handle to unregister the ISR service.

`esp_err_t pcnt_isr_register (void (*fn) void*)`,
void *arg, int intr_alloc_flags, pcnt_isr_handle_t *handle
Register PCNT interrupt handler, the handler is an ISR. The handler will be attached to the same CPU core that this function is running on. Please do not use `pcnt_isr_service_install` if this function was called.

**Return**
- ESP_OK Success
- ESP_ERR_NOT_FOUND Can not find the interrupt that matches the flags.
- ESP_ERR_INVALID_ARG Function pointer error

**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. Calling `pcnt_isr_unregister` to unregister this ISR service if needed, but only if the handle is not NULL.

`esp_err_t pcnt_set_pin (pcnt_unit_t unit, pcnt_channel_t channel, int pulse_io, int ctrl_io)`
Configure PCNT pulse signal input pin and control input pin.

**Note** Set the signal input to PCNT_PIN_NOT_USED if unused.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- unit: PCNT unit number
- channel: PCNT channel number
- pulse_io: Pulse signal input GPIO
- ctrl_io: Control signal input GPIO

`esp_err_t pcnt_filter_enable (pcnt_unit_t unit)`
Enable PCNT input filter.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- unit: PCNT unit number

`esp_err_t pcnt_filter_disable (pcnt_unit_t unit)`
Disable PCNT input filter.

**Return**
• ESP_OK Success
• ESP_ERR_INVALID_STATE pcnt driver has not been initialized
• ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- *unit*: PCNT unit number

```c
esp_err_t pcnt_set_filter_value(pcnt_unit_t unit, uint16_t filter_val)
```

Set PCNT filter value.

**Note** filter_val is a 10-bit value, so the maximum filter_val should be limited to 1023.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- *unit*: PCNT unit number
- *filter_val*: PCNT signal filter value, counter in APB_CLK cycles. Any pulses lasting shorter than this will be ignored when the filter is enabled.

```c
esp_err_t pcnt_get_filter_value(pcnt_unit_t unit, uint16_t* filter_val)
```

Get PCNT filter value.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- *unit*: PCNT unit number
- *filter_val*: Pointer to accept PCNT filter value.

```c
esp_err_t pcnt_set_mode(pcnt_unit_t unit, pcnt_channel_t channel, pcnt_count_mode_t pos_mode, pcnt_count_mode_t neg_mode, pcnt_ctrl_mode_t hctrl_mode, pcnt_ctrl_mode_t lctrl_mode)
```

Set PCNT counter mode.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- *unit*: PCNT unit number
- *channel*: PCNT channel number
- *pos_mode*: Counter mode when detecting positive edge
- *neg_mode*: Counter mode when detecting negative edge
- *hctrl_mode*: Counter mode when control signal is high level
- *lctrl_mode*: Counter mode when control signal is low level

```c
esp_err_t pcnt_isr_handler_add(pcnt_unit_t unit, void (*isr_handler)(void *, void *), void *args)
```

Add ISR handler for specified unit.

Call this function after using pcnt_isr_service_install() to install the PCNT driver’s ISR handler service.

The ISR handlers do not need to be declared with IRAM_ATTR, unless you pass the ESP_INTR_FLAG_IRAM flag when allocating the ISR in pcnt_isr_service_install().

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 PCNT interrupt handler due to the additional level of indirection.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- *unit*: PCNT unit number
- *isr_handler*: ISR handler function
- *args*: User-defined data passed to the ISR.
Chapter 2. API Reference

- `unit`: PCNT unit number
- `isr_handler`: Interrupt handler function.
- `args`: Parameter for handler function

**esp_err_t pcnt_isr_service_install** (**int intr_alloc_flags**) 
Install PCNT ISR service.

**Note** We can manage different interrupt service for each unit. This function will use the default ISR handle service. Calling `pcnt_isr_service_uninstall` to uninstall the default service if needed. Please do not use `pcnt_isr_register` if this function was called.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_NO_MEM No memory to install this service
- ESP_ERR_INVALID_STATE ISR service already installed

**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.

**void pcnt_isr_service_uninstall** (**void**) 
Uninstall PCNT ISR service, freeing related resources.

**esp_err_t pcnt_isr_handler_remove** (**pcnt_unit_t unit**) 
Delete ISR handler for specified unit.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE pcnt driver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- `unit`: PCNT unit number

**Structures**

**struct pcnt_config_t**
Pulse Counter configuration for a single channel.

**Public Members**

- `int pulse_gpio_num` 
Pulse input GPIO number, if you want to use GPIO16, enter `pulse_gpio_num = 16`, a negative value will be ignored
- `int ctrl_gpio_num` 
Control signal input GPIO number, a negative value will be ignored
- `pcnt_ctrl_mode_t lctrl_mode` 
PCNT low control mode
- `pcnt_ctrl_mode_t hctrl_mode` 
PCNT high control mode
- `pcnt_count_mode_t pos_mode` 
PCNT positive edge count mode
- `pcnt_count_mode_t neg_mode` 
PCNT negative edge count mode
- `int16_t counter_h_lim` 
Maximum counter value
- `int16_t counter_l_lim` 
Minimum counter value
Chapter 2. API Reference

```c
pcnt_unit_t unit
    PCNT unit number
pcnt_channel_t channel
    the PCNT channel
```

### Macros

**PCNT_PIN_NOT_USED**
When selected for a pin, this pin will not be used.

**PCNT_MODE_KEEP**
Control mode: won’t change counter mode.

**PCNT_MODE_REVERSE**
Control mode: invert counter mode (increase -> decrease, decrease -> increase).

**PCNT_MODE_DISABLE**
Control mode: Inhibit counter (counter value will not change in this condition).

**PCNT_MODE_MAX**

**PCNT_COUNT_DIS**
Counter mode: Inhibit counter (counter value will not change in this condition).

**PCNT_COUNT_INC**
Counter mode: Increase counter value.

**PCNT_COUNT_DEC**
Counter mode: Decrease counter value.

**PCNT_COUNT_MAX**

### Type Definitions

```c
typedef intr_handle_t pcnt_isr_handle_t
typedef pcnt_channel_level_action_t pcnt_ctrl_mode_t
```

Selection of available modes that determine the counter’s action depending on the state of the control signal’s input GPIO.

**Note** Configuration covers two actions, one for high, and one for low level on the control input.

```c
typedef pcnt_channel_edge_action_t pcnt_count_mode_t
```

Selection of available modes that determine the counter’s action on the edge of the pulse signal’s input GPIO.

**Note** Configuration covers two actions, one for positive, and one for negative edge on the pulse input.

### Enumerations

```c
enum pcnt_port_t
    PCNT port number, the max port number is (PCNT_PORT_MAX - 1).

Values:

**PCNT_PORT_0**
    PCNT port 0

**PCNT_PORT_MAX**
    PCNT port max

enum pcnt_unit_t
    Selection of all available PCNT units.

Values:

**PCNT_UNIT_0**
    PCNT unit 0

**PCNT_UNIT_1**
    PCNT unit 1
```
Chapter 2. API Reference

PCNT_UNIT_2
PCNT unit 2

PCNT_UNIT_3
PCNT unit 3

PCNT_UNIT_MAX

enum pcnt_channel_t
Selection of channels available for a single PCNT unit.

Values:

PCNT_CHANNEL_0
PCNT channel 0

PCNT_CHANNEL_1
PCNT channel 1

PCNT_CHANNEL_MAX

enum pcnt_evt_type_t
Selection of counter’s events the may trigger an interrupt.

Values:

PCNT_EVT_THRES_1 = 1 << 2
PCNT watch point event: threshold1 value event

PCNT_EVT_THRES_0 = 1 << 3
PCNT watch point event: threshold0 value event

PCNT_EVT_L_LIM = 1 << 4
PCNT watch point event: Minimum counter value

PCNT_EVT_H_LIM = 1 << 5
PCNT watch point event: Maximum counter value

PCNT_EVT_ZERO = 1 << 6
PCNT watch point event: counter value zero event

PCNT_EVT_MAX

Header File

• components/hal/include/hal/pcnt_types.h

Enumerations

enum pcnt_channel_level_action_t
PCNT channel action on control level.

Values:

PCNT_CHANNEL_LEVEL_ACTION_KEEP
Keep current count mode

PCNT_CHANNEL_LEVEL_ACTION_INVERSE
Invert current count mode (increase -> decrease, decrease -> increase)

PCNT_CHANNEL_LEVEL_ACTION_HOLD
Hold current count value

enum pcnt_channel_edge_action_t
PCNT channel action on signal edge.

Values:

PCNT_CHANNEL_EDGE_ACTION_HOLD
Hold current count value
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**PCNT_CHANNEL_EDGE_ACTION_INCREASE**
Increase count value

**PCNT_CHANNEL_EDGE_ACTION_DECREASE**
Decrease count value

defined as:

```c
enum pcnt_unit_count_sign_t
{
  PCNT_UNIT_COUNT_SIGN_ZERO_POS,  // positive value to zero
  PCNT_UNIT_COUNT_SIGN_ZERO_NEG,  // negative value to zero
  PCNT_UNIT_COUNT_SIGN_NEG,       // counter value negative
  PCNT_UNIT_COUNT_SIGN_POS        // counter value positive
};
```

## 2.3.13 Remote Control (RMT)

The RMT (Remote Control) module driver can be used to send and receive infrared remote control signals. Due to the flexibility of the RMT module, the driver can also be used to generate or receive many other types of signals.

The signal, which consists of a series of pulses, is generated by RMT’s transmitter based on a list of values. The values define the pulse duration and a binary level, see below. The transmitter can also provide a carrier and modulate it with provided pulses.

The reverse operation is performed by the receiver, where a series of pulses is decoded into a list of values containing the pulse duration and binary level. A filter may be applied to remove high frequency noise from the input signal.

There are a couple of typical steps to setup and operate the RMT and they are discussed in the following sections:

1. **Configure Driver**
2. **Transmit Data or Receive Data**
3. **Change Operation Parameters**
4. **Use Interrupts**

The RMT has eight channels numbered from zero to seven. The first half (i.e. Channel 0 ~ 3) channels can only be configured for transmitting, and the other half (i.e. Channel 4 ~ 7) channels can only be configured for receiving. They are referred to using indexes defined in structure `rmt_channel_t`.

![RMT Transmitter Overview](image-url)
Configure Driver

There are several parameters that define how particular channel operates. Most of these parameters are configured by setting specific members of `rmt_config_t` structure. Some of the parameters are common to both transmit or receive mode, and some are mode specific. They are all discussed below.

Common Parameters

- The channel to be configured, select one from the `rmt_channel_t` enumerator.
- The RMT operation mode - whether this channel is used to transmit or receive data, selected by setting a `rmt_mode` member to one of the values from `rmt_mode_t`.
- What is the pin number to transmit or receive RMT signals, selected by setting `gpio_num`.
- How many memory blocks will be used by the channel, set with `mem_block_num`.
- Extra miscellaneous parameters for the channel can be set in the `flags`.
  - When `RMT_CHANNEL_FLAGS_AWARE_DFS` is set, RMT channel will take REF_TICK or XTAL as source clock. The benefit is, RMT channel can continue work even when APB clock is changing. See `power_management` for more information.
  - When `RMT_CHANNEL_FLAGS_INVERT_SIG` is set, the driver will invert the RMT signals sending to or receiving from the channel. It just works like an external inverter connected to the GPIO of certain RMT channel.
- A clock divider, that will determine the range of pulse length generated by the RMT transmitter or discriminated by the receiver. Selected by setting `clk_div` to a value within [1..255] range. The RMT source clock is typically APB CLK, 80Mhz by default. But when `RMT_CHANNEL_FLAGS_AWARE_DFS` is set in `flags`, RMT source clock is changed to REF_TICK or XTAL.

Note: The period of a square wave after the clock divider is called a ‘tick’. The length of the pulses generated by the RMT transmitter or discriminated by the receiver is configured in number of ‘ticks’.

There are also couple of specific parameters that should be set up depending if selected channel is configured in Transmit Mode or Receive Mode:

Transmit Mode  When configuring channel in transmit mode, set `tx_config` and the following members of `rmt_tx_config_t`:

- Transmit the currently configured data items in a loop - `loop_en`
- Enable the RMT carrier signal - `carrier_en`
- Frequency of the carrier in Hz - `carrier_freq_hz`
- Duty cycle of the carrier signal in percent (%) - `carrier_duty_percent`
- Level of the RMT output, when the carrier is applied - `carrier_level`
• Enable the RMT output if idle - `idle_output_en`
• Set the signal level on the RMT output if idle - `idle_level`
• Specify maximum number of transmissions in a loop - `loop_count`

**Receive Mode**  In receive mode, set `rx_config` and the following members of `rmt_rx_config_t`:

• Enable a filter on the input of the RMT receiver - `filter_en`
• A threshold of the filter, set in the number of ticks - `filter_ticks_thresh`. Pulses shorter than this setting will be filtered out. Note, that the range of entered tick values is [0..255].
• A pulse length threshold that will turn the RMT receiver idle, set in number of ticks - `idle_threshold`. The receiver will ignore pulses longer than this setting.
• Enable the RMT carrier demodulation - `carrier_rm`
• Frequency of the carrier in Hz - `carrier_freq_hz`
• Duty cycle of the carrier signal in percent (%) - `carrier_duty_percent`
• Level of the RMT input, where the carrier is modulated to - `carrier_level`

**Finalize Configuration**  Once the `rmt_config_t` structure is populated with parameters, it should be then invoked with `rmt_config()` to make the configuration effective.

The last configuration step is installation of the driver in memory by calling `rmt_driver_install()`. If `rx_buf_size` parameter of this function is > 0, then a ring buffer for incoming data will be allocated. A default ISR handler will be installed, see a note in Use Interrupts.

Now, depending on how the channel is configured, we are ready to either Transmit Data or Receive Data. This is described in next two sections.

**Transmit Data**

Before being able to transmit some RMT pulses, we need to define the pulse pattern. The minimum pattern recognized by the RMT controller, later called an ‘item’, is provided in a structure `rmt_item32_t`. Each item consists of two pairs of two values. The first value in a pair describes the signal duration in ticks and is 15 bits long, the second provides the signal level (high or low) and is contained in a single bit. A block of couple of items and the structure of an item is presented below.

![Structure of RMT items](image)

For a simple example how to define a block of items see `peripherals/rmt/morse_code`. 
The items are provided to the RMT controller by calling function `rmt_write_items()`. This function also automatically triggers start of transmission. It may be called to wait for transmission completion or exit just after transmission start. In such case you can wait for the transmission end by calling `rmt_wait_tx_done()`. This function does not limit the number of data items to transmit. It is using an interrupt to successively copy the new data chunks to RMT’s internal memory as previously provided data are sent out.

Another way to provide data for transmission is by calling `rmt_fill_tx_items()`. In this case transmission is not started automatically. To control the transmission process use `rmt_tx_start()` and `rmt_tx_stop()`. The number of items to sent is restricted by the size of memory blocks allocated in the RMT controller’s internal memory, see `rmt_set_mem_block_num()`.

**Receive Data**

Before starting the receiver we need some storage for incoming items. The RMT controller has 384 x 32-bits of internal RAM shared between all eight channels.

In typical scenarios it is not enough as an ultimate storage for all incoming (and outgoing) items. Therefore this API supports retrieval of incoming items on the fly to save them in a ring buffer of a size defined by the user. The size is provided when calling `rmt_driver_install()` discussed above. To get a handle to this buffer call `rmt_get_ringbuf_handle()`.

With the above steps complete we can start the receiver by calling `rmt_rx_start()` and then move to checking what’s inside the buffer. To do so, you can use common FreeRTOS functions that interact with the ring buffer. Please see an example how to do it in `peripherals/rmt/ir_protocols`.

To stop the receiver, call `rmt_rx_stop()`.

**Change Operation Parameters**

Previously described function `rmt_config()` provides a convenient way to set several configuration parameters in one shot. This is usually done on application start. Then, when the application is running, the API provides an alternate way to update individual parameters by calling dedicated functions. Each function refers to the specific RMT channel provided as the first input parameter. Most of the functions have `_get_` counterpart to read back the currently configured value.

**Parameters Common to Transmit and Receive Mode**

- Selection of a GPIO pin number on the input or output of the RMT - `rmt_set_gpio()`
- Number of memory blocks allocated for the incoming or outgoing data - `rmt_set_mem_pd()`
- Setting of the clock divider - `rmt_set_clk_div()`
- Selection of the clock source, note that currently one clock source is supported, the APB clock which is 80Mhz - `rmt_set_source_clk()`

**Transmit Mode Parameters**

- Enable or disable the loop back mode for the transmitter - `rmt_set_tx_loop_mode()`
- Binary level on the output to apply the carrier - `rmt_set_tx_carrier()`, selected from `rmt_carrier_level_t`
- Determines the binary level on the output when transmitter is idle - `rmt_set_idle_level()`, selected from `rmt_idle_level_t`
- Enable or disable loop count feature to automatically transmit items for N iterations, then trigger an ISR callback - `rmt_set_tx_loop_count()`
- Enable automatically stopping when the number of iterations matches the set loop count. Note this is not reliable for target that doesn’t support `SOC_RMT_SUPPORT_TX_LOOP_AUTOSTOP` - `rmt_enable_tx_loop_autostop()`
Receive Mode Parameters

- The filter setting - `rmt_set_rx_filter()`
- The receiver threshold setting - `rmt_set_rx_idle_thresh()`
- Whether the transmitter or receiver is entitled to access RMT’s memory - `rmt_set_memory_owner()`, selection is from `rmt_mem_owner_t`.

Use Interrupts

Registering of an interrupt handler for the RMT controller is done by calling `rmt_isr_register()`.

**Note:** When calling `rmt_driver_install()` to use the system RMT driver, a default ISR is being installed. In such a case you cannot register a generic ISR handler with `rmt_isr_register()`.

The RMT controller triggers interrupts on four specific events described below. To enable interrupts on these events, the following functions are provided:

- The RMT receiver has finished receiving a signal - `rmt_set_rx_intr_en()`
- The RMT transmitter has finished transmitting the signal - `rmt_set_tx_intr_en()`
- The number of events the transmitter has sent matches a threshold value - `rmt_set_tx_thr_intr_en()`
- Ownership to the RMT memory block has been violated - `rmt_set_err_intr_en()`

Setting or clearing an interrupt enable mask for specific channels and events may be also done by calling `rmt_set_intr_enable_mask()` or `rmt_clr_intr_enable_mask()`.

When servicing an interrupt within an ISR, the interrupt need to explicitly cleared. To do so, set specific bits described as `RMT.int.clr.val.chN_event_name` and defined as a volatile struct in `soc/esp32s3/include/soc/rmt_struct.h`, where N is the RMT channel number [0, n] and the `event_name` is one of four events described above.

If you do not need an ISR anymore, you can deregister it by calling a function `rmt_isr_deregister()`.

**Warning:** It’s not recommended for users to register an interrupt handler in their applications. RMT driver is highly dependent on interrupt, especially when doing transaction in a ping-pong way, so the driver itself has registered a default handler called `rmt_driver_isr_default`. Instead, if what you want is to get a notification when transaction is done, go ahead with `rmt_register_tx_end_callback()`.

Uninstall Driver

If the RMT driver has been installed with `rmt_driver_install()` for some specific period of time and then not required, the driver may be removed to free allocated resources by calling `rmt_driver_uninstall()`.

Application Examples

- Using RMT to send morse code: `peripherals/rmt/morse_code`
- Using RMT to drive RGB LED strip: `peripherals/rmt/led_strip`
- NEC remote control TX and RX example: `peripherals/rmt/ir_protocols`
- Musical buzzer example: `peripherals/rmt/musical_buzzer`

API Reference

Header File

- `components/driver/include/driver/rmt.h`
Chapter 2. API Reference

**Functions**

```c
esp_err_t rmt_set_clk_div (rmt_channel_t channel, uint8_t div_cnt)
```
Set RMT clock divider, channel clock is divided from source clock.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- div_cnt: RMT counter clock divider

```c
esp_err_t rmt_get_clk_div (rmt_channel_t channel, uint8_t* div_cnt)
```
Get RMT clock divider, channel clock is divided from source clock.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- div_cnt: pointer to accept RMT counter divider

```c
esp_err_t rmt_set_rx_idle_thresh (rmt_channel_t channel, uint16_t thresh)
```
Set RMT RX idle threshold value.

In receive mode, when no edge is detected on the input signal for longer than idle_thres channel clock cycles, the receive process is finished.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- thresh: RMT RX idle threshold

```c
esp_err_t rmt_get_rx_idle_thresh (rmt_channel_t channel, uint16_t* thresh)
```
Get RMT idle threshold value.

In receive mode, when no edge is detected on the input signal for longer than idle_thres channel clock cycles, the receive process is finished.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- thresh: pointer to accept RMT RX idle threshold value

```c
esp_err_t rmt_set_mem_block_num (rmt_channel_t channel, uint8_t rmt_mem_num)
```
Set RMT memory block number for RMT channel.

This function is used to configure the amount of memory blocks allocated to channel n. The 8 channels share a 512x32-bit RAM block which can be read and written by the processor cores over the APB bus, as well as read by the transmitters and written by the receivers.

The RAM address range for channel n is start_addr_CHn to end_addr_CHn, which are defined by:

```
Memory block start address is RMT_CHANNEL_MEM(n) (in soc/rmt_reg.h), that is, start_addr_CHn = RMT base address + 0x800 + 64 * 4 * n, and end_addr_CHn = RMT base address + 0x800 + 64 * 4 * n + 64 * 4 * RMT_MEM_SIZE_CHn mod 512 + 4
```

(continues on next page)
If memory block number of one channel is set to a value greater than 1, this channel will occupy the memory block of the next channel. Channel 0 can use at most 8 blocks of memory, accordingly channel 7 can only use one memory block.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- `channel`: RMT channel
- `rmt_mem_num`: RMT RX memory block number, one block has 64 * 32 bits.

```c
esp_err_t rmt_get_mem_block_num(rmt_channel_t channel, uint8_t* rmt_mem_num)
```

Get RMT memory block number.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- `channel`: RMT channel
- `rmt_mem_num`: Pointer to accept RMT RX memory block number

```c
esp_err_t rmt_set_tx_carrier(rmt_channel_t channel, bool carrier_en, uint16_t high_level, uint16_t low_level, rmt_carrier_level_t carrier_level)
```

Configure RMT carrier for TX signal.

Set different values for `carrier_high` and `carrier_low` to set different frequency of carrier. The unit of `carrier_high`/`low` is the source clock tick, not the divided channel counter clock.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- `channel`: RMT channel
- `carrier_en`: Whether to enable output carrier.
- `high_level`: High level duration of carrier
- `low_level`: Low level duration of carrier.
- `carrier_level`: Configure the way carrier wave is modulated for channel.
  - 1'b1: transmit on low output level
  - 1'b0: transmit on high output level

```c
esp_err_t rmt_set_mem_pd(rmt_channel_t channel, bool pd_en)
```

Set RMT memory in low power mode.

Reduce power consumed by memory. memory is in low power state.

Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters
- `channel`: RMT channel
- `pd_en`: RMT memory low power enable.

```c
esp_err_t rmt_get_mem_pd(rmt_channel_t channel, bool *pd_en)
```

Get RMT memory low power mode.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel
• pd_en: Pointer to accept RMT memory low power mode.

\texttt{esp_err_t rmt\_tx\_start(rmt\_channel\_t channel, bool tx\_idx\_rst)}

Set RMT start sending data from memory.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel

\texttt{esp_err_t rmt\_tx\_stop(rmt\_channel\_t channel)}

Set RMT stop sending.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel

\texttt{esp_err_t rmt\_rx\_start(rmt\_channel\_t channel, bool rx\_idx\_rst)}

Set RMT start receiving data.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel

\texttt{esp_err_t rmt\_rx\_stop(rmt\_channel\_t channel)}

Set RMT stop receiving data.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel

\texttt{esp_err_t rmt\_tx\_memory\_reset(rmt\_channel\_t channel)}

Reset RMT TX memory.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel

\texttt{esp_err_t rmt\_rx\_memory\_reset(rmt\_channel\_t channel)}

Reset RMT RX memory.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel
**esp_err_t rmt_set_memory_owner (rmt_channel_t channel, rmt_mem_owner_t owner)**

Set RMT memory owner.

**Note** Setting memory is only valid for RX channel.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- owner: To set when the transmitter or receiver can process the memory of channel.

**esp_err_t rmt_get_memory_owner (rmt_channel_t channel, rmt_mem_owner_t *owner)**

Get RMT memory owner.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- owner: Pointer to get memory owner.

**esp_err_t rmt_set_tx_loop_mode (rmt_channel_t channel, bool loop_en)**

Set RMT tx loop mode.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- loop_en: Enable RMT transmitter loop sending mode. If set true, transmitter will continue sending from the first data to the last data in channel over and over again in a loop.

**esp_err_t rmt_get_tx_loop_mode (rmt_channel_t channel, bool *loop_en)**

Get RMT tx loop mode.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- loop_en: Pointer to accept RMT transmitter loop sending mode.

**esp_err_t rmt_set_rx_filter (rmt_channel_t channel, bool rx_filter_en, uint8_t thresh)**

Set RMT RX filter.

In receive mode, channel will ignore input pulse when the pulse width is smaller than threshold.

Counted in source clock, not divided counter clock.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- rx_filter_en: To enable RMT receiver filter.
- thresh: Threshold of pulse width for receiver.

**esp_err_t rmt_set_source_clk (rmt_channel_t channel, rmt_source_clk_t base_clk)**

Set RMT source clock.

RMT module has two clock sources:
1. APB clock which is 80Mhz
2. REF tick clock, which would be 1Mhz (not supported in this version).
Return

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters

- channel: RMT channel
- base_clk: To choose source clock for RMT module.

**esp_err_t rmt_get_source_clk (rmt_channel_t channel, rmt_source_clk_t *src_clk)**

Get RMT source clock.

---

RMT module has two clock sources:
1. APB clock which is 80Mhz
2. REF tick clock, which would be 1Mhz (not supported in this version).

Return

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters

- channel: RMT channel
- src_clk: Pointer to accept source clock for RMT module.

**esp_err_t rmt_set_idle_level (rmt_channel_t channel, bool idle_out_en, rmt_idle_level_t level)**

Set RMT idle output level for transmitter.

Return

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters

- channel: RMT channel
- idle_out_en: To enable idle level output.
- level: To set the output signal’s level for channel in idle state.

**esp_err_t rmt_get_idle_level (rmt_channel_t channel, bool *idle_out_en, rmt_idle_level_t *level)**

Get RMT idle output level for transmitter.

Return

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters

- channel: RMT channel
- idle_out_en: Pointer to accept value of enable idle.
- level: Pointer to accept value of output signal’s level in idle state for specified channel.

**esp_err_t rmt_get_status (rmt_channel_t channel, uint32_t *status)**

Get RMT status.

Return

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters

- channel: RMT channel
- status: Pointer to accept channel status. Please refer to RMT_CHnSTATUS_REG(n=0-7) in rmt_reg.h for more details of each field.

**esp_err_t rmt_set_rx_intr_en (rmt_channel_t channel, bool en)**

Set RMT RX interrupt enable.

Return

- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

Parameters

- channel: RMT channel
- en: enable or disable RX interrupt.
**esp_err_t rmt_set_err_intr_en(rmt_channel_t channel, bool en)**

Set RMT RX error interrupt enable.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- en: enable or disable RX err interrupt.

**esp_err_t rmt_set_tx_intr_en(rmt_channel_t channel, bool en)**

Set RMT TX interrupt enable.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- en: enable or disable TX interrupt.

**esp_err_t rmt_set_tx_thr_intr_en(rmt_channel_t channel, bool en, uint16_t evt_thresh)**

Set RMT TX threshold event interrupt enable.

An interrupt will be triggered when the number of transmitted items reaches the threshold value.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- channel: RMT channel
- en: enable or disable TX event interrupt.
- evt_thresh: RMT event interrupt threshold value

**esp_err_t rmt_set_gpio(rmt_channel_t channel, rmt_mode_t mode, gpio_num_t gpio_num, bool invert_signal)**

Configure the GPIO used by RMT channel.

**Return**
- ESP_ERR_INVALID_ARG Configure RMT GPIO failed because of wrong parameter
- ESP_OK Configure RMT GPIO successfully

**Parameters**
- channel: RMT channel
- mode: RMT mode, either RMT_MODE_TX or RMT_MODE_RX
- gpio_num: GPIO number, which is connected with certain RMT signal
- invert_signal: Invert RMT signal physically by GPIO matrix

**esp_err_t rmt_config(const rmt_config_t *rmt_param)**

Configure RMT parameters.

**Return**
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

**Parameters**
- rmt_param: RMT parameter struct

**esp_err_t rmt_isr_register(void (*fn) void * arg, int intr_alloc_flags, rmt_isr_handle_t *handle)**

Register RMT interrupt handler, the handler is an ISR.

The handler will be attached to the same CPU core that this function is running on.

**Note** If you already called rmt_driver_install to use system RMT driver, please do not register ISR handler again.
Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Function pointer error.
• ESP_FAIL System driver installed, can not register ISR handler for RMT

Parameters
• fn: Interrupt handler function.
• arg: Parameter for 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: If non-zero, a handle to later clean up the ISR gets stored here.

`esp_err_t rmt_isr_deregister(rmt_isr_handle_t handle)`
Deregister previously registered RMT interrupt handler.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Handle invalid

Parameters
• handle: Handle obtained from rmt_isr_register

`esp_err_t rmt_fill_tx_items(rmt_channel_t channel, const rmt_item32_t *item, uint16_t item_num, uint16_t mem_offset)`
Fill memory data of channel with given RMT items.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel
• item: Pointer of items.
• item_num: RMT sending items number.
• mem_offset: Index offset of memory.

`esp_err_t rmt_driver_install(rmt_channel_t channel, size_t rx_buf_size, int intr_alloc_flags)`
Initialize RMT driver.

Return
• ESP_ERR_INVALID_STATE Driver is already installed, call rmt_driver_uninstall first.
• ESP_ERR_NO_MEM Memory allocation failure
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel
• rx_buf_size: Size of RMT RX ringbuffer. Can be 0 if the RX ringbuffer is not used.
• intr_alloc_flags: Flags for the RMT driver interrupt handler. Pass 0 for default flags. See esp_intr_alloc.h for details. If ESP_INTR_FLAG_IRAM is used, please do not use the memory allocated from psram when calling rmt_write_items.

`esp_err_t rmt_driver_uninstall(rmt_channel_t channel)`
Uninstall RMT driver.

Return
• ESP_ERR_INVALID_ARG Parameter error
• ESP_OK Success

Parameters
• channel: RMT channel

`esp_err_t rmt_get_channel_status(rmt_channel_status_result_t *channel_status)`
Get the current status of eight channels.

Note Do not call this function if it is possible that rmt_driver_uninstall will be called at the same time.

Return
**Chapter 2. API Reference**

- **ESP_ERR_INVALID_ARG** Parameter is NULL
- **ESP_OK** Success

### Parameters
- **channel_status**: store the current status of each channel

```c
esp_err_t rmt_get_counter_clock(rmt_channel_t channel, uint32_t* clock_hz)
```

Get speed of channel’s internal counter clock.

**Return**
- **ESP_ERR_INVALID_ARG** Parameter is NULL
- **ESP_OK** Success

### Parameters
- **channel**: RMT channel
- **clock_hz**: counter clock speed, in hz

```c
esp_err_t rmt_write_items(rmt_channel_t channel, const rmt_item32_t* rmt_item, int item_num, bool wait_tx_done)
```

RMT send waveform from rmt_item array.

**Note**
This function will not copy data, instead, it will point to the original items, and send the waveform items.

If `wait_tx_done` is set to true, this function will block and will not return until all items have been sent out. If `wait_tx_done` is set to false, this function will return immediately, and the driver interrupt will continue sending the items. We must make sure the item data will not be damaged when the driver is still sending items in driver interrupt.

**Return**
- **ESP_ERR_INVALID_ARG** Parameter error
- **ESP_OK** Success

### Parameters
- **channel**: RMT channel
- **rmt_item**: head point of RMT items array. If ESP_INTR_FLAG_IRAM is used, please do not use the memory allocated from psram when calling rmt_write_items.
- **item_num**: RMT data item number.
- **wait_tx_done**:
  - If set 1, it will block the task and wait for sending done.
  - If set 0, it will not wait and return immediately.

```c
esp_err_t rmt_wait_tx_done(rmt_channel_t channel, TickType_t wait_time)
```

Wait RMT TX finished.

**Return**
- **ESP_OK** RMT Tx done successfully
- **ESP_ERR_TIMEOUT** Exceeded the ‘wait_time’ given
- **ESP_ERR_INVALID_ARG** Parameter error
- **ESP_FAIL** Driver not installed

### Parameters
- **channel**: RMT channel
- **wait_time**: Maximum time in ticks to wait for transmission to be complete. If set 0, return immediately with ESP_ERR_TIMEOUT if TX is busy (polling).

```c
esp_err_t rmt_get_ringbuf_handle(rmt_channel_t channel, RingbufHandle_t* buf_handle)
```

Get ringbuffer from RMT.

**Return**
- **ESP_ERR_INVALID_ARG** Parameter error
- **ESP_OK** Success

### Parameters
- **channel**: RMT channel
- **buf_handle**: Pointer to buffer handle to accept RX ringbuffer handle.

Users can get the RMT RX ringbuffer handle, and process the RX data.
**Chapter 2. API Reference**

**esp_err_t rmt_translator_init (rmt_channel_t channel, sample_to_rmt_t fn)**

Init rmt translator and register user callback. The callback will convert the raw data that needs to be sent to rmt format. If a channel is initialized more than once, the user callback will be replaced by the later.

**Return**
- ESP_FAIL Init fail.
- ESP_OK Init success.

**Parameters**
- channel: RMT channel.
- fn: Point to the data conversion function.

**esp_err_t rmt_translator_set_context (rmt_channel_t channel, void *context)**

Set user context for the translator of specific channel.

**Return**
- ESP_FAIL Set context fail
- ESP_OK Set context success

**Parameters**
- channel: RMT channel number
- context: User context

**esp_err_t rmt_translator_get_context (const size_t *item_num, void **context)**

Get the user context set by ‘rmt_translator_set_context’.

**Note** This API must be invoked in the RMT translator callback function, and the first argument must be the actual parameter ‘item_num’ you got in that callback function.

**Return**
- ESP_FAIL Get context fail
- ESP_OK Get context success

**Parameters**
- item_num: Address of the memory which contains the number of translated items (It’s from driver’s internal memory)
- context: Returned User context

**esp_err_t rmt_write_sample (rmt_channel_t channel, const uint8_t *src, size_t src_size, bool wait_tx_done)**

Translate uint8_t type of data into rmt format and send it out. Requires rmt_translator_init to init the translator first.

**Return**
- ESP_FAIL Send fail
- ESP_OK Send success

**Parameters**
- channel: RMT channel.
- src: Pointer to the raw data.
- src_size: The size of the raw data.
- wait_tx_done: Set true to wait all data sent done.

**rmt_tx_end_callback_t rmt_register_tx_end_callback (rmt_tx_end_fn_t function, void *arg)**

Registers a callback that will be called when transmission ends.

Called by rmt_driver_isr_default in interrupt context.

**Note** Requires rmt_driver_install to install the default ISR handler.

**Return** the previous callback settings (members will be set to NULL if there was none)

**Parameters**
- function: Function to be called from the default interrupt handler or NULL.
- arg: Argument which will be provided to the callback when it is called.

**esp_err_t rmt_set_rx_thr_intr_en (rmt_channel_t channel, bool en, uint16_t evt_thresh)**

Set RMT RX threshold event interrupt enable.

An interrupt will be triggered when the number of received items reaches the threshold value.
### ESP_ERR_INVALID_ARG Parameter error
- Parameter error

### ESP_OK Success
- Success

### Parameters
- channel: RMT channel
- en: enable or disable RX event interrupt.
- evt_thresh: RMT event interrupt threshold value

### `esp_err_t rmt_add_channel_to_group (rmt_channel_t channel)`
Add channel into a synchronous group (channels in the same group can start transaction simultaneously)

#### Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

#### Parameters
- channel: RMT channel

### `esp_err_t rmt_remove_channel_from_group (rmt_channel_t channel)`
Remove channel out of a group.

#### Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

#### Parameters
- channel: RMT channel

### `esp_err_t rmt_set_tx_loop_count (rmt_channel_t channel, uint32_t count)`
Set loop count threshold value for RMT TX channel.

When tx loop count reaches this value, an ISR callback will notify user

#### Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

#### Parameters
- channel: RMT channel
- count: loop count, 1 ~ 1023

### `esp_err_t rmt_enable_tx_loop_autostop (rmt_channel_t channel, bool en)`
Enable or disable the feature that when loop count reaches the threshold, RMT will stop transmitting.

- When the loop auto-stop feature is enabled will halt RMT transmission after the loop count reaches a certain threshold
- When disabled, the RMT transmission continue indefinitely until halted by the users

#### Note
- The auto-stop feature is implemented in hardware on particular targets (i.e. those with SOC_RMT_SUPPORT_TX_LOOP_AUTOSTOP defined). Otherwise, the auto-stop feature is implemented in software via the interrupt.

#### Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

#### Parameters
- channel: RMT channel
- en: enable bit

### `esp_err_t rmt_memory_rw_rst (rmt_channel_t channel)`
Reset RMT TX/RX memory index.

#### Return
- ESP_ERR_INVALID_ARG Parameter error
- ESP_OK Success

#### Parameters
- channel: RMT channel
void \texttt{rmt\_set\_intr\_enable\_mask} (uint32\_t \texttt{mask})
Set mask value to RMT interrupt enable register.

\textbf{Parameters}
- \texttt{mask}: Bit mask to set to the register

void \texttt{rmt\_clr\_intr\_enable\_mask} (uint32\_t \texttt{mask})
Clear mask value to RMT interrupt enable register.

\textbf{Parameters}
- \texttt{mask}: Bit mask to clear the register

\texttt{esp\_err\_t rmt\_set\_pin} (rmt\_channel\_t \texttt{channel}, rmt\_mode\_t \texttt{mode}, gpio\_num\_t \texttt{gpio\_num})
Set RMT pin.

\textbf{Return}
- ESP\_ERR\_INVALID\_ARG Parameter error
- ESP\_OK Success

\textbf{Parameters}
- \texttt{channel}: RMT channel
- \texttt{mode}: TX or RX mode for RMT
- \texttt{gpio\_num}: GPIO number to transmit or receive the signal.

\textbf{Structures}
\texttt{struct rmt\_item32\_t}
Definition of RMT item.

\textbf{Public Members}
- \texttt{uint32\_t duration0}: 15
  Duration of level0
- \texttt{uint32\_t level0}: 1
  Level of the first part
- \texttt{uint32\_t duration1}: 15
  Duration of level1
- \texttt{uint32\_t level1}: 1
  Level of the second part
- \texttt{uint32\_t val}
  Equivalent unsigned value for the RMT item

\texttt{struct rmt\_tx\_config\_t}
Data struct of RMT TX configure parameters.

\textbf{Public Members}
- \texttt{uint32\_t carrier\_freq\_hz}
  RMT carrier frequency

\texttt{rmt\_carrier\_level\_t carrier\_level}
Level of the RMT output, when the carrier is applied

\texttt{rmt\_idle\_level\_t idle\_level}
RMT idle level

\texttt{uint8\_t carrier\_duty\_percent}
RMT carrier duty (%)

\texttt{uint32\_t loop\_count}
Maximum loop count
bool carrier_en
   RMT carrier enable

bool loop_en
   Enable sending RMT items in a loop

bool idle_output_en
   RMT idle level output enable

struct rmt_rx_config_t
   Data struct of RMT RX configure parameters.

Public Members

    uint16_t idle_threshold
       RMT RX idle threshold

    uint8_t filter_ticks_thresh
       RMT filter tick number

    bool filter_en
       RMT receiver filter enable

    bool rm_carrier
       RMT receiver remove carrier enable

    uint32_t carrier_freq_hz
       RMT carrier frequency

    uint8_t carrier_duty_percent
       RMT carrier duty (%)

    rmt_carrier_level_t carrier_level
       The level to remove the carrier

struct rmt_config_t
   Data struct of RMT configure parameters.

Public Members

    rmt_mode_t rmt_mode
       RMT mode: transmitter or receiver

    rmt_channel_t channel
       RMT channel

    gpio_num_t gpio_num
       RMT GPIO number

    uint8_t clk_div
       RMT channel counter divider

    uint8_t mem_block_num
       RMT memory block number

    uint32_t flags
       RMT channel extra configurations, OR’d with RMT_CHANNEL_FLAGS[*]

    rmt_tx_config_t tx_config
       RMT TX parameter

    rmt_rx_config_t rx_config
       RMT RX parameter

struct rmt_tx_end_callback_t
   Structure encapsulating a RMT TX end callback.
Public Members

```c
rmt_tx_end_fn_t function
    Function which is called on RMT TX end

void *arg
    Optional argument passed to function
```

Macros

```c
RMT_CHANNEL_FLAGS_AWARE_DFS
    Channel can work during APB clock scaling

RMT_CHANNEL_FLAGS_INVERT_SIG
    Invert RMT signal

RMT_MEM_ITEM_NUM
    Define memory space of each RMT channel (in words = 4 bytes)

RMT_DEFAULT_CONFIG_TX (gpio, channel_id)
    Default configuration for Tx channel.

RMT_DEFAULT_CONFIG_RX (gpio, channel_id)
    Default configuration for RX channel.
```

Type Definitions

```c
typedef intr_handle_t rmt_isr_handle_t
    RMT interrupt handle.

typedef void (*rmt_tx_end_fn_t)(rmt_channel_t channel, void *arg)
    Type of RMT Tx End callback function.

typedef void (*sample_to_rmt_t)(const void *src, rmt_item32_t *dest, size_t src_size, size_t wanted_num, size_t *translated_size, size_t *item_num)
    User callback function to convert uint8_t type data to rmt format(rmt_item32_t).
```

Note
In fact, item_num should be a multiple of translated_size, e.g.: When we convert each byte of uint8_t type data to rmt format data, the relation between item_num and translated_size should be item_num = translated_size*8.

Parameters

- `src`: Pointer to the buffer storing the raw data that needs to be converted to rmt format.
- `[out] dest`: Pointer to the buffer storing the rmt format data.
- `src_size`: The raw data size.
- `wanted_num`: The number of rmt format data that wanted to get.
- `[out] translated_size`: The size of the raw data that has been converted to rmt format, it should return 0 if no data is converted in user callback.
- `[out] item_num`: The number of the rmt format data that actually converted to, it can be less than wanted_num if there is not enough raw data, but cannot exceed wanted_num. it should return 0 if no data was converted.

Header File

- `components/hal/include/hal/rmt_types.h`

Structures

```c
struct rmt_channel_status_result_t
    Data struct of RMT channel status.
```
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Public Members

```c
rmt_channel_status_t status[RMT_CHANNEL_MAX]
```

Store the current status of each channel

Enumerations

```c
class rmt_channel_t
RMT channel ID.

Values:
- RMT_CHANNEL_0: RMT channel number 0
- RMT_CHANNEL_1: RMT channel number 1
- RMT_CHANNEL_2: RMT channel number 2
- RMT_CHANNEL_3: RMT channel number 3
- RMT_CHANNEL_4: RMT channel number 4
- RMT_CHANNEL_5: RMT channel number 5
- RMT_CHANNEL_6: RMT channel number 6
- RMT_CHANNEL_7: RMT channel number 7
- RMT_CHANNEL_MAX: Number of RMT channels
```

```c
class rmt_mem_owner_t
RMT Internal Memory Owner.

Values:
- RMT_MEM_OWNER_TX: RMT RX mode, RMT transmitter owns the memory block
- RMT_MEM_OWNER_RX: RMT RX mode, RMT receiver owns the memory block
- RMT_MEM_OWNER_MAX
```

```c
class rmt_source_clk_t
Clock Source of RMT Channel.

Values:
- RMT_BASECLK_APB = 1: RMT source clock is APB CLK, 80Mhz by default
- RMT_BASECLK_XTAL = 3: RMT source clock is XTAL clock, 40Mhz by default
- RMT_BASECLK_MAX
```

```c
class rmt_data_mode_t
RMT Data Mode.

Note: We highly recommended to use MEM mode not FIFO mode since there will be some gotcha in FIFO mode.
```

```c
enum rmt_mem_owner_t
RMT Internal Memory Owner.

Values:
- RMT_MEM_OWNER_TX: RMT RX mode, RMT transmitter owns the memory block
- RMT_MEM_OWNER_RX: RMT RX mode, RMT receiver owns the memory block
- RMT_MEM_OWNER_MAX
```

```c
class rmt_source_clk_t
Clock Source of RMT Channel.

Values:
- RMT_BASECLK_APB = 1: RMT source clock is APB CLK, 80Mhz by default
- RMT_BASECLK_XTAL = 3: RMT source clock is XTAL clock, 40Mhz by default
- RMT_BASECLK_MAX
```

```c
class rmt_data_mode_t
RMT Data Mode.

Note: We highly recommended to use MEM mode not FIFO mode since there will be some gotcha in FIFO mode.
```
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Values:

RMT_DATA_MODE_FIFO
RMT_DATA_MODE_MEM
RMT_DATA_MODE_MAX

enum rmt_mode_t
RMT Channel Working Mode (TX or RX)

Values:

RMT_MODE_TX
RMT_TX mode
RMT_MODE_RX
RMT RX mode
RMT_MODE_MAX

enum rmt_idle_level_t
RMT Idle Level.

Values:

RMT_IDLE_LEVEL_LOW
RMT TX idle level: low Level
RMT_IDLE_LEVEL_HIGH
RMT TX idle level: high Level
RMT_IDLE_LEVEL_MAX

enum rmt_carrier_level_t
RMT Carrier Level.

Values:

RMT_CARRIER_LEVEL_LOW
RMT carrier wave is modulated for low Level output
RMT_CARRIER_LEVEL_HIGH
RMT carrier wave is modulated for high Level output
RMT_CARRIER_LEVEL_MAX

enum rmt_channel_status_t
RMT Channel Status.

Values:

RMT_CHANNEL_UNINIT
RMT channel uninitialized
RMT_CHANNEL_IDLE
RMT channel status idle
RMT_CHANNEL_BUSY
RMT channel status busy

2.3.14 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-S3 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.

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-S3 SDMMC host controller allows using any of GPIOs for any of SD interface signals. However, it is recommended to avoid using strapping GPIOs, GPIOs with internal weak pull-downs and GPIOs commonly used for other purposes to prevent conflicts:

- GPIO0 (strapping pin)
- GPIO45, GPIO46 (strapping pins, internal weak pulldown)
- GPIO26 - GPIO32 (commonly used for SPI Flash and PSRAM)
- GPIO33 - GPIO37 (when using chips and modules with Octal SPI Flash or Octal PSRAM)
- GPIO43, GPIO44 (GPIOs used for UART0 by default)
- GPIO19, GPIO20 (GPIOs used for USB by default)

#### Systems in Packages (SIP)

#### Modules

#### Development Boards

- ESP32-S3-DevKitC-1
  - No Pull-ups
- ESP32-S3-USB-OTG
  - The board may be used in 1-line and 4-line SD mode or SPI mode.
  - Required pull-ups are provided on GPIOs 33-38.
- ESP32-S3-EYE
  - The board is limited to 1-line SD mode.
  - Required pull-ups are provided on GPIOs 38-40.

#### 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.
Related Information

2.3.15 SDMMC Host Driver

Overview

ESP32-S3’s SDMMC host peripheral has two slots. Each slot can be used independently to connect to an SD card, SDIO device or eMMC chip.

Both slots (SDMMC_HOST_SLOT_0, SDMMC_HOST_SLOT_1) support 1-, 4- and 8-line SD interface. The slots are connected to ESP32-S3 GPIOs using GPIO matrix. This means that any GPIO may be used for each of the SD card signals.

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:

```
sdmmc_host_t host = SDMMC_HOST_DEFAULT();
host.max_freq_khz = SDMMC_FREQ_HIGHSPEED;
```

To configure the bus width, set the width field of sdmmc_slot_config_t. For example, to set 1-line mode:

```
sdmmc_slot_config_t slot = SDMMC_SLOT_CONFIG_DEFAULT();
slot.width = 1;
```
Configuring GPIOs

ESP32-S3 SDMMC Host can be configured to use arbitrary GPIOs for each of the signals. Configuration is performed by setting members of `sdmmc_slot_config_t` structure. For example, to use GPIOs 1-6 for CLK, CMD, D0 - D3 signals, respectively:

```c
sdmmc_slot_config_t slot = SDMMC_SLOT_CONFIG_DEFAULT();
slot.clk = GPIO_NUM_1;
slot.cmd = GPIO_NUM_2;
slot.d0 = GPIO_NUM_3;
slot.d1 = GPIO_NUM_4;
slot.d2 = GPIO_NUM_5;
slot.d3 = GPIO_NUM_6;
```

It is also possible to configure Card Detect and Write Protect pins. Similar to other signals, set `cd` and `wp` members of the same structure:

```c
slot.cd = GPIO_NUM_7;
slot.wp = GPIO_NUM_8;
```

`SDMMC_SLOT_CONFIG_DEFAULT` sets both to `GPIO_NUM_NC`, meaning that by default the signals are not used.

Once `sdmmc_slot_config_t` structure is initialized this way, you can use it when calling `sdmmc_host_init_slot()` or one of the higher level functions, such as `esp_vfs_fat_sdmmc_mount()`.

**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

DDR 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* for the higher level driver which implements the protocol layer.

See *SD SPI Host Driver* for a similar driver which uses the SPI controller and is limited to SD protocol’s SPI mode.

See *SD Pull-up Requirements* for pullup support and compatibilities of modules and development kits.

**API Reference**

**Header File**

- components/driver/include/driver/sdmmc_host.h

**Functions**

- `esp_err_t sdmmc_host_init(void)`
  
  Initialize SDMMC host peripheral.

  **Note** This function is not thread safe

  **Return**

  - ESP_OK on success
Chapter 2. API Reference

- ESP_ERR_INVALID_STATE if sdmmc_host_init was already called
- ESP_ERR_NO_MEM if memory can not be allocated

\texttt{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.

\textbf{Note} This function is not thread safe

\textbf{Return}

- ESP_OK on success
- ESP_ERR_INVALID_STATE if host has not been initialized using sdmmc_host_init

\textbf{Parameters}

- \texttt{slot}: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- \texttt{slot_config}: additional configuration for the slot

\texttt{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)

\textbf{Note} This function is not thread safe

\textbf{Return}

- ESP_OK on success
- ESP_ERR_INVALID_ARG if slot number or width is not valid

\textbf{Parameters}

- \texttt{slot}: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- \texttt{width}: bus width (1, 4, or 8 for slot 0; 1 or 4 for slot 1)

\texttt{size_t sdmmc_host_get_slot_width (int slot)}

Get bus width configured in sdmmc_host_init_slot to be used for data transfer.

\textbf{Return} configured bus width of the specified slot.

\textbf{Parameters}

- \texttt{slot}: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)

\texttt{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.

\textbf{Note} This function is not thread safe

\textbf{Return}

- ESP_OK on success
- other error codes may be returned in the future

\textbf{Parameters}

- \texttt{slot}: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- \texttt{freq_khz}: card clock frequency, in kHz

\texttt{esp_err_t sdmmc_host_set_bus_ddr_mode (int slot, bool ddr_enabled)}

Enable or disable DDR mode of SD interface.

\textbf{Return}

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if DDR mode is not supported on this slot

\textbf{Parameters}

- \texttt{slot}: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- \texttt{ddr_enabled}: enable or disable DDR mode
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.

**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.

**Attention** Data buffer passed in cmdinfo->data must be in DMA capable memory

**Return**
- 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

**Parameters**
- slot: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- cmdinfo: pointer to structure describing command and data to transfer

esp_err_t sdmmc_host_io_int_enable (int slot)

Enable IO interrupts.

This function configures the host to accept SDIO interrupts.

**Return** returns ESP_OK, other errors possible in the future

**Parameters**
- slot: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)

esp_err_t sdmmc_host_io_int_wait (int slot, TickType_t timeout_ticks)

Block until an SDIO interrupt is received, or timeout occurs.

**Return**
- ESP_OK on success (interrupt received)
- ESP_ERR_TIMEOUT if the interrupt did not occur within timeout_ticks

**Parameters**
- slot: slot number (SDMMC_HOST_SLOT_0 or SDMMC_HOST_SLOT_1)
- timeout_ticks: number of RTOS ticks to wait for the interrupt

esp_err_t sdmmc_host_deinit (void)

Disable SDMMC host and release allocated resources.

**Note** This function is not thread safe

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if sdmmc_host_init function has not been called

esp_err_t sdmmc_host_pullup_en (int slot, int width)

Enable the pull-ups of sd pins.

This function is deprecated. Please set SDMMC_SLOT_FLAG_INTERNAL_PULLUP flag in sdmmc_slot_config_t::flags instead.

**Note** You should always place actual pullups on the lines instead of using this function. Internal pullup resistance are high and not sufficient, may cause instability in products. This is for debug or examples only.

**Return**
- ESP_OK: if success
- ESP_ERR_INVALID_ARG: if configured width larger than maximum the slot can support

**Parameters**
- slot: Slot to use, normally set it to 1.
- width: Bit width of your configuration, 1 or 4.
Structures

```c
struct sdmmc_slot_config_t
    Extra configuration for SDMMC peripheral slot
```

Public Members

```c
gpio_num_t clk
    GPIO number of CLK signal.

gpio_num_t cmd
    GPIO number of CMD signal.

gpio_num_t d0
    GPIO number of D0 signal.

gpio_num_t d1
    GPIO number of D1 signal.

gpio_num_t d2
    GPIO number of D2 signal.

gpio_num_t d3
    GPIO number of D3 signal.

gpio_num_t d4
    GPIO number of D4 signal. Ignored in 1- or 4-line mode.

gpio_num_t d5
    GPIO number of D5 signal. Ignored in 1- or 4-line mode.

gpio_num_t d6
    GPIO number of D6 signal. Ignored in 1- or 4-line mode.

gpio_num_t d7
    GPIO number of D7 signal. Ignored in 1- or 4-line mode.

gpio_num_t gpio_cd
    GPIO number of card detect signal.

gpio_num_t cd
    GPIO number of card detect signal; shorter name.

gpio_num_t gpio_wp
    GPIO number of write protect signal.

gpio_num_t wp
    GPIO number of write protect signal; shorter name.

uint8_t width
    Bus width used by the slot (might be less than the max width supported)

uint32_t flags
    Features used by this slot.
```

Macros

```c
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
```
### Chapter 2. API Reference

#### SDMMC_SLOT_FLAG_INTERNAL_PULLUP
Enable internal pullups 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

### 2.3.16 SD SPI Host Driver

#### Overview
The SD SPI host driver allows communicating with one or more SD cards by the SPI Master driver which makes use of the SPI host. Each card is accessed through an SD SPI device represented by an `sdspi_dev_handle_t` `spi_handler` returned when attaching the device to an SPI bus by calling `sdspi_host_init_device`. The bus should be already initialized before (by `spi_bus_initialize`).

With the help of the SPI Master 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.

#### How to Use
Firstly, use the macro `SDSPI_DEVICE_CONFIG_DEFAULT` to initialize a structure `sdmmc_slot_config_t`, which is used to initialize an SD SPI device. This macro will also fill in the default pin mappings, which is same as the pin mappings of 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 `SDSPI_HOST_DEFAULT` macro to initialize a `sdmmc_host_t` structure, which is used to store the state and configurations of upper layer (SD/SDIO/MMC driver). Modify the `slot` parameter of the structure to the SD SPI device `spi_handler` 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 the 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 10kOhm to 50kOhm, 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/include/driver/sdspi_host.h

**Functions**

`esp_err_t sdspi_host_init (void)`
Initialize SD SPI driver.

*Note* This function is not thread safe

*Return*  
- ESP_OK on success  
- other error codes may be returned in future versions

`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 over sdspi needs an extra interrupt line. Call `gpio_install_isr_service()` before this function.

*Return*  
- ESP_OK on success  
- ESP_ERR_INVALID_ARG if sdspi_host_init_device has invalid arguments  
- ESP_ERR_NO_MEM if memory can not be allocated  
- other errors from the underlying spi_master and gpio drivers

*Parameters*  
- `dev_config`: pointer to device configuration structure  
- `out_handle`: Output of the handle to the sdspi device.

`esp_err_t sdspi_host_remove_device (sdspi_dev_handle_t handle)`  
Remove an SD SPI device.

*Return* Always ESP_OK

*Parameters*  
- `handle`: Handle of the SD SPI device

`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.

Return
- 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

Parameters
- handle: Handle of the sdspi device
- cmdinfo: pointer to structure describing command and data to transfer

```c
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

Return
- ESP_OK on success
- other error codes may be returned in the future

Parameters
- host: Handle of the sdspi device
- freq_khz: card clock frequency, in kHz

```c
esp_err_t sdspi_host_deinit(void)
```
Release resources allocated using sdspi_host_init.

Note This function is not thread safe

Return
- ESP_OK on success
- ESP_ERR_INVALID_STATE if sdspi_host_init function has not been called

```c
esp_err_t sdspi_host_io_int_enable(sdspi_dev_handle_t handle)
```
Enable SDIO interrupt.

Return
- ESP_OK on success

Parameters
- handle: Handle of the sdspi device

```c
esp_err_t sdspi_host_io_int_wait(sdspi_dev_handle_t handle, TickType_t timeout_ticks)
```
Wait for SDIO interrupt until timeout.

Return
- ESP_OK on success

Parameters
- handle: Handle of the sdspi device
- timeout_ticks: Ticks to wait before timeout.

```c
esp_err_t sdspi_host_init_slot(int slot, const sdspi_slot_config_t *slot_config)
```
Initialize SD SPI driver for the specific SPI controller.

Note This function is not thread safe

Note The SDIO over.sdspi needs an extra interrupt line. Call gpio_install_isr_service() before this function.

Parameters
- slot: SPI controller to use (SPI2_HOST or SPI3_HOST)
- slot_config: pointer to slot configuration structure

Return
- ESP_OK on success
- ESP_ERR_INVALID_ARG if sdspi_init_slot has invalid arguments
Chapter 2. API Reference

- ESP_ERR_NO_MEM if memory cannot be allocated
- other errors from the underlying spi_master and gpio drivers

**Structures**

```c
struct sdspi_device_config_t
    Extra configuration for SD SPI device.
```

**Public Members**

```c
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.
```

```c
struct sdspi_slot_config_t
    Extra configuration for SPI host.
```

**Public Members**

```c
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.

gpio_num_t gpio_miso
    GPIO number of MISO signal.

gpio_num_t gpio_mosi
    GPIO number of MOSI signal.

gpio_num_t gpio_sck
    GPIO number of SCK signal.

int dma_channel
    DMA channel to be used by SPI driver (1 or 2).
```

**Macros**

```c
SDSPI_DEFAULT_HOST
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_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.

SDSPI_SLOT_CONFIG_DEFAULT()
Macro defining default configuration of SPI host

**Type Definitions**

```c
typedef int sdspi_dev_handle_t
Handle representing an SD SPI device.
```

### 2.3.17 Sigma-delta Modulation

**Introduction**

ESP32-S3 has a second-order sigma-delta modulation module. This driver configures the channels of the sigma-delta module.

**Functionality Overview**

There are 8 independent sigma-delta modulation channels identified with `sigmadelta_channel_t`. Each channel is capable to output the binary, hardware generated signal with the sigma-delta modulation.

Selected channel should be set up by providing configuration parameters in `sigmadelta_config_t` and then applying this configuration with `sigmadelta_config()`.

Another option is to call individual functions, that will configure all required parameters one by one:

- **Prescaler** of the sigma-delta generator - `sigmadelta_set_prescale()`
- **Duty** of the output signal - `sigmadelta_set_duty()`
- **GPIO pin** to output modulated signal - `sigmadelta_set_pin()`

The range of the ‘duty’ input parameter of `sigmadelta_set_duty()` is from -128 to 127 (eight bit signed integer). If zero value is set, then the output signal’s duty will be about 50%, see description of `sigmadelta_set_duty()`.

**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.

**Application Example**

Sigma-delta Modulation example: `peripherals/sigmadelta`. 
Fig. 15: Sallen-Key Low Pass Filter

API Reference

Header File

- components/driver/include/driver/sigmadelta.h

Functions

`esp_err_t sigmadelta_config(const sigmadelta_config_t *config)`
Configure Sigma-delta channel.

Return

- ESP_OK Success
- ESP_ERR_INVALID_STATE sigmadeltadriver already initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `config`: Pointer of Sigma-delta channel configuration struct

This function is used to set Sigma-delta channel duty, if you add a capacitor between the output pin and ground, the average output voltage will be Vdc = VDDIO / 256 * duty + VDDIO/2, where VDDIO is the power supply voltage.

`esp_err_t sigmadelta_set_duty(sigmadelta_channel_t channel, int8_t duty)`
Set Sigma-delta channel duty.

Return

- ESP_OK Success
- ESP_ERR_INVALID_STATE sigmadeltadriver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

Parameters

- `channel`: Sigma-delta channel number
- `duty`: Sigma-delta duty of one channel, the value ranges from -128 to 127, recommended range is -90 ~ 90. The waveform is more like a random one in this range.
**esp_err_t sigmadelta_set_prescale** (sigmadelta_channel_t channel, uint8_t prescale)

Set Sigma-delta channel’s clock pre-scale value. The source clock is APP_CLK, 80MHz. The clock frequency of the sigma-delta channel is APP_CLK / pre_scale.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE sigmadeltadriver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- `channel`: Sigma-delta channel number
- `prescale`: The divider of source clock, ranges from 0 to 255

**esp_err_t sigmadelta_set_pin** (sigmadelta_channel_t channel, gpio_num_t gpio_num)

Set Sigma-delta signal output pin.

**Return**

- ESP_OK Success
- ESP_ERR_INVALID_STATE sigmadeltadriver has not been initialized
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**

- `channel`: Sigma-delta channel number
- `gpio_num`: GPIO number of output pin

**Structures**

**struct sigmadelta_config_t**

Sigma-delta configure struct.

**Public Members**

**sigmadelta_channel_t channel**

Sigma-delta channel number

**int8_t sigmadelta_duty**

Sigma-delta duty, duty ranges from -128 to 127.

**uint8_t sigmadelta_prescale**

Sigma-delta prescale, prescale ranges from 0 to 255.

**uint8_t sigmadelta_gpio**

Sigma-delta output io number, refer to gpio.h for more details.

**Header File**

- components/hal/include/hal/sigmadelta_types.h

**Enumerations**

**enum sigmadelta_port_t**

SIGMADELTA port number, the max port number is (SIGMADELTA_NUM_MAX -1).

**Values:**

- **SIGMADELTA_PORT_0** SIGMADELTA port 0
- **SIGMADELTA_PORT_MAX** SIGMADELTA port max

**enum sigmadelta_channel_t**

Sigma-delta channel list.

**Values:**
2.3.18 SPI Master Driver

SPI Master driver is a program that controls ESP32-S3’s SPI peripherals while they function as masters.

Overview of ESP32-S3’s SPI peripherals

ESP32-S3 integrates 4 SPI peripherals.

- SPI0 and SPI1 are used internally to access the ESP32-S3’s attached flash memory. Both controllers share the same SPI bus signals, and there is an arbiter to determine which can access the bus. Currently, SPI Master driver does not support SPI1 bus.

- SPI2 and SPI3 are general purpose SPI controllers. They are open to users. SPI2 and SPI3 have independent signal buses with the same respective names. SPI2 has 6 CS lines. SPI3 has 3 CS lines. Each CS line can be used to drive one SPI slave.

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><strong>Host</strong></td>
<td>The SPI controller peripheral inside ESP32-S3 that initiates SPI transmissions over the bus, and acts as an SPI Master.</td>
</tr>
<tr>
<td><strong>Device</strong></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><strong>Bus</strong></td>
<td>A signal bus, common to all Devices connected to one Host. In general, a bus includes the following lines: MOSI, MISO, 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><strong>MOSI</strong></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><strong>MISO</strong></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><strong>SCLK</strong></td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td><strong>CS</strong></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><strong>QUADWP</strong></td>
<td>Protect signal. Used for 4-bit (qio/qout) transactions. Also for data2 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td><strong>QUADHD</strong></td>
<td>Signal. Used for 4-bit (qio/qout) transactions. Also for data3 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td><strong>DATA4</strong></td>
<td>Data4 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td><strong>DATA5</strong></td>
<td>Data5 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td><strong>DATA6</strong></td>
<td>Data6 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td><strong>DATA7</strong></td>
<td>Data7 signal in Octal/OPI mode.</td>
</tr>
<tr>
<td><strong>Assert</strong></td>
<td>The action of activating a line.</td>
</tr>
<tr>
<td><strong>De-assert</strong></td>
<td>The action of returning the line back to inactive (back to idle) status.</td>
</tr>
<tr>
<td><strong>Transaction</strong></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><strong>Launch edge</strong></td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td><strong>Latch edge</strong></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-S3 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.
- 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 (SPI Master, SPI Flash, etc.), an SPI bus lock is applied on each SPI bus. Drivers can attach their devices onto the bus with the arbitration of the lock.

Each bus lock are initialized with a BG (background) service registered, all devices request to do transactions on the bus should wait until the BG to be successfully disabled.

- For SPI1 bus, the BG is the cache, the bus lock will help to disable the cache before device operations starts, and enable it again after device releasing the lock. No devices on SPI1 is allowed using ISR (it’s meaningless for the task to yield to other tasks when the cache is disabled).
- For other buses, the driver may register its ISR as the BG. The bus lock will block a device task when it requests for exclusive use of the bus, try to disable the ISR, and unblock the device task allowed to exclusively use the bus when the ISR is successfully disabled. When the task releases the lock, the lock will also try to resume the ISR if there are pending transactions to be done 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 (0-32 bit) is transmitted over the bus by the Host.</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>Dummy</td>
<td>This phase is configurable and is used to meet the timing requirements.</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 `length` and `rxlength` members of the struct `spi_transaction_t` 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 `command_bits` and/or `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 `rx_buffer` is NULL and `SPI_TRANS_USE_RXDATA` is not set, the read phase is skipped. If `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-S3 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>SPI_TRANS_MODE_DIO</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>SPICOMMON_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>1</td>
</tr>
<tr>
<td>Quad Output</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>SPI_TRANS_MODE_QIO</td>
<td>SPICOMMON_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>1</td>
</tr>
<tr>
<td>Octal Output</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>SPI_TRANS_MODE_OCT</td>
<td>SPICOMMON_BUSFLAG_OCTAL</td>
</tr>
<tr>
<td>OPI</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>SPI_TRANS_MODE_OCT</td>
<td>1</td>
</tr>
</tbody>
</table>

**Command and Address Phases**  During the command and address phases, the members `cmd` and `addr` in the struct `spi_transaction_t` 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
Chapter 2. API Reference

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 command_bits and 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 rx_buffer and tx_buffer of the structure spi_transaction_t. 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. Please use full duplex mode.

**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 tx_data member and setting the SPI_TRANS_USE_TXDATA flag on the transmission. For received data, use rx_data and set SPI_TRANS_USE_RXDATA. In both cases, do not touch the tx_buffer or rx_buffer members, because they use the same memory locations as tx_data and 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-S3 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.

Transfer Speed Considerations

There are three factors limiting the transfer speed:

- Transaction interval
- SPI clock frequency
- Cache miss of SPI functions, including callbacks

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 µs 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 µs, 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: 26 µs.
- Interrupt Transaction via CPU: 24 µs.
- Polling Transaction via DMA: 11 µs.
- Polling Transaction via CPU: 9 µs.

**SPI Clock Frequency**   Transferring each byte takes eight times the clock period $8/f_{spi}$.

**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.

For an interrupt transaction, the overall cost is $20+8n/f_{spi}[MHz][\mu s]$ 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 (µs)</th>
<th>Transaction Length (bytes)</th>
<th>Total Time (µs)</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**.

**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

struct spi_line_mode_t
Line mode of SPI transaction phases: CMD, ADDR, DOUT/DIN.

Public Members

uint8_t cmd_lines
The line width of command phase, e.g. 2-line-cmd-phase.

uint8_t addr_lines
The line width of address phase, e.g. 1-line-addr-phase.

uint8_t data_lines
The line width of data phase, e.g. 4-line-data-phase.

Enumerations

enum spi_host_device_t
Enum with the three SPI peripherals that are software-accessible in it.

Values:

SPI1_HOST = 0
SPI1.

SPI2_HOST = 1
SPI2.

SPI3_HOST = 2
SPI3.

SPI_HOST_MAX
invalid host value

enum spi_clock_source_t

Values:

SPI_CLK_APB
Select APB as the source clock.

SPI_CLK_XTAL
Select XTAL as the source clock.

enum spi_event_t

SPI Events.

Values:

SPI_EV_BUF_TX = BIT(0)
The buffer has sent data to master.

SPI_EV_BUF_RX = BIT(1)
The buffer has received data from master.

SPI_EV_SEND_DMA_READY = BIT(2)
Slave has loaded its TX data buffer to the hardware (DMA).

SPI_EV_SEND = BIT(3)
Master has received certain number of the data, the number is determined by Master.

SPI_EV_RECV_DMA_READY = BIT(4)
Slave has loaded its RX data buffer to the hardware (DMA).

SPI_EV_RECV = BIT(5)
Slave has received certain number of data from master, the number is determined by Master.

SPI_EV_CMD9 = BIT(6)
Received CMD9 from master.
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SPI_EV_CMDA = BIT(7)
Received CMDA from master.

SPI_EV_TRANS = BIT(8)
A transaction has done.

Header File
• components/driver/include/driver/spi_common.h

Functions

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.

Return
• 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

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.

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.

Return
• 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

Parameters
• host_id: SPI peripheral to free

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.

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.
Public Members

int mosi_io_num
   GPIO pin for Master Out Slave In (=spi_d) signal, or -1 if not used.

int data0_io_num
   GPIO pin for spi data0 signal in quad/octal mode, or -1 if not used.

int miso_io_num
   GPIO pin for Master In Slave Out (=spi_q) signal, or -1 if not used.

int data1_io_num
   GPIO pin for spi data1 signal in quad/octal mode, or -1 if not used.

int sclk_io_num
   GPIO pin for SPI Clock signal, or -1 if not used.

int quadwp_io_num
   GPIO pin for WP (Write Protect) signal, or -1 if not used.

int data2_io_num
   GPIO pin for spi data2 signal in quad/octal mode, or -1 if not used.

int quadhd_io_num
   GPIO pin for HD (Hold) signal, or -1 if not used.

int data3_io_num
   GPIO pin for spi data3 signal in quad/octal mode, or -1 if not used.

int data4_io_num
   GPIO pin for spi data4 signal in octal mode, or -1 if not used.

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.

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:

```c
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.

**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_SCLCK**
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_I04_I07**
Check existing of I04-I07 pins. Or indicates IO4~IO7 pins initialized.

**SPICOMMON_BUSFLAG_OCTAL**
Check existing of MOSI/MISO/WP/HD/SPI04/SPI05/SPI06/SPI07 pins as output. Or indicates bus able to work under octal mode.

**SPICOMMON_BUSFLAG_NATIVE_PINS**

**Type Definitions**
```c
typedef spi_common_dma_t spi_dma_chan_t
```

**Enumerations**
```c
enum spi_common_dma_t
    SPI_DMA_DISABLED = 0
    Do not enable DMA for SPI.
```
SPI_DMA_CH_AUTO = 3
Enable DMA, channel is automatically selected by driver.

API Reference - SPI Master

Header File
- components/driver/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.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- 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

**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

```c
esp_err_t spi_bus_remove_device(spi_device_handle_t handle)
```

Remove a device from the SPI bus.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_INVALID_STATE if device already is freed
- ESP_OK on success

**Parameters**
- handle: Device handle to free

```c
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.

**Return**
- 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

**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.
**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.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_ERR_TIMEOUT if there was no completed transaction before `ticks_to_wait` expired
- ESP_OK on success

**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 timeout.

**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 has’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.

**Return**
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**
- `handle`: Device handle obtained using `spi_host_add_dev`
- `trans_desc`: Description of transaction to execute

**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.

**Return**
- 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

**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 `portMAX_DELAY` is supported.

**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.

**Return**
Chapter 2. API Reference

- 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

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.

```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.

Return
- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

Parameters
- handle: Device handle obtained using spi_host_add_dev
- trans_desc: Description of transaction to execute

```c
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.

Return
- ESP_ERR_INVALID_ARG: wait is not set to portMAX_DELAY.
- ESP_OK: Success.

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.

```c
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.

```c
int spi_cal_clock(int fapb, int hz, int duty_cycle, uint32_t *reg_o)
```
Calculate the working frequency that is most close to desired frequency, and also the register value.

Parameters
- fapb: The frequency of apb clock, should be APB_CLK_FREQ.
- hz: Desired working frequency
- duty_cycle: Duty cycle of the spi clock
- reg_o: Output of value to be set in clock register, or NULL if not needed.

Return Actual working frequency that most fit.

```c
int spi_get_actual_clock(int fapb, int hz, int duty_cycle)
```
Calculate the working frequency that is most close to desired frequency.

Return Actual working frequency that most fit.

Parameters
- fapb: The frequency of apb clock, should be APB_CLK_FREQ.
- hz: Desired working frequency
- duty_cycle: Duty cycle of the spi clock
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_cal_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.

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.

**Return** Frequency limit of current configurations.

**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.

**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
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.

```c
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.

```c
uint8_t cs_ena_posttrans
```

Amount of SPI bit-cycles the cs should stay active after the transmission (0-16)
Chapter 2. API Reference

int clock_speed_hz
   Clock speed, divisors of 80MHz, in Hz. See SPI_MASTER_FREQ_*.

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).

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-IDF3.0.
   Example: write 0x123400 and address_bits=24 to send address of 0x12, 0x34, 0x00 (in previous version,
   you may have to write 0x12340000).

size_t length
   Total data length, in bits.

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).
void *user
User-defined variable. Can be used to store eg transaction ID.

const void *tx_buffer
Pointer to transmit buffer, or NULL for no MOSI phase.

uint8_t tx_data[4]
If SPI_TRANS_USE_TXDATA is set, data set here is sent directly from this variable.

void *rx_buffer
Pointer to receive buffer, or NULL for no MISO phase. Written by 4 bytes-unit if DMA is used.

uint8_t rx_data[4]
If SPI_TRANS_USE_RXDATA is set, data is received directly to this variable.

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

struct spi_transaction_t base
Transaction data, so that pointer to spi_transaction_t can be converted into spi_transaction_ext_t.

uint8_t command_bits
The command length in this transaction, in bits.

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 master clock is divided by 80MHz apb clock. Below defines are example frequencies, and are accurate. Be free to specify a random frequency, it will be rounded to closest frequency (to macros below if above 8MHz).

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.

**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_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 struct spi_transaction_t spi_transaction_t

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.

2.3.19 SPI Slave Driver

SPI Slave driver is a program that controls ESP32-S3’s SPI peripherals while they function as slaves.

Overview of ESP32-S3’s SPI peripherals

ESP32-S3 integrates two general purpose SPI controllers which can be used as slave nodes driven by an off-chip SPI master

SPI2 and SPI3 have independent signal buses with the same respective names.

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><strong>Host</strong></td>
<td>The SPI controller peripheral external to ESP32-S3 that initiates SPI transmissions over the bus, and acts as an SPI Master.</td>
</tr>
<tr>
<td><strong>Device</strong></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><strong>Bus</strong></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><strong>MISO</strong></td>
<td>Master In, Slave Out, a.k.a. Q. Data transmission from a Device to Host.</td>
</tr>
<tr>
<td><strong>MOSI</strong></td>
<td>Master Out, Slave in, a.k.a. D. Data transmission from a Host to Device.</td>
</tr>
<tr>
<td><strong>SCLK</strong></td>
<td>Serial Clock. Oscillating signal generated by a Host that keeps the transmission of data bits in sync.</td>
</tr>
<tr>
<td><strong>CS</strong></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><strong>QUADWP</strong></td>
<td>Write Protect signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td><strong>QUADHD</strong></td>
<td>Hold signal. Only used for 4-bit (qio/qout) transactions.</td>
</tr>
<tr>
<td><strong>Assertion</strong></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><strong>Transaction</strong></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><strong>Launch edge</strong></td>
<td>Edge of the clock at which the source register launches the signal onto the line.</td>
</tr>
<tr>
<td><strong>Latch edge</strong></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.

**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 host 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 have a choice to configure the `spi_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. 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 `bus_config` struct. Set the unused signals to `-1`.
- 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 `rx_buffer` and `tx_buffer` members of the `spi_transaction_t` structure. 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 the member `spi_transaction_t::length`. However, this member does not define the actual length of an SPI transaction. A transaction's length is determined by a Host which drives the clock and CS lines. 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 `length` member will be sent and received. In this case, `trans_len` is set to `length` instead of the actual transaction length. To meet the actual transaction length requirements, set `length` to a value greater than the maximum `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.

**Speed and Timing Considerations**

**Transaction Interval** The ESP32-S3 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`.

---

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SCLK Frequency Requirements  The SPI slaves are designed to operate at up to 60 MHz. The data cannot be recognized or received correctly if the clock is too fast or does not have a 50% duty cycle.

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.

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/include/driver/spi_slave.h

Functions

*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.

**Return**

- ESP_ERR_INVALID_ARG if configuration is invalid
- ESP_ERR_INVALID_STATE if host already 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

**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_CHANNEL to let the driver to allocate the DMA channel.

*esp_err_t* spi_slave_free*(spi_host_device_t* host)*

Free a SPI bus claimed as a SPI slave interface.

**Return**

- 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

**Parameters**
• **host**: SPI peripheral to free

```c
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.

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**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.

```c
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`.

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**Parameters**

- **host**: SPI peripheral to that is acting as a slave
- **[out] trans_desc**: 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.

```c
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`.

**Return**

- ESP_ERR_INVALID_ARG if parameter is invalid
- ESP_OK on success

**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.

**Structures**
**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)
```

**slave_transaction_cb / 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.

**slave_transaction_cb / 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.

**struct spi_slave_transaction_t**

This structure describes one SPI transaction

**Public Members**

```c
size_t length
    Total data length, in bits.
```

```c
size_t trans_len
    Transaction data length, in bits.
```

```c
const void *tx_buffer
    Pointer to transmit buffer, or NULL for no MOSI phase.
```

```c
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.
```

```c
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.

Type Definitions
typedef struct spi_slave_transaction_t spi_slave_transaction_t
typedef void (*slave_transaction_cb_t)(spi_slave_transaction_t *trans)

2.3.20 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.

Touch sensor on ESP32-S3 can support up to 14 capacitive touch pads / GPIOs.

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-S3 Technical Reference Manual > On-Chip Sensors and Analog Signal Processing [PDF].

In-depth design details of touch sensors and firmware development guidelines for ESP32-S3 are available in Touch Sensor Application Note.

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().

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 function come in handy to read raw measurements from the sensor:

- `touch_pad_read_raw_data()`

It 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.

For the demonstration of how to read the touch pad data, check the application example `peripherals/touch_sensor/touch_sensor_v2/touch_pad_read`.

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_meas_time()`.

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()`
- Measurement time: `touch_pad_set_meas_time()`

Relationship between the voltage range (high / low reference voltages), speed (slope), and measurement time is shown in the figure below.

![Fig. 16: Touch pad - relationship between measurement parameters](image)

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. The ESP32-S3’s touch functionality provide two sets of APIs for doing this.
There is an internal touch channel that is not connected to any external GPIO. The measurements from this denoise pad can be used to filters out interference introduced on all channels, such as noise introduced by the power supply and external EMI. The denoise parameters are set with the function `touch_pad_denoise_set_config()` and started by with `touch_pad_denoise_enable()`.

There is also a configurable hardware implemented IIR-filter (infinite impulse response). This IIR-filter is configured with the function `touch_pad_filter_set_config()` and enabled by calling `touch_pad_filter_enable()`.

**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_v2/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. 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()`.

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()`.

**Application Examples**

- Touch sensor read example: `peripherals/touch_sensor/touch_sensor_v2/touch_pad_read`.
- Touch sensor interrupt example: `peripherals/touch_sensor/touch_sensor_v2/touch_pad_interrupt`.

**API Reference**

**Header File**

- `components/driver/esp32s3/include/driver/touch_sensor.h`

**Functions**

- `esp_err_t touch_pad_fsm_start (void)`
  - Set touch sensor FSM start.
  - **Note** Start FSM after the touch sensor FSM mode is set.
  - **Note** Call this function will reset benchmark of all touch channels.
  - **Return**
    - ESP_OK on success

- `esp_err_t touch_pad_fsm_stop (void)`
  - Stop touch sensor FSM.
Return

- ESP_OK on success

```
esp_err_t touch_pad_sw_start (void)
```

Trigger a touch sensor measurement, only support in SW mode of FSM.

Return

- ESP_OK on success

```
esp_err_t touch_pad_set_meas_time (uint16_t sleep_cycle, uint16_t meas_times)
```

Set touch sensor times of charge and discharge 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 greater the duty cycle of the measurement time, the more system power is consumed.

Return

- ESP_OK on success

Parameters

- sleep_cycle: The touch sensor will sleep after each measurement. sleep_cycle decide the interval between each measurement. t_sleep = sleep_cycle / (RTC_SLOW_CLK frequency). The approximate frequency value of RTC_SLOW_CLK can be obtained using rtc_clk_slow_freq_get_hz function.
- meas_times: The times of charge and discharge in each measure process of touch channels. The timer frequency is 8Mhz. Range: 0 ~ 0xffff. Recommended typical value: Modify this value to make the measurement time around 1ms.

```
esp_err_t touch_pad_get_meas_time (uint16_t *sleep_cycle, uint16_t *meas_times)
```

Get touch sensor times of charge and discharge and sleep time.

Return

- ESP_OK on success

Parameters

- sleep_cycle: Pointer to accept sleep cycle number
- meas_times: Pointer to accept measurement times count.

```
esp_err_t touch_pad_set_idle_channel_connect (touch_pad_conn_type_t type)
```

Set connection type of touch channel in idle status. When a channel is in measurement mode, other initialized channels are in idle mode. The touch channel is generally adjacent to the trace, so the connection state of the idle channel affects the stability and sensitivity of the test channel. The CONN_HIGHZ(high resistance) setting increases the sensitivity of touch channels. The CONN_GND(grounding) setting increases the stability of touch channels.

Return

- ESP_OK on success

Parameters

- type: Select idle channel connect to high resistance state or ground.

```
esp_err_t touch_pad_get_idle_channel_connect (touch_pad_conn_type_t *type)
```

Set connection type of touch channel in idle status. When a channel is in measurement mode, other initialized channels are in idle mode. The touch channel is generally adjacent to the trace, so the connection state of the idle channel affects the stability and sensitivity of the test channel. The CONN_HIGHZ(high resistance) setting increases the sensitivity of touch channels. The CONN_GND(grounding) setting increases the stability of touch channels.

Return

- ESP_OK on success

Parameters

- type: Pointer to connection type.

```
esp_err_t touch_pad_set_thresh (touch_pad_t touch_num, uint32_t threshold)
```

Set the trigger threshold of touch sensor. The threshold determines the sensitivity of the touch sensor. The threshold is the original value of the trigger state minus the benchmark value.

Note If set "TOUCH_PAD_THRESHOLD_MAX", the touch is never be triggered.

Return

- ESP_OK on success
• ESP_OK on success

Parameters
• touch_num: touch pad index
• threshold: threshold of touch sensor. Should be less than the max change value of touch.

```c
esp_err_t touch_pad_get_thresh(touch_pad_t touch_num, uint32_t* threshold)
```
Get touch sensor trigger threshold.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• touch_num: touch pad index
• threshold: pointer to accept threshold

```c
esp_err_t touch_pad_set_channel_mask(uint16_t enable_mask)
```
Register touch channel into touch sensor scan group. The working mode of the touch sensor is cyclically scanned. This function will set the scan bits according to the given bitmask.

Note
If set this mask, the FSM timer should be stop firstly.
Note
The touch sensor that in scan map, should be deinit GPIO function firstly by `touch_pad_io_init`.

Return
• ESP_OK on success

Parameters
• enable_mask: bitmask of touch sensor scan group. e.g. TOUCH_PAD_NUM14 -> BIT(14)

```c
esp_err_t touch_pad_get_channel_mask(uint16_t* enable_mask)
```
Get the touch sensor scan group bit mask.

Return
• ESP_OK on success

Parameters
• enable_mask: Pointer to bitmask of touch sensor scan group. e.g. TOUCH_PAD_NUM14 -> BIT(14)

```c
esp_err_t touch_pad_clear_channel_mask(uint16_t enable_mask)
```
Clear touch channel from touch sensor scan group. The working mode of the touch sensor is cyclically scanned. This function will clear the scan bits according to the given bitmask.

Note
If clear all mask, the FSM timer should be stop firstly.

Return
• ESP_OK on success

Parameters
• enable_mask: bitmask of touch sensor scan group. e.g. TOUCH_PAD_NUM14 -> BIT(14)

```c
esp_err_t touch_pad_config(touch_pad_t touch_num)
```
Configure parameter for each touch channel.

Note
Touch num 0 is denoise channel, please use `touch_pad_denoise_enable` to set denoise function

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG if argument wrong
• ESP_FAIL if touch pad not initialized

Parameters
• touch_num: touch pad index

```c
esp_err_t touch_pad_reset(void)
```
Reset the FSM of touch module.

Note
Call this function after `touch_pad_fsm_stop`.

Return
• ESP_OK Success

```c
touch_pad_t touch_pad_get_current_meas_channel(void)
```
Get the current measure channel.
Note Should be called when touch sensor measurement is in cyclic scan mode.

Return
- touch channel number

uint32_t touch_pad_read_intr_status_mask (void)
Get the touch sensor interrupt status mask.

Return
- touch interrupt bit

esp_err_t touch_pad_intr_enable (touch_pad_intr_mask_t int_mask)
Enable touch sensor interrupt by bitmask.

Note This API can be called in ISR handler.

Return
- ESP_OK on success

Parameters
- int_mask: Pad mask to enable interrupts

esp_err_t touch_pad_intr_disable (touch_pad_intr_mask_t int_mask)
Disable touch sensor interrupt by bitmask.

Note This API can be called in ISR handler.

Return
- ESP_OK on success

Parameters
- int_mask: Pad mask to disable interrupts

esp_err_t touch_pad_intr_clear (touch_pad_intr_mask_t int_mask)
Clear touch sensor interrupt by bitmask.

Return
- ESP_OK on success

Parameters
- int_mask: Pad mask to clear interrupts

esp_err_t touch_pad_isr_register (intr_handler_t fn, void *arg, touch_pad_intr_mask_t intr_mask)
Register touch-pad ISR. The handler will be attached to the same CPU core that this function is running on.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Arguments error
- ESP_ERR_NO_MEM No memory

Parameters
- fn: Pointer to ISR handler
- arg: Parameter for ISR
- intr_mask: Enable touch sensor interrupt handler by bitmask.

esp_err_t touch_pad_timeout_set (bool enable, uint32_t threshold)
Enable/disable the timeout check and set timeout threshold for all touch sensor channels measurements. If enable: When the touch reading of a touch channel exceeds the measurement threshold, a timeout interrupt will be generated. If disable: the FSM does not check if the channel under measurement times out.

Note The threshold compared with touch readings.

Note In order to avoid abnormal short circuit of some touch channels. This function should be turned on. Ensure the normal operation of other touch channels.

Return
- ESP_OK Success

Parameters
- enable: true(default): Enable the timeout check; false: Disable the timeout check.
- threshold: For all channels, the maximum value that will not be exceeded during normal operation.

esp_err_t touch_pad_timeout_resume (void)
Call this interface after timeout to make the touch channel resume normal work. Point on the next channel to
measure. If this API is not called, the touch FSM will stop the measurement after timeout interrupt.

**Note** Call this API after finishes the exception handling by user.

**Return**
- ESP_OK Success

```c
esp_err_t touch_pad_read_raw_data(touch_pad_t touch_num, uint32_t *raw_data)
```
get raw data of touch sensor.

**Note** After the initialization is complete, the “raw_data” is max value. You need to wait for a measurement cycle before you can read the correct touch value.

**Return**
- ESP_OK Success
- ESP_FAIL Touch channel 0 haven’t this parameter.

**Parameters**
- touch_num: touch pad index
- raw_data: pointer to accept touch sensor value

```c
esp_err_t touch_pad_read_benchmark(touch_pad_t touch_num, uint32_t *benchmark)
```
get benchmark of touch sensor.

**Note** After initialization, the benchmark value is the maximum during the first measurement period.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch channel 0 haven’t this parameter.

**Parameters**
- touch_num: touch pad index
- benchmark: pointer to accept touch sensor benchmark value

```c
esp_err_t touch_pad_filter_read_smooth(touch_pad_t touch_num, uint32_t *smooth)
```
Get smoothed data that obtained by filtering the raw data.

**Parameters**
- touch_num: touch pad index
- smooth: pointer to smoothed data

```c
esp_err_t touch_pad_reset_benchmark(touch_pad_t touch_num)
```
Force reset benchmark to raw data of touch sensor.

**Return**
- ESP_OK Success

**Parameters**
- touch_num: touch pad index
  - TOUCH_PAD_MAX Reset baseline of all channels

```c
esp_err_t touch_pad_filter_set_config(const touch_filter_config_t *filter_info)
```
set parameter of touch sensor filter and detection algorithm. For more details on the detection algorithm, please refer to the application documentation.

**Return**
- ESP_OK Success

**Parameters**
- filter_info: select filter type and threshold of detection algorithm

```c
esp_err_t touch_pad_filter_get_config(touch_filter_config_t *filter_info)
```
get parameter of touch sensor filter and detection algorithm. For more details on the detection algorithm, please refer to the application documentation.

**Return**
- ESP_OK Success

**Parameters**
- filter_info: select filter type and threshold of detection algorithm

```c
esp_err_t touch_pad_filter_enable(void)
```
enable touch sensor filter for detection algorithm. For more details on the detection algorithm, please refer to
the application documentation.

Return
• ESP_OK Success

Esp_err_t touch_pad_filter_disable (void)
disable touch sensor filter for detection algorithm. For more details on the detection algorithm, please refer to
the application documentation.

Return
• ESP_OK Success

Esp_err_t touch_pad_denoise_set_config (const touch_pad_denoise_t *denoise)
set parameter of denoise pad (TOUCH_PAD_NUM0). T0 is an internal channel that does not have a corre-
spending external GPIO. T0 will work simultaneously with the measured channel Tn. Finally, the actual
measured value of Tn is the value after subtracting lower bits of T0. The noise reduction function filters out
interference introduced simultaneously on all channels, such as noise introduced by power supplies and external
EMI.

Return
• ESP_OK Success

Parameters
• denoise: parameter of denoise

Esp_err_t touch_pad_denoise_get_config (touch_pad_denoise_t *denoise)
get parameter of denoise pad (TOUCH_PAD_NUM0).

Return
• ESP_OK Success

Parameters
• denoise: Pointer to parameter of denoise

Esp_err_t touch_pad_denoise_enable (void)
enable denoise function. T0 is an internal channel that does not have a corresponding external GPIO. T0 will
work simultaneously with the measured channel Tn. Finally, the actual measured value of Tn is the value after
subtracting lower bits of T0. The noise reduction function filters out interference introduced simultaneously
on all channels, such as noise introduced by power supplies and external EMI.

Return
• ESP_OK Success

Esp_err_t touch_pad_denoise_disable (void)
disable denoise function.

Return
• ESP_OK Success

Esp_err_t touch_pad_denoise_read_data (uint32_t *data)
Get denoise measure value (TOUCH_PAD_NUM0).

Return
• ESP_OK Success

Parameters
• data: Pointer to receive denoise value

Esp_err_t touch_pad_waterproof_set_config (const touch_pad_waterproof_t *waterproof)
set parameter of waterproof function.

The waterproof function includes a shielded channel (TOUCH_PAD_NUM14) and a
→guard channel. Guard pad is used to detect the large area of water covering the touch...
→panel. Shield pad is used to shield the influence of water droplets covering the...
→touch panel. It is generally designed as a grid and is placed around the touch buttons.
Return
• ESP_OK Success

Parameters
• waterproof: parameter of waterproof

\texttt{esp_err_t touch_pad_waterproof_get_config(touch_pad_waterproof_t \*waterproof)}
get parameter of waterproof function.

Return
• ESP_OK Success

Parameters
• waterproof: parameter of waterproof

\texttt{esp_err_t touch_pad_waterproof_enable (void)}
Enable parameter of waterproof function. Should be called after function touch_pad_waterproof_set_config.

Return
• ESP_OK Success

\texttt{esp_err_t touch_pad_waterproof_disable (void)}
Disable parameter of waterproof function.

Return
• ESP_OK Success

\texttt{esp_err_t touch_pad_proximity_enable (touch_pad_t touch_num, bool enabled)}
Enable/disable proximity function of touch channels. The proximity sensor measurement is the accumulation of touch channel measurements.

Note Supports up to three touch channels configured as proximity sensors.

Return
• ESP_OK: Configured correctly.
• ESP_ERR_INVALID_ARG: Touch channel number error.
• ESP_ERR_NOT_SUPPORTED: Don’t support configured.

Parameters
• touch_num: touch pad index
• enabled: true: enable the proximity function; false: disable the proximity function

\texttt{esp_err_t touch_pad_proximity_set_count (touch_pad_t touch_num, uint32_t count)}
Set measure count of proximity channel. The proximity sensor measurement is the accumulation of touch channel measurements.

Note All proximity channels use the same \texttt{count} value. So please pass the parameter \texttt{TOUCH_PAD_MAX}.

Return
• ESP_OK: Configured correctly.
• ESP_ERR_INVALID_ARG: Touch channel number error.

Parameters
• touch_num: Touch pad index. In this version, pass the parameter \texttt{TOUCH_PAD_MAX}.
• count: The cumulative times of measurements for proximity pad. Range: 0 ~ 255.

\texttt{esp_err_t touch_pad_proximity_get_count (touch_pad_t touch_num, uint32_t \*count)}
Get measure count of proximity channel. The proximity sensor measurement is the accumulation of touch channel measurements.

Note All proximity channels use the same \texttt{count} value. So please pass the parameter \texttt{TOUCH_PAD_MAX}.

Return
• ESP_OK: Configured correctly.
• ESP_ERR_INVALID_ARG: Touch channel number error.

Parameters
• touch_num: Touch pad index. In this version, pass the parameter \texttt{TOUCH_PAD_MAX}.
• count: The cumulative times of measurements for proximity pad. Range: 0 ~ 255.
esp_err_t touch_pad_proximity_get_data (touch_pad_t touch_num, uint32_t *measure_out)

Get the accumulated measurement of the proximity sensor. The proximity sensor measurement is the accumulation of touch channel measurements.

Return
- ESP_OK Success
- ESP_ERR_INVALID_ARG Touch num is not proximity

Parameters
- touch_num: touch pad index
- measure_out: If the accumulation process does not end, the measure_out is the process value.

esp_err_t touch_pad_sleep_channel_get_info (touch_pad_sleep_channel_t *slp_config)

Get parameter of touch sensor sleep channel. The touch sensor can works in sleep mode to wake up sleep.

Note After the sleep channel is configured, Please use special functions for sleep channel. e.g. The user should use touch_pad_sleep_channel_read_data instead of touch_pad_read_raw_data to obtain the sleep channel reading.

Return
- ESP_OK Success

Parameters
- slp_config: touch sleep pad config.

esp_err_t touch_pad_sleep_channel_enable (touch_pad_t pad_num, bool enable)

Enable/Disable sleep channel function for touch sensor. The touch sensor can works in sleep mode to wake up sleep.

Note ESP32S2 only support one sleep channel.

Note After the sleep channel is configured, Please use special functions for sleep channel. e.g. The user should use touch_pad_sleep_channel_read_data instead of touch_pad_read_raw_data to obtain the sleep channel reading.

Return
- ESP_OK Success

Parameters
- pad_num: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- enable: true: enable sleep pad for touch sensor; false: disable sleep pad for touch sensor;

esp_err_t touch_pad_sleep_channel_enable_proximity (touch_pad_t pad_num, bool enable)

Enable/Disable proximity function for sleep channel. The touch sensor can works in sleep mode to wake up sleep.

Note ESP32S2 only support one sleep channel.

Return
- ESP_OK Success

Parameters
- pad_num: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- enable: true: enable proximity for sleep channel; false: disable proximity for sleep channel;

esp_err_t touch_pad_sleep_set_threshold (touch_pad_t pad_num, uint32_t touch_thres)

Set the trigger threshold of touch sensor in deep sleep. The threshold determines the sensitivity of the touch sensor.

Note In general, the touch threshold during sleep can use the threshold parameter parameters before sleep.

Return
- ESP_OK Success

Parameters
- pad_num: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- touch_thres: touch sleep pad threshold
**esp_err_t touch_pad_sleep_get_threshold (touch_pad_t pad_num, uint32_t *touch_thres)**

Get the trigger threshold of touch sensor in deep sleep. The threshold determines the sensitivity of the touch sensor.

**Note** In general, the touch threshold during sleep can use the threshold parameter parameters before sleep.

**Return**
- ESP_OK Success

**Parameters**
- **pad_num**: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- **touch_thres**: touch sleep pad threshold

**esp_err_t touch_pad_sleep_channel_read_benchmark (touch_pad_t pad_num, uint32_t *benchmark)**

Read benchmark of touch sensor sleep channel.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter is NULL

**Parameters**
- **pad_num**: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- **benchmark**: pointer to accept touch sensor benchmark value

**esp_err_t touch_pad_sleep_channel_read_smooth (touch_pad_t pad_num, uint32_t *smooth_data)**

Read smoothed data of touch sensor sleep channel. Smoothed data is filtered from the raw data.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter is NULL

**Parameters**
- **pad_num**: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- **smooth_data**: pointer to accept touch sensor smoothed data

**esp_err_t touch_pad_sleep_channel_read_data (touch_pad_t pad_num, uint32_t *raw_data)**

Read raw data of touch sensor sleep channel.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter is NULL

**Parameters**
- **pad_num**: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- **raw_data**: pointer to accept touch sensor raw data

**esp_err_t touch_pad_sleep_channel_reset_benchmark (void)**

Reset benchmark of touch sensor sleep channel.

**Return**
- ESP_OK Success

**esp_err_t touch_pad_sleep_channel_read_proximity_cnt (touch_pad_t pad_num, uint32_t *proximity_cnt)**

Read proximity count of touch sensor sleep channel.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG parameter is NULL

**Parameters**
- **pad_num**: Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode.
- **proximity_cnt**: pointer to accept touch sensor proximity count value
Change the operating frequency of touch pad in deep sleep state. Reducing the operating frequency can effectively reduce power consumption. If this function is not called, the working frequency of touch in the deep sleep state is the same as that in the wake-up state.

Return
• ESP_OK Success

Parameters
• sleep_cycle: The touch sensor will sleep after each measurement. sleep_cycle decide the interval between each measurement. \( t_{\text{sleep}} = \frac{\text{sleep_cycle}}{(\text{RTC}_\text{SLOW}_\text{CLK} \text{ frequency})} \). The approximate frequency value of RTC\_SLOW\_CLK can be obtained using \text{rtc\_clk\_slow\_freq\_get\_hz} function.
• meas_times: The times of charge and discharge in each measure process of touch channels. The timer frequency is 8Mhz. Range: 0 ~ 0xffff. Recommended typical value: Modify this value to make the measurement time around 1ms.

Header File
• components/driver/include/driver/touch_sensor_common.h

Functions

\text{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.

Return
• ESP_OK Success
• ESP_ERR_NO_MEM Touch pad init error
• ESP_ERR_NOT_SUPPORTED Touch pad is providing current to external XTAL

\text{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.

Return
• ESP_OK Success
• ESP_FAIL Touch pad driver not initialized

\text{esp\_err\_t touch\_pad\_io\_init} (\text{touch\_pad\_t touch\_num})
Initialize touch pad GPIO.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• touch_num: touch pad index

\text{esp\_err\_t touch\_pad\_set\_voltage} (\text{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.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• refh: the value of DREFH
• refl: the value of DREFL
• atten: the attenuation on DREFH
```
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.

Return
• ESP_OK on success

Parameters
• refh: pointer to accept DREFH value
• refl: pointer to accept DREFL value
• atten: pointer to accept the attenuation on DREFH
```

```
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.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• touch_num: touch pad index
• slope: touch pad charge/discharge speed
• opt: the initial voltage
```

```
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.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong

Parameters
• touch_num: touch pad index
• slope: pointer to accept touch pad charge/discharge slope
• opt: pointer to accept the initial voltage
```

```
esp_err_t touch_pad_isr_deregister(void (*fn)) void *
                                  , void *arg

Deregister the handler previously registered using touch_pad_isr_handler_register.

Return
• ESP_OK on success
• ESP_ERR_INVALID_STATE if a handler matching both fn and arg isn’t registered

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)
```

```
esp_err_t touch_pad_get_wakeup_status(touch_pad_t *pad_num)

Get the touch pad which caused wakeup from deep sleep.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG parameter is NULL

Parameters
• pad_num: pointer to touch pad which caused wakeup
```

```
esp_err_t touch_pad_set_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.

Return
• ESP_OK on success
• ESP_ERR_INVALID_ARG if argument is wrong
```
Parameters
• mode: FSM mode

`esp_err_t touch_pad_get_fsm_mode (touch_fsm_mode_t *mode)`
Get touch sensor FSM mode.

Return
• ESP_OK on success

Parameters
• mode: pointer to accept FSM mode

`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.

Return
• 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.

Return
• The touch sensor status. e.g. Touch1 trigger status is `status_mask & BIT1`.

`bool touch_pad_meas_is_done (void)`
Check touch sensor measurement status.

Return
• 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/esp32s3/include/soc/touch_sensor_channel.h`

Macros
`TOUCH_PAD_GPIO1_CHANNEL`
`TOUCH_PAD_NUM1_GPIO_NUM`
`TOUCH_PAD_GPIO2_CHANNEL`
`TOUCH_PAD_NUM2_GPIO_NUM`
`TOUCH_PAD_GPIO3_CHANNEL`
`TOUCH_PAD_NUM3_GPIO_NUM`
`TOUCH_PAD_GPIO4_CHANNEL`
`TOUCH_PAD_NUM4_GPIO_NUM`
`TOUCH_PAD_GPIO5_CHANNEL`
`TOUCH_PAD_NUM5_GPIO_NUM`
`TOUCH_PAD_GPIO6_CHANNEL`
`TOUCH_PAD_NUM6_GPIO_NUM`
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TOUCH_PAD_GPIO7_CHANNEL
TOUCH_PAD_NUM7_GPIO_NUM
TOUCH_PAD_GPIO8_CHANNEL
TOUCH_PAD_NUM8_GPIO_NUM
TOUCH_PAD_GPIO9_CHANNEL
TOUCH_PAD_NUM9_GPIO_NUM
TOUCH_PAD_GPIO10_CHANNEL
TOUCH_PAD_NUM10_GPIO_NUM
TOUCH_PAD_GPIO11_CHANNEL
TOUCH_PAD_NUM11_GPIO_NUM
TOUCH_PAD_GPIO12_CHANNEL
TOUCH_PAD_NUM12_GPIO_NUM
TOUCH_PAD_GPIO13_CHANNEL
TOUCH_PAD_NUM13_GPIO_NUM
TOUCH_PAD_GPIO14_CHANNEL
TOUCH_PAD_NUM14_GPIO_NUM

Header File
- components/hal/include/hal/touch_sensor_types.h

Structures
struct touch_pad_denoise
  Touch sensor denoise configuration

  Public Members

  touch_pad_denoise_grade_t grade
  Select denoise range of denoise channel. Determined by measuring the noise amplitude of the denoise channel.

  touch_pad_denoise_cap_t cap_level
  Select internal reference capacitance of denoise channel. Ensure that the denoise readings are closest to the readings of the channel being measured. Use touch_pad_denoise_read_data to get the reading of denoise channel. The equivalent capacitance of the shielded channel can be calculated from the reading of denoise channel.

struct touch_pad_waterproof
  Touch sensor waterproof configuration

  Public Members

  touch_pad_t guard_ring_pad
  Waterproof. Select touch channel use for guard pad. Guard pad is used to detect the large area of water covering the touch panel.

  touch_pad_shield_driver_t shield_driver
  Waterproof. Shield channel drive capability configuration. Shield pad is used to shield the influence of water droplets covering the touch panel. When the waterproof function is enabled, Touch14 is set as shield channel by default. The larger the parasitic capacitance on the shielding channel, the higher
the drive capability needs to be set. The equivalent capacitance of the shield channel can be estimated through the reading value of the denoise channel (Touch0).

```c
struct touch_filter_config
    Touch sensor filter configuration

Public Members

touch_filter_mode_t mode
    Set filter mode. The input of the filter is the raw value of touch reading, and the output of the filter is involved in the judgment of the touch state.

uint32_t debounce_cnt
    Set debounce count, such as \( n \). If the measured values continue to exceed the threshold for \( n+1 \) times, the touch sensor state changes. Range: 0 ~ 7

uint32_t noise_thr
    Noise threshold coefficient. Higher = More noise resistance. The actual noise should be less than (noise coefficient * touch threshold). Range: 0 ~ 3. The coefficient is 0: 4/8; 1: 3/8; 2: 2/8; 3: 1;

uint32_t jitter_step
    Set jitter filter step size. Range: 0 ~ 15

touch_smooth_mode_t smh_lvl
    Level of filter applied on the original data against large noise interference.
```

```c
struct touch_pad_sleep_channel_t
    Touch sensor channel sleep configuration

Public Members

touch_pad_t touch_num
    Set touch channel number for sleep pad. Only one touch sensor channel is supported in deep sleep mode. If clear the sleep channel, point this pad to TOUCH_PAD_NUM0

bool en_proximity
    enable proximity function for sleep pad
```

**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**

Excessive total time will slow down the touch response. Too small measurement time will not be sampled enough, resulting in inaccurate measurements.

**Note** The greater the duty cycle of the measurement time, the more system power is consumed. The number of sleep cycle in each measure process of touch channels. The timer frequency is RTC_SLOW_CLK (can be 150k or 32k depending on the options). Range: 0 ~ 0xffff
Chapter 2. API Reference

**TOUCH_PAD_MEASURE_CYCLE_DEFAULT**

The times of charge and discharge in each measure process of touch channels. The timer frequency is 8Mhz. Recommended typical value: Modify this value to make the measurement time around 1ms. Range: 0 ~ 0xffff

**TOUCH_PAD_INTR_MASK_ALL**

All touch interrupt type enable.

**TOUCH_PROXIMITY_MEAS_NUM_MAX**

Touch sensor proximity detection configuration

**TOUCH_DEBOUNCE_CNT_MAX**

**TOUCH_NOISE_THR_MAX**

**TOUCH_JITTER_STEP_MAX**

**Type Definitions**

```c
typedef struct touch_pad_denoise touch_pad_denoise_t

typedef struct touch_pad_waterproof touch_pad_waterproof_t

typedef struct touch_filter_config touch_filter_config_t
```

**Enumerations**

```c
enum touch_pad_t

 Values:

 TOUCH_PAD_NUM0 = 0
 Touch pad channel 0 is GPIO4(ESP32)

 TOUCH_PAD_NUM1
 Touch pad channel 1 is GPIO0(ESP32) / GPIO1(ESP32-S2)

 TOUCH_PAD_NUM2
 Touch pad channel 2 is GPIO2(ESP32) / GPIO2(ESP32-S2)

 TOUCH_PAD_NUM3
 Touch pad channel 3 is GPIO15(ESP32) / GPIO3(ESP32-S2)

 TOUCH_PAD_NUM4
 Touch pad channel 4 is GPIO13(ESP32) / GPIO4(ESP32-S2)

 TOUCH_PAD_NUM5
 Touch pad channel 5 is GPIO12(ESP32) / GPIO5(ESP32-S2)

 TOUCH_PAD_NUM6
 Touch pad channel 6 is GPIO14(ESP32) / GPIO6(ESP32-S2)

 TOUCH_PAD_NUM7
 Touch pad channel 7 is GPIO27(ESP32) / GPIO7(ESP32-S2)

 TOUCH_PAD_NUM8
 Touch pad channel 8 is GPIO33(ESP32) / GPIO8(ESP32-S2)

 TOUCH_PAD_NUM9
 Touch pad channel 9 is GPIO32(ESP32) / GPIO9(ESP32-S2)

 TOUCH_PAD_NUM10
 Touch channel 10 is GPIO10(ESP32-S2)

 TOUCH_PAD_NUM11
 Touch channel 11 is GPIO11(ESP32-S2)
```
**Chapter 2. API Reference**

`TOUCH_PAD_NUM12`
- Touch channel 12 is GPIO12(ESP32-S2)

`TOUCH_PAD_NUM13`
- Touch channel 13 is GPIO13(ESP32-S2)

`TOUCH_PAD_NUM14`
- Touch channel 14 is GPIO14(ESP32-S2)

**`TOUCH_PAD_MAX`**

**`enum touch_high_volt_t`**
- Touch sensor high reference voltage

*Values:*

- `TOUCH_HVOLT_KEEP = -1`  
  Touch sensor high reference voltage, no change

- `TOUCH_HVOLT_2V4 = 0`  
  Touch sensor high reference voltage, 2.4V

- `TOUCH_HVOLT_2V5`  
  Touch sensor high reference voltage, 2.5V

- `TOUCH_HVOLT_2V6`  
  Touch sensor high reference voltage, 2.6V

- `TOUCH_HVOLT_2V7`  
  Touch sensor high reference voltage, 2.7V

**`TOUCH_HVOLT_MAX`**

**`enum touch_low_volt_t`**
- Touch sensor low reference voltage

*Values:*

- `TOUCH_LVOLT_KEEP = -1`  
  Touch sensor low reference voltage, no change

- `TOUCH_LVOLT_0V5`  
  Touch sensor low reference voltage, 0.5V

- `TOUCH_LVOLT_0V6`  
  Touch sensor low reference voltage, 0.6V

- `TOUCH_LVOLT_0V7`  
  Touch sensor low reference voltage, 0.7V

- `TOUCH_LVOLT_0V8`  
  Touch sensor low reference voltage, 0.8V

**`TOUCH_LVOLT_MAX`**

**`enum touch_volt_atten_t`**
- Touch sensor high reference voltage attenuation

*Values:*

- `TOUCH_HVOLT_ATTEN_KEEP = -1`  
  Touch sensor high reference voltage attenuation, no change

- `TOUCH_HVOLT_ATTEN_1V5 = 0`  
  Touch sensor high reference voltage attenuation, 1.5V attenuation

- `TOUCH_HVOLT_ATTEN_1V`  
  Touch sensor high reference voltage attenuation, 1.0V attenuation

- `TOUCH_HVOLT_ATTEN_0V5`  
  Touch sensor high reference voltage attenuation, 0.5V attenuation
**TOUCH_HVOLT_ATTEN_0V**
Touch sensor high reference voltage attenuation, 0V attenuation

**TOUCH_HVOLT_ATTEN_MAX**

enum touch_cnt_slope_t
Touch sensor charge/discharge speed

Values:

- **TOUCH_PAD_SLOPE_0** = 0
  Touch sensor charge / discharge speed, always zero
- **TOUCH_PAD_SLOPE_1** = 1
  Touch sensor charge / discharge speed, slowest
- **TOUCH_PAD_SLOPE_2** = 2
  Touch sensor charge / discharge speed
- **TOUCH_PAD_SLOPE_3** = 3
  Touch sensor charge / discharge speed
- **TOUCH_PAD_SLOPE_4** = 4
  Touch sensor charge / discharge speed
- **TOUCH_PAD_SLOPE_5** = 5
  Touch sensor charge / discharge speed
- **TOUCH_PAD_SLOPE_6** = 6
  Touch sensor charge / discharge speed
- **TOUCH_PAD_SLOPE_7** = 7
  Touch sensor charge / discharge speed, fast

**TOUCH_PAD_SLOPE_MAX**

enum touch_tie_opt_t
Touch sensor initial charge level

Values:

- **TOUCH_PAD_TIE_OPT_LOW** = 0
  Initial level of charging voltage, low level
- **TOUCH_PAD_TIE_OPT_HIGH** = 1
  Initial level of charging voltage, high level

**TOUCH_PAD_TIE_OPT_MAX**

enum touch_fsm_mode_t
Touch sensor FSM mode

Values:

- **TOUCH_FSM_MODE_TIMER** = 0
  To start touch FSM by timer
- **TOUCH_FSM_MODE_SW**
  To start touch FSM by software trigger

**TOUCH_FSM_MODE_MAX**

enum touch_trigger_mode_t

Values:

- **TOUCH_TRIGGER_BELOW** = 0
  Touch interrupt will happen if counter value is less than threshold.
- **TOUCH_TRIGGER_ABOVE** = 1
  Touch interrupt will happen if counter value is larger than threshold.
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TOUCH_TRIGGER_MAX

enum touch_trigger_src_t
Values:

TOUCH_TRIGGER_SOURCE_BOTH = 0
wakeup interrupt is generated if both SET1 and SET2 are “touched”

TOUCH_TRIGGER_SOURCE_SET1 = 1
wakeup interrupt is generated if SET1 is “touched”

TOUCH_TRIGGER_SOURCE_MAX

enum touch_pad_intr_mask_t
Values:

TOUCH_PAD_INTR_MASK_DONE = BIT(0)
  Measurement done for one of the enabled channels.

TOUCH_PAD_INTR_MASK_ACTIVE = BIT(1)
  Active for one of the enabled channels.

TOUCH_PAD_INTR_MASK_INACTIVE = BIT(2)
  Inactive for one of the enabled channels.

TOUCH_PAD_INTR_MASK_SCAN_DONE = BIT(3)
  Measurement done for all the enabled channels.

TOUCH_PAD_INTR_MASK_TIMEOUT = BIT(4)
  Timeout for one of the enabled channels.

TOUCH_PAD_INTR_MASK_PROXI_MEAS_DONE = BIT(5)
  For proximity sensor, when the number of measurements reaches the set count of measurements, an interrupt will be generated.

enum touch_pad_denoise_grade_t
Values:

TOUCH_PAD_DENOISE_BIT12 = 0
  Denoise range is 12bit

TOUCH_PAD_DENOISE_BIT10 = 1
  Denoise range is 10bit

TOUCH_PAD_DENOISE_BIT8 = 2
  Denoise range is 8bit

TOUCH_PAD_DENOISE_BIT4 = 3
  Denoise range is 4bit

TOUCH_PAD_DENOISE_MAX

enum touch_pad_denoise_cap_t
Values:

TOUCH_PAD_DENOISE_CAP_L0 = 0
  Denoise channel internal reference capacitance is 5pf

TOUCH_PAD_DENOISE_CAP_L1 = 1
  Denoise channel internal reference capacitance is 6.4pf

TOUCH_PAD_DENOISE_CAP_L2 = 2
  Denoise channel internal reference capacitance is 7.8pf

TOUCH_PAD_DENOISE_CAP_L3 = 3
  Denoise channel internal reference capacitance is 9.2pf

TOUCH_PAD_DENOISE_CAP_L4 = 4
  Denoise channel internal reference capacitance is 10.6pf
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 TOUCH_PAD_DENOISE_CAP_L5 = 5
    Denoise channel internal reference capacitance is 12.0pf

 TOUCH_PAD_DENOISE_CAP_L6 = 6
    Denoise channel internal reference capacitance is 13.4pf

 TOUCH_PAD_DENOISE_CAP_L7 = 7
    Denoise channel internal reference capacitance is 14.8pf

 TOUCH_PAD_DENOISE_CAP_MAX = 8

 enum touch_pad_shield_driver_t
    Touch sensor shield channel drive capability level

 Values:

 TOUCH_PAD_SHIELD_DRV_L0 = 0
    The max equivalent capacitance in shield channel is 40pf

 TOUCH_PAD_SHIELD_DRV_L1
    The max equivalent capacitance in shield channel is 80pf

 TOUCH_PAD_SHIELD_DRV_L2
    The max equivalent capacitance in shield channel is 120pf

 TOUCH_PAD_SHIELD_DRV_L3
    The max equivalent capacitance in shield channel is 160pf

 TOUCH_PAD_SHIELD_DRV_L4
    The max equivalent capacitance in shield channel is 200pf

 TOUCH_PAD_SHIELD_DRV_L5
    The max equivalent capacitance in shield channel is 240pf

 TOUCH_PAD_SHIELD_DRV_L6
    The max equivalent capacitance in shield channel is 280pf

 TOUCH_PAD_SHIELD_DRV_L7
    The max equivalent capacitance in shield channel is 320pf

 TOUCH_PAD_SHIELD_DRV_MAX

 enum touch_pad_conn_type_t
    Touch channel idle state configuration

 Values:

 TOUCH_PAD_CONN_HIGHZ = 0
    Idle status of touch channel is high resistance state

 TOUCH_PAD_CONN_GND = 1
    Idle status of touch channel is ground connection

 TOUCH_PAD_CONN_MAX

 enum touch_filter_mode_t
    Touch channel IIR filter coefficient configuration.

 Note On ESP32S2. There is an error in the IIR calculation. The magnitude of the error is twice the filter coefficient. So please select a smaller filter coefficient on the basis of meeting the filtering requirements. Recommended filter coefficient selection IIR_16.

 Values:

 TOUCH_PAD_FILTER_IIR_4 = 0
    The filter mode is first-order IIR filter. The coefficient is 4.

 TOUCH_PAD_FILTER_IIR_8
    The filter mode is first-order IIR filter. The coefficient is 8.
The filter mode is first-order IIR filter. The coefficient is 16 (Typical value).

The filter mode is first-order IIR filter. The coefficient is 32.

The filter mode is first-order IIR filter. The coefficient is 64.

The filter mode is first-order IIR filter. The coefficient is 128.

The filter mode is first-order IIR filter. The coefficient is 256.

The filter mode is jitter filter

**enum touch_smooth_mode_t**

Level of filter applied on the original data against large noise interference.

**Note** On ESP32S2, there is an error in the IIR calculation. The magnitude of the error is twice the filter coefficient. So please select a smaller filter coefficient on the basis of meeting the filtering requirements.

Recommended filter coefficient selection **IIR_2**.

**Values:**

**TOUCH_PAD_SMOOTH_OFF** = 0

No filtering of raw data.

**TOUCH_PAD_SMOOTH_IIR_2** = 1

Filter the raw data. The coefficient is 2 (Typical value).

**TOUCH_PAD_SMOOTH_IIR_4** = 2

Filter the raw data. The coefficient is 4.

**TOUCH_PAD_SMOOTH_IIR_8** = 3

Filter the raw data. The coefficient is 8.

**TOUCH_PAD_SMOOTH_MAX**

### 2.3.21 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-S3’s peripherals contains a TWAI controller 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:

1. **TWAI Protocol Summary**
2. **Signals Lines and Transceiver**
3. **Driver Configuration**
4. **Driver Operation**
5. **Examples**
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 from 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-S3’s GPIO pads.
**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 (APB 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.
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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_RX_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 (80 MHz APB clock). On the ESP32-S3, the brp can be any even number from 2 to 128.

The sample point of a bit is located on the intersection of Timing Segment 1 and 2. Enabling **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 Synchronization Jump Width is used to determine the maximum number of time quanta a single bit time can be lengthened/shortened for synchronization purposes. sjw can range from 1 to 4.
Note: Multiple combinations of \( brp, tseg_1, tseg_2 \), and \( sjw \) 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 propagation delay, node information processing time, and phase errors.

Bit timing **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()}
- \texttt{TWAI\_TIMING\_CONFIG\_20KBITS()}
- \texttt{TWAI\_TIMING\_CONFIG\_16KBITS()}
- \texttt{TWAI\_TIMING\_CONFIG\_12\_5KBITS()}
- \texttt{TWAI\_TIMING\_CONFIG\_10KBITS()}
- \texttt{TWAI\_TIMING\_CONFIG\_5KBITS()}
- \texttt{TWAI\_TIMING\_CONFIG\_1KBITS()}

**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 acceptance code and the acceptance mask.

The **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 **acceptance mask** is a bit sequence specifying which bits of the acceptance code can be ignored. This allows for messages of different IDs to be accepted by a single acceptance code.

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. 19: Bit layout of single filter mode (Right side MSBit)](image-url)
**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. 20: Bit layout of dual filter mode (Right side MSBit)

**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).

**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.

Fig. 21: State transition diagram of the TWAI driver (see table below)
<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>twai_driver_install()</td>
</tr>
<tr>
<td>B</td>
<td>Stopped -&gt; Uninstalled</td>
<td>twai_driver_uninstall()</td>
</tr>
<tr>
<td>C</td>
<td>Stopped -&gt; Running</td>
<td>twai_start()</td>
</tr>
<tr>
<td>D</td>
<td>Running -&gt; Stopped</td>
<td>twai_stop()</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>twai_driver_uninstall()</td>
</tr>
<tr>
<td>G</td>
<td>Bus-Off -&gt; Recovering</td>
<td>twai_initiate_recovery()</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.

**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 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 retransmitted 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 be 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.
Chapter 2. API Reference

```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_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.
// 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.

#include "driver/twai.h"
...
// 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 twai_stop() and 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 `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:

<table>
<thead>
<tr>
<th>ID1</th>
<th>11'b101 1010 0000</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID2</td>
<td>11'b101 1010 0001</td>
</tr>
<tr>
<td>ID3</td>
<td>11'b101 1010 0100</td>
</tr>
<tr>
<td>ID4</td>
<td>11'b101 1010 1000</td>
</tr>
</tbody>
</table>

// Acceptance Mask
MASK = 11'b000 0000 1101

**Application Examples**

**Network Example:** The TWAINetwork example demonstrates communication between two ESP32-S3s 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 `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**

`struct twai_message_t`

Structure to store a TWAI message.

**Note** The flags member is deprecated

**Public Members**

- `uint32_t extd : 1`
  - Extended Frame Format (29bit ID)
- `uint32_t rtr : 1`
  - 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

uint8_t data[TWAI_FRAME_MAX_DLC]  
Data bytes (not relevant in RTR frame)

struct twai_timing_config_t  
Structure for bit timing configuration of the TWAI driver.

Note  Macro initializers are available for this structure

Public Members

uint32_t brp  
Baudrate prescaler (i.e., APB clock divider). Any even number from 2 to 128 for ESP32, 2 to 32768 for ESP32S2. For ESP32 Rev 2 or later, multiples of 4 from 132 to 256 are also supported

uint8_t tseg_1  
Timing segment 1 (Number of time quanta, between 1 to 16)

uint8_t tseg_2  
Timing segment 2 (Number of time quanta, 1 to 8)

uint8_t sjw  
Synchronization Jump Width (Max time quanta jump for synchronize from 1 to 4)

bool triple_sampling  
Enables triple sampling when the TWAI controller samples a bit

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

uint32_t acceptance_code  
32-bit acceptance code

uint32_t acceptance_mask  
32-bit acceptance mask

bool single_filter  
Use Single Filter Mode (see documentation)
Chapter 2. API Reference

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

Enumerations

enum twai_mode_t
TWAI Controller operating modes.
Values:

**TWAI_MODE_NORMAL**
Normal operating mode where TWAI controller can send/receive/acknowledge messages

**TWAI_MODE_NO_ACK**
Transmission does not require acknowledgment. Use this mode for self testing

**TWAI_MODE_LISTEN_ONLY**
The TWAI controller will not influence the bus (No transmissions or acknowledgments) but can receive messages

Header File

- components/driver/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

Return

- ESP_OK: Successfully installed TWAI driver
- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_NO_MEM: Insufficient memory
- ESP_ERR_INVALID_STATE: Driver is already installed

Parameters

- [in] g_config: General configuration structure
- [in] t_config: Timing configuration structure
- [in] f_config: Filter configuration structure
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.

**Return**
- 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.

**Return**
- 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.

**Return**
- ESP_OK: TWAI driver is now Stopped
- ESP_ERR_INVALID_STATE: Driver is not in running state, or is not installed

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.

**Note** The TX_IDLE alert can be used to alert the application when no other messages are awaiting transmission.

**Return**
- 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

**Parameters**
- [in] message: Message to transmit
- [in] ticks_to_wait: Number of FreeRTOS ticks to block on the TX queue

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.

**Return**
- ESP_OK: Message successfully received from RX queue
- ESP_ERR_TIMEOUT: Timed out waiting for message
- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

**Parameters**
- `[out] message`: Received message
- `[in] ticks_to_wait`: Number of FreeRTOS ticks to block on RX queue

```c
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.

**Return**
- 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

**Parameters**
- `[out] alerts`: Bit field of raised alerts (see documentation for alert flags)
- `[in] ticks_to_wait`: Number of FreeRTOS ticks to block for alert

```c
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.

**Return**
- ESP_OK: Alerts reconfigured
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

**Parameters**
- `[in] alerts_enabled`: Bit field of alerts to enable (see documentation for alert flags)
- `[out] current_alerts`: Bit field of currently raised alerts. Set to NULL if unused

```c
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.

**Return**
- ESP_OK: Bus recovery started
- ESP_ERR_INVALID_STATE: TWAI driver is not in the bus-off state, or is not installed

```c
esp_err_t twai_get_status_info (twai_status_info_t *status_info)```

Get current status information of the TWAI driver.

**Return**
- ESP_OK: Status information retrieved
- ESP_ERR_INVALID_ARG: Arguments are invalid
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

**Parameters**
- `[out] status_info`: Status information

```c
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.

**Return**
- ESP_OK: Transmit queue cleared
- ESP_ERR_INVALID_STATE: TWAI driver is not installed or TX queue is disabled

```c
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.

**Return**
- ESP_OK: Transmit queue cleared
- ESP_ERR_INVALID_STATE: TWAI driver is not installed

**Structures**

```c
struct twai_general_config_t
```

Structure for general configuration of the TWAI driver.

**Note** Macro initializers are available for this structure

**Public Members**

```c
twai_mode_t mode
```

Mode of TWAI controller

```c
gpio_num_t tx_io
```

Transmit GPIO number

```c
gpio_num_t rx_io
```

Receive GPIO number

```c
gpio_num_t clkout_io
```

CLKOUT GPIO number (optional, set to -1 if unused)

```c
gpio_num_t bus_off_io
```

Bus off indicator GPIO number (optional, set to -1 if unused)

```c
uint32_t tx_queue_len
```

Number of messages TX queue can hold (set to 0 to disable TX Queue)

```c
uint32_t rx_queue_len
```

Number of messages RX queue can hold

```c
uint32_t alerts_enabled
```

Bit field of alerts to enable (see documentation)

```c
uint32_t clkout_divider
```

CLKOUT divider. Can be 1 or any even number from 2 to 14 (optional, set to 0 if unused)

```c
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.

```c
struct twai_status_info_t
```

Structure to store status information of TWAI driver.
Public Members

\begin{verbatim}
\textbf{twai_state_t} \textbf{state}
Current state of TWAI controller (Stopped/Running/Bus-Off/Recovery)

\textbf{uint32_t} \textbf{msgs_to_tx}
Number of messages queued for transmission or awaiting transmission completion

\textbf{uint32_t} \textbf{msgs_to_rx}
Number of messages in RX queue waiting to be read

\textbf{uint32_t} \textbf{tx_error_counter}
Current value of Transmit Error Counter

\textbf{uint32_t} \textbf{rx_error_counter}
Current value of Receive Error Counter

\textbf{uint32_t} \textbf{tx_failed_count}
Number of messages that failed transmissions

\textbf{uint32_t} \textbf{rx_missed_count}
Number of messages that were lost due to a full RX queue (or errata workaround if enabled)

\textbf{uint32_t} \textbf{rx_overrun_count}
Number of messages that were lost due to a RX FIFO overrun

\textbf{uint32_t} \textbf{arb_lost_count}
Number of instances arbitration was lost

\textbf{uint32_t} \textbf{bus_error_count}
Number of instances a bus error has occurred
\end{verbatim}

Macros

\begin{verbatim}
\textbf{TWAI_IO_UNUSED}
Marks GPIO as unused in TWAI configuration
\end{verbatim}

Enumerations

\begin{verbatim}
\textbf{enum twai_state_t}
TWAI driver states.

Values:

\textbf{TWAI_STATE_STOPPED}
Stopped state. The TWAI controller will not participate in any TWAI bus activities

\textbf{TWAI_STATE_RUNNING}
Running state. The TWAI controller can transmit and receive messages

\textbf{TWAI_STATE_BUS_OFF}
Bus-off state. The TWAI controller cannot participate in bus activities until it has recovered

\textbf{TWAI_STATE_RECOVERING}
Recovering state. The TWAI controller is undergoing bus recovery
\end{verbatim}

2.3.22 Universal Asynchronous Receiver/Transmitter (UART)

Overview

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, RS485. A UART provides a widely adopted and cheap method to realize full-duplex or half-duplex data exchange among different devices.
The ESP32-S3 chip has three UART controllers (UART0, UART1, and UART2), 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 protocols (IrDA).

**Functional Overview**

The following overview describes how to establish communication between an ESP32-S3 and other UART devices using the functions and data types of the UART driver. The overview reflects a typical programming workflow and is broken down into the sections provided below:

1. **Setting Communication Parameters** - Setting baud rate, data bits, stop bits, etc.
2. **Setting Communication Pins** - Assigning pins for connection to a device.
3. **Driver Installation** - Allocating ESP32-S3’s resources for the UART driver.
4. **Running UART Communication** - Sending / receiving data
5. **Using 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.

**Setting 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 6: Functions for Configuring specific parameters individually**

<table>
<thead>
<tr>
<th>Parameter to Configure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baud rate</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 \texttt{uart\_get\_baudrate()}.

**Setting 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 \texttt{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 \texttt{UART\_PIN\_NO\_CHANGE}.

The same macro 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));
```

**Driver Installation**  Once the communication pins are set, install the driver by calling \texttt{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.

```c
// 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.

**Running 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 be limited to writing and reading data from a respective buffer using \texttt{uart\_write\_bytes()} and \texttt{uart\_read\_bytes()} respectively, and the FSM will do the rest.

**Transmitting**  After preparing the data for transmission, call the function \texttt{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.\n";
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)
```

**Receiving**  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.

```c
// 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.

```c
// Setup UART in rs485 half duplex mode
ESP_ERROR_CHECK(uart_set_mode(uart_num, UART_MODE_RS485_HALF_DUPLEX));
```

**Using Interrupts**  There are many interrupts that can be generated following specific UART states or detected errors. The full list of available interrupts is provided in [ESP32-S3 Technical Reference Manual > UART Controller (UART) > UART Interrupts and UHCI Interrupts](#). You can enable or disable specific interrupts by calling `uart_enable_intr_mask()` or `uart_disable_intr_mask()` respectively. The mask of all interrupts is available as `UART_INTR_MASK`.

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 Driver Installation. 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 for a number of times. This functionality is demonstrated in the example peripherals/uart/uart_events.
  - It can be used, e.g., to detect a command string followed by a specific number of identical characters (the ‘pattern’) added at the end of the command string. The following functions are available:
    - Configure and enable this interrupt using uart_enable_pattern_det_intr()
    - Disable the interrupt using uart_disable_pattern_det_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-S3 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 (removes collisions automatically by hardware).

The ESP32-S3’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-S3 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 com-
munication 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-S3’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**

```
VCC ---------------+     
|                  |
|                  |
+--------x--------+
RXD <--------| R |
|            | B|----------<> B |
TXD ------->| D | ADM483 |
|            | RS485 bus side |
ESP       | RTS ------->| DE |
|              | A|----------<> A |
|              | /RE |
| +-----| /RE |
| +--------x--------+
| |
| GND     GND
```

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**

```
VCC ---------------+     
|                  |
|                  |
+--------x--------+
RXD <--------| R |
|            | B|----------<> B |
TXD ------->| D | ADM483 |
|            | RS485 bus side |
ESP       | RTS ------->| DE |
|              | A|----------<> A |
|              | /RE |
| +-----| /RE |
| +--------x--------+
| |
| GND
```

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>
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<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>
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<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 peripherals/uart/uart_echo but allows communication through an RS485 interface chip connected to ESP32-S3 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/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.

Return
- ESP_OK Success
- ESP_FAIL Parameter error

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 (ORed) 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)

esp_err_t uart_driver_delete(uart_port_t uart_num)
Uninstall UART driver.

Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).

bool uart_is_driver_installed(uart_port_t uart_num)
Checks whether the driver is installed or not.

Return
- true driver is installed
- false driver is not installed

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).

esp_err_t uart_set_word_length(uart_port_t uart_num, uart_word_length_t data_bit)
Set UART data bits.

Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- data_bit: UART data bits

esp_err_t uart_get_word_length(uart_port_t uart_num, uart_word_length_t *data_bit)
Get the UART data bit configuration.

Return
- ESP_FAIL Parameter error
- ESP_OK Success, result will be put in (*data_bit)

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.

esp_err_t uart_set_stop_bits(uart_port_t uart_num, uart_stop_bits_t stop_bits)
Set UART stop bits.

Return
- ESP_OK Success
- ESP_FAIL Fail

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- stop_bits: UART stop bits
esp_err_t uart_get_stop_bits(uart_port_t uart_num, uart_stop_bits_t *stop_bits)
Get the UART stop bit configuration.

Return
• ESP_FAIL Parameter error
• ESP_OK Success, result will be put in (*stop_bits)

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.

esp_err_t uart_set_parity(uart_port_t uart_num, uart_parity_t parity_mode)
Set UART parity mode.

Return
• ESP_FAIL Parameter error
• ESP_OK Success

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• parity_mode: the enum of uart parity configuration

esp_err_t uart_get_parity(uart_port_t uart_num, uart_parity_t *parity_mode)
Get the UART parity mode configuration.

Return
• ESP_FAIL Parameter error
• ESP_OK Success, result will be put in (*parity_mode)

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.

esp_err_t uart_set_baudrate(uart_port_t uart_num, uint32_t baudrate)
Set UART baud rate.

Return
• ESP_FAIL Parameter error
• ESP_OK Success

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• baudrate: UART baud rate.

esp_err_t uart_get_baudrate(uart_port_t uart_num, uint32_t *baudrate)
Get the UART baud rate configuration.

Return
• ESP_FAIL Parameter error
• ESP_OK Success, result will be put in (*baudrate)

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• baudrate: Pointer to accept value of UART baud rate

esp_err_t uart_set_line_inverse(uart_port_t uart_num, uint32_t inverse_mask)
Set UART line inverse mode.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

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

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.
Return
• ESP_OK Success
• ESP_FAIL Parameter error

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.

`esp_err_t uart_set_sw_flow_ctrl(uart_port_t uart_num, bool enable, uint8_t rx_thresh_xon, uint8_t rx_thresh_xoff)`
Set software flow control.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART_NUM_0, UART_NUM_1 or UART_NUM_2
• enable: switch on or off
• rx_thresh_xon: low water mark
• rx_thresh_xoff: high water mark

`esp_err_t uart_get_hw_flow_ctrl(uart_port_t uart_num, uart_hw_flowcontrol_t *flow_ctrl)`
Get the UART hardware flow control configuration.

Return
• ESP_FAIL Parameter error
• ESP_OK Success, result will be put in (*flow_ctrl)

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• flow_ctrl: Option for different flow control mode.

`esp_err_t uart_clear_intr_status(uart_port_t uart_num, uint32_t clr_mask)`
Clear UART interrupt status.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• clr_mask: Bit mask of the interrupt status to be cleared.

`esp_err_t uart_enable_intr_mask(uart_port_t uart_num, uint32_t enable_mask)`
Set UART interrupt enable.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• enable_mask: Bit mask of the enable bits.

`esp_err_t uart_disable_intr_mask(uart_port_t uart_num, uint32_t disable_mask)`
Clear UART interrupt enable bits.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• disable_mask: Bit mask of the disable bits.

`esp_err_t uart_enable_rx_intr(uart_port_t uart_num)`
Enable UART RX interrupt (RX_FULL & RX_TIMEOUT INTERRUPT)
Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).

```c
esp_err_t uart_disable_rx_intr(uart_port_t uart_num)
```

Disable UART RX interrupt (RX_FULL & RX_TIMEOUT INTERRUPT)

Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).

```c
esp_err_t uart_disable_tx_intr(uart_port_t uart_num)
```

Disable UART TX interrupt (TX_FULL & TX_TIMEOUT INTERRUPT)

Return
- ESP_OK Success
- ESP_FAIL Parameter error

Parameters
- uart_num: UART port number

```c
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)

Return
- ESP_OK Success
- ESP_FAIL Parameter error

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

```c
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.

Return
- ESP_OK Success
- ESP_FAIL Parameter error

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.

```c
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.

Return
- ESP_OK Success
• ESP_FAIL Parameter error

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)

`esp_err_t uart_set_dtr(uart_port_t uart_num, int level)`
Manually set the UART DTR pin level.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• level: 1: DTR output low; 0: DTR output high

`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.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

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)

`esp_err_t uart_param_config(uart_port_t uart_num, const uart_config_t *uart_config)`
Set UART configuration parameters.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• uart_config: UART parameter settings

`esp_err_t uart_intr_config(uart_port_t uart_num, const uart_intr_config_t *intr_conf)`
Configure UART interrupts.

Return
• ESP_OK Success
• ESP_FAIL Parameter error

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• intr_conf: UART interrupt settings

`esp_err_t uart_wait_tx_done(uart_port_t uart_num, TickType_t ticks_to_wait)`
Wait until UART TX FIFO is empty.

Return
• ESP_OK Success
• ESP_FAIL Parameter error
• ESP_ERR_TIMEOUT Timeout

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
• ticks_to_wait: Timeout, count in RTOS ticks

`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.

Return
Chapter 2. API Reference

- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

**Parameters**
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- buffer: data buffer address
- len: data length to send

```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.

**Return**
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

**Parameters**
- uart_num: UART port number, the max port number is (UART_NUM_MAX -1).
- src: data buffer address
- size: data length to send

```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.

**Return**
- (-1) Parameter error
- OTHERS (>=0) The number of bytes pushed to the TX FIFO

**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

```c
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.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error
### Parameters
- uart_num: UART port number, the max port number is (UART_NUM_MAX - 1).

#### `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.

**Return**
- 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.

**Return**
- ESP_OK Success
- ESP_FAIL 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.

**Return**
- 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.

**Return**
- ESP_OK Success
- ESP_FAIL Parameter error

#### `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.

Return
• (-1) No pattern found for current index or parameter error
• others the pattern position in rx buffer.

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).

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.

Return
• (-1) No pattern found for current index or parameter error
• others the pattern position in rx buffer.

Parameters
• uart_num: UART port number, the max port number is (UART_NUM_MAX -1).

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.

Return
• ESP_ERR_NO_MEM No enough memory
• ESP_ERR_INVALID_STATE Driver not installed
• ESP_FAIL Parameter error
• ESP_OK Success

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.

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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error

Parameters
• uart_num: Uart number to configure, the max port number is (UART_NUM_MAX -1).
• mode: UART UART mode to set

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.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Parameter error
• ESP_ERR_INVALID_STATE Driver is not installed

Parameters
• uart_num: UART_NUM_0, UART_NUM_1 or UART_NUM_2
• threshold: Threshold value above which RX fifo full interrupt is generated
**esp_err_t uart_set_tx_empty_threshold** *(uart_port_t uart_num, int threshold)*

Set uart threshold values for TX fifo empty.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_INVALID_STATE Driver is not installed

**Parameters**
- **uart_num**: UART_NUM_0, UART_NUM_1 or UART_NUM_2
- **threshold**: Threshold value below which TX fifo empty interrupt is generated

**esp_err_t uart_set_rx_timeout** *(uart_port_t uart_num, const uint8_t tout_thresh)*

UART set threshold timeout for TOUT feature.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_INVALID_STATE Driver is not installed

**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 expired the UART_RXFIFO_TOUT_INT interrupt is triggered. If tout_thresh == 0, the TOUT feature is disabled.

**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()).

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Parameter error

**Parameters**
- **uart_num**: Uart number to configure the max port number is (UART_NUM_MAX -1).
- **collision_flag**: Pointer to variable of type bool to return collision flag.

**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 make sure that UART has correct baud rate all the time, select REF_TICK as UART clock source, by setting use_ref_tick field in uart_config_t to true.

**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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if uart_num is incorrect or wakeup_threshold is outside of [3, 0x3ff] range.

**Parameters**
- **uart_num**: UART number, the max port number is (UART_NUM_MAX -1).
• wakeuup_threshold: number of RX edges for light sleep wakeup, value is 3 .. 0x3ff.

\[\text{esp_err_t uart_get_wakeup_threshold (uart_port_t uart_num, int *out_wakeup_threshold)}\]

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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if out_wakeup_threshold is NULL

**Parameters**
- \(\text{uart_num}\): UART number, the max port number is (UART_NUM_MAX -1).
- \(\text{[out] out_wakeup_threshold}\): output, set to the current value of wakeuup threshold for the given UART.

\[\text{esp_err_t uart_wait_tx_idle_polling (uart_port_t uart_num)}\]

Wait until UART tx memory empty and the last char send ok (polling mode).

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Driver not installed

**Parameters**
- \(\text{uart_num}\): UART number

\[\text{esp_err_t uart_set_loop_back (uart_port_t uart_num, bool loop_back_en)}\]

Configure TX signal loop back to RX module, just for the test usage.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_FAIL Driver not installed

**Parameters**
- \(\text{uart_num}\): UART number
- \(\text{loop_back_en}\): Set true to enable the loop back function, else set it false.

\[\text{void uart_set_always_rx_timeout (uart_port_t uart_num, bool always_rx_timeout_en)}\]

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**
- \(\text{uart_num}\): UART number
- \(\text{always_rx_timeout_en}\): Set to false enable the default behavior of timeout interrupt, set it to true to always trigger timeout interrupt.

**Structures**

\textbf{struct uart_intr_config_t}

UART interrupt configuration parameters for uart_intr_config function.

**Public Members**

\textbf{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

\textbf{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

enum uart_event_type_t
  UART event types used in the ring buffer.

  Values:

  UART_DATA
    UART data event

  UART_BREAK
    UART break event

  UART_BUFFER_FULL
    UART RX buffer full event

  UART_FIFO_OVF
    UART FIFO overflow event
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UART_FRAME_ERR
UART RX frame error event

UART_PARITY_ERR
UART RX parity event

UART_DATA_BREAK
UART TX data and break event

UART_PATTERN_DET
UART pattern detected

UART_WAKEUP
UART wakeup event

UART_EVENT_MAX
UART event max index

Header File
- components/hal/include/hal/uart_types.h

Structures

struct uart_at_cmd_t
UART AT cmd char configuration parameters Note that this function may different on different chip. Please refer to the TRM at configuration.

Public Members

uint8_t cmd_char
UART AT cmd char

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

uart_hw_flowcontrol_t flow_ctrl
UART HW flow control mode (cts/rts)

uint8_t rx_flow_ctl_thresh
UART HW RTS threshold

uart_sclk_t source_clk
UART source clock selection

bool use_ref_tick
Deprecated method to select ref tick clock source, set source_clk field instead

Type Definitions
typedef int uart_port_t
UART port number, can be UART_NUM_0 - (UART_NUM_MAX -1).

Enumerations
enum uart_mode_t
UART mode selection.
Values:

UART_MODE_UART = 0x00
mode: regular UART mode

UART_MODE_RS485_HALF_DUPLEX = 0x01
mode: half duplex RS485 UART mode control by RTS pin

UART_MODE_IRDA = 0x02
mode: IRDA UART mode

UART_MODE_RS485_COLLISION_DETECT = 0x03
mode: RS485 collision detection UART mode (used for test purposes)

UART_MODE_RS485_APP_CTRL = 0x04
mode: application control RS485 UART mode (used for test purposes)

enum uart_word_length_t
UART word length constants.
Values:

UART_DATA_5_BITS = 0x0
word length: 5bits

UART_DATA_6_BITS = 0x1
word length: 6bits
UART_DATA_7_BITS = 0x2
    word length: 7bits
UART_DATA_8_BITS = 0x3
    word length: 8bits
UART_DATA_BITS_MAX = 0x4

enum uart_stop_bits_t
    UART stop bits number.
    Values:
    UART_STOP_BITS_1 = 0x1
        stop bit: 1bit
    UART_STOP_BITS_1_5 = 0x2
        stop bit: 1.5bits
    UART_STOP_BITS_2 = 0x3
        stop bit: 2bits
    UART_STOP_BITS_MAX = 0x4

enum uart_parity_t
    UART parity constants.
    Values:
    UART_PARITY_DISABLE = 0x0
        Disable UART parity
    UART_PARITY_EVEN = 0x2
        Enable UART even parity
    UART_PARITY_ODD = 0x3
        Enable UART odd parity

enum uart_hw_flowcontrol_t
    UART hardware flow control modes.
    Values:
    UART_HW_FLOWCTRL_DISABLE = 0x0
        disable hardware flow control
    UART_HW_FLOWCTRL_RTS = 0x1
        enable RX hardware flow control (rts)
    UART_HW_FLOWCTRL_CTS = 0x2
        enable TX hardware flow control (cts)
    UART_HW_FLOWCTRL_CTS_RTS = 0x3
        enable hardware flow control
    UART_HW_FLOWCTRL_MAX = 0x4

enum uart_signal_inv_t
    UART signal bit map.
    Values:
    UART_SIGNAL_INV_DISABLE = 0
        Disable UART signal inverse
    UART_SIGNAL_IRDA_TX_INV = (0x1 << 0)
        inverse the UART irda_tx signal
    UART_SIGNAL_IRDA_RX_INV = (0x1 << 1)
        inverse the UART irda_rx signal
UART_SIGNAL_RXD_INV = (0x1 << 2)  
inverse the UART rxdsignal
UART_SIGNAL_CTS_INV = (0x1 << 3)  
inverse the UART cts signal
UART_SIGNAL_DSR_INV = (0x1 << 4)  
inverse the UART dsr signal
UART_SIGNAL_TXD_INV = (0x1 << 5)  
inverse the UART txd signal
UART_SIGNAL_RTS_INV = (0x1 << 6)  
inverse the UART rts signal
UART_SIGNAL_DTR_INV = (0x1 << 7)  
inverse the UART dtr signal

enum uart_sclk_t
UART source clock.

Values:

UART_SCLK_APB = 0x0  
UART source clock from APB
UART_SCLK_RTC = 0x1  
UART source clock from RTC
UART_SCLK_XTAL = 0x2  
UART source clock from XTAL

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). Similar to the above macro but specifies the pin function which is also part of the IO_MUX assignment.

Header File

- components/soc/esp32s3/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
2.3.23 USB Device Driver

Overview

The driver allows users to use ESP32-S3 chips to develop USB devices on top the TinyUSB stack. TinyUSB is integrating with ESP-IDF to provide USB features of the framework. Using this driver the chip works as a composite device supporting to represent several USB devices simultaneously. Currently, only the communications device class (CDC) type of the device with the ACM (Abstract Control Model) subclass is supported.
Chapter 2. API Reference

Features

- Configuration of device and string USB descriptors
- USB Serial Device (CDC-ACM)
- Input and output through USB Serial Device

Hardware USB Connection

- Any board with the ESP32-S3 chip with USB connectors or with exposed USB’s D+ and D- (DATA+/DATA-) pins.

If the board has no USB connector but has the pins, connect pins directly to the host (e.g. with do-it-yourself cable from any USB connection cable).

On ESP32-S3, connect GPIO 20 and 19 to D+/D- respectively:

Driver Structure

As the basis is used the TinyUSB stack.

On top of it the driver implements:

- Customization of USB descriptors
- Serial device support
- Redirecting of standard streams through the Serial device
- Encapsulated driver’s task servicing the TinyUSB

Configuration

Via Menuconfig options you can specify:

- Several of descriptor’s parameters (see: Descriptors Configuration below)
- USB Serial low-level Configuration
- The verbosity of the TinyUSB’s log
- Disable the TinyUSB main task (for the custom implementation)

Descriptors Configuration

The driver’s descriptors are provided by the tinyusb_config_t structure’s descriptor and string_descriptor members. Therefore, users should initialize tinyusb_config_t to their desired descriptor before calling tinyusb_driver_install() to install driver.
However, the driver also provides a default descriptor. The driver can be installed with the default descriptor by setting the `descriptor` and `string_descriptor` members of `tinyusb_config_t` to `NULL` before calling `tinyusb_driver_install()`. The driver’s default descriptor is specified using Menuconfig, where the following fields should be configured:

- PID
- VID
- bcdDevice
- Manufacturer
- Product name
- Name of CDC device if it is On
- Serial number

If you want to use own descriptors with extended modification, you can define them during the driver installation process.

**Install Driver**

To initialize the driver, users should call `tinyusb_driver_install()`. The driver’s configuration is specified in a `tinyusb_config_t` structure that is passed as an argument to `tinyusb_driver_install()`.

Note that the `tinyusb_config_t` structure can be zero initialized (e.g. `tinyusb_config_t tusb_cfg = { 0 }`) or partially (as shown below). For any member that is initialized to `0` or `NULL`, the driver will use its default configuration values for that member (see example below)

```c
tinyusb_config_t partial_init = {
    .descriptor = NULL, //Uses default descriptor specified in Menuconfig
    .string_descriptor = NULL, //Uses default string specified in Menuconfig
    .external_phy = false,
}
```

**USB Serial Device (CDC-ACM)**

If the CDC option is enabled in Menuconfig, the USB Serial Device could be initialized with `tusb_cdc_acm_init()` according to the settings from `tinyusb_config_cdcacm_t` (see example below).

```c
tinyusb_config_cdcacm_t amc_cfg = {
    .usb_dev = TINYUSB_USBDEV_0,
    .cdc_port = TINYUSB_CDC_ACM_0,
    .rx_unread_buf_sz = 64,
    .callback_rx = NULL,
    .callback_rx_wanted_char = NULL,
    .callback_line_state_changed = NULL,
    .callback_line_coding_changed = NULL
};
tusb_cdc_acm_init(&amc_cfg);
```

To specify callbacks you can either set the pointer to your `tusb_cdcacm_callback_t` function in the configuration structure or call `tinyusb_cdcacm_register_callback()` after initialization.

**USB Serial Console**  The driver allows to redirect all standard application strings (stdin/out/err) to the USB Serial Device and return them to UART using `esp_tusb_init_console()/esp_tusb_deinit_console()` functions.

**Application Examples**

The table below describes the code examples available in the directory `peripherals/usb/`. 
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**API Reference**

**Header File**

- `components/tinyusb/additions/include/tinyusb.h`

**Functions**

```c
esp_err_t tinyusb_driver_install(const tinyusb_config_t *config)
```

This is an all-in-one helper function, including:

1. USB device driver initialization
2. Descriptors preparation
3. TinyUSB stack initialization
4. Creates and start a task to handle usb events

**Note** Don’t change Custom descriptor, but if it has to be done, Suggest to define as follows in order to match the Interface Association Descriptor (IAD): bDeviceClass = TUSB_CLASS_MISC, bDeviceSubClass = MISC_SUBCLASS_COMMON,

**Parameters**

- `config`: tinyusb stack specific configuration

**Return Value**

- `ESP_ERR_INVALID_ARG`: Install driver and tinyusb stack failed because of invalid argument
- `ESP_FAIL`: Install driver and tinyusb stack failed because of internal error
- `ESP_OK`: Install driver and tinyusb stack successfully

**Structures**

```c
struct tinyusb_config_t
```

Configuration structure of the tinyUSB core.

**Public Members**

- `tusb_desc_device_t *descriptor`
  Pointer to a device descriptor
- `const char **string_descriptor`
  Pointer to an array of string descriptors
- `bool external_phy`
  Should USB use an external PHY

**Header File**

- `components/tinyusb/additions/include/tinyusb_types.h`

**Macros**

- `USB_ESPRESSIF_VID`
- `USB_STRING_DESCRIPTOR_ARRAY_SIZE`
### Enumerations

**enum tinyusb_usbdev_t**

Values:

- **TINYUSB_USBDEV_0**

### Header File

- components/tinyusb/additions/include/tusb_cdc_acm.h

### Functions

**esp_err_t tusb_cdc_acm_init(const tinyusb_config_cdcacm_t *cfg)**

Initialize CDC ACM. Initialization will be finished with the `tud_cdc_line_state_cb` callback.

- **Return esp_err_t**
- **Parameters**
  - `cfg`: init configuration structure

**esp_err_t tusb_cdcacm_register_callback(tinyusb_cdcacm_itf_t itf, cdcacm_event_type_t event_type, tusb_cdcacm_callback_t callback)**

Register a callback invoking on CDC event. If the callback had been already registered, it will be overwritten.

- **Return esp_err_t**: ESP_OK or ESP_ERR_INVALID_ARG
- **Parameters**
  - `itf`: number of a CDC object
  - `event_type`: type of registered event for a callback
  - `callback`: callback function

**esp_err_t tusb_cdcacm_unregister_callback(tinyusb_cdcacm_itf_t itf, cdcacm_event_type_t event_type)**

Unregister a callback invoking on CDC event.

- **Return esp_err_t**: ESP_OK or ESP_ERR_INVALID_ARG
- **Parameters**
  - `itf`: number of a CDC object
  - `event_type`: type of registered event for a callback

**size_t tinyusb_cdcacm_write_queue_char(tinyusb_cdcacm_itf_t itf, char ch)**

Sent one character to a write buffer.

- **Return size_t**: amount of queued bytes
- **Parameters**
  - `itf`: number of a CDC object
  - `ch`: character to send

**size_t tinyusb_cdcacm_write_queue(tinyusb_cdcacm_itf_t itf, const uint8_t *in_buf, size_t in_size)**

Write data to write buffer from a byte array.

- **Return size_t**: amount of queued bytes
- **Parameters**
  - `itf`: number of a CDC object
  - `in_buf`: a source array
  - `in_size`: size to write from arr_src

**esp_err_t tusb_cdcacm_write_flush(tinyusb_cdcacm_itf_t itf, uint32_t timeout_ticks)**

Send all data from a write buffer. Use `tinyusb_cdcacm_write_queue` to add data to the buffer.

---

WARNING! TinyUSB can block output Endpoint for several RX callbacks, after...

---

...will do additional flush
after the each trasfer. That can leads to the situation when you requested...

---

...a flush, but it will fail until
out of the next callbacks ends.

SO USING OF THE FLUSH WITH TIMEOUTS IN CALLBACKS IS NOT RECOMENDED - YOU...

---

...CAN GET A LOCK FOR THE TIMEOUT
Return esp_err_t - ESP_OK if (timeout_ticks > 0) and and flush was successful, ESP_ERR_TIMEOUT if timeout occurred3 or flush was successful with (timeout_ticks == 0) ESP_FAIL if flush was unsuccessful

Parameters

• if: - number of a CDC object
• timeout_ticks: - waiting until flush will be considered as failed

`esp_err_t tinyusb_cdcacm_read(tinyusb_cdcacm_itf_t itf, uint8_t *out_buf, size_t out_buf_sz, size_t *rx_data_size)`

Read a content to the array, and defines it’s size to the sz_store.

Return esp_err_t ESP_OK, ESP_FAIL or ESP_ERR_INVALID_STATE

Parameters

• if: - number of a CDC object
• out_buf: - to this array will be stored the object from a CDC buffer
• out_buf_sz: - size of buffer for results
• rx_data_size: - to this address will be stored the object’s size

`bool tusb_cdc_acm_initialized(tinyusb_cdcacm_itf_t if)`

Check if the ACM initialized.

Return true or false

Parameters

• if: - number of a CDC object

Structures

`struct cdcacm_event_rx_wanted_char_data_t`

Data provided to the input of the callback_rx_wanted_char callback.

Public Members

char wanted_char

Wanted character

`struct cdcacm_event_line_state_changed_data_t`

Data provided to the input of the callback_line_state_changed callback.

Public Members

bool dtr

Data Terminal Ready (DTR) line state

bool rts

Request To Send (RTS) line state

`struct cdcacm_event_line_coding_changed_data_t`

Data provided to the input of the line_coding_changed callback.

Public Members

const cdc_line_coding_t *p_line_coding

New line coding value

`struct cdcacm_event_t`

Describes an event passing to the input of a callbacks.
Public Members

cdcacm_event_type_t type
    Event type

cdcacm_event_rx_wanted_char_data_t rx_wanted_char_data
    Data input of the callback_rx_wanted_char callback

cdcacm_event_line_state_changed_data_t line_state_changed_data
    Data input of the callback_line_state_changed callback

cdcacm_event_line_coding_changed_data_t line_coding_changed_data
    Data input of the line_coding_changed callback

struct tinyusb_config_cdcacm_t
    Configuration structure for CDC-ACM.

Public Members

tinyusb_usbdev_t usb_dev
    Usb device to set up

tinyusb_cdcacm_if_t cdc_port
    CDC port

size_t rx_unread_buf_sz
    Amount of data that can be passed to the AMC at once

tusb_cdcacm_callback_t callback_rx
    Pointer to the function with the tusb_cdcacm_callback_t type that will be handled as a callback

tusb_cdcacm_callback_t callback_rx_wanted_char
    Pointer to the function with the tusb_cdcacm_callback_t type that will be handled as a callback

tusb_cdcacm_callback_t callback_line_state_changed
    Pointer to the function with the tusb_cdcacm_callback_t type that will be handled as a callback

tusb_cdcacm_callback_t callback_line_coding_changed
    Pointer to the function with the tusb_cdcacm_callback_t type that will be handled as a callback

Type Definitions
typedef void (*tusb_cdcacm_callback_t)(int ift, cdcacm_event_t *event)
    CDC-ACM callback type.

Enumerations
enum tinyusb_cdcacm_if_t
    CDC ports available to setup.

Values:
    TINYUSB_CDC_ACM_0 = 0x0
    TINYUSB_CDC_ACM_1
    TINYUSB_CDC_ACM_MAX

enum cdcacm_event_type_t
    Types of CDC ACM events.

Values:
    CDC_EVENT_RX
    CDC_EVENT_RX_WANTED_CHAR
    CDC_EVENT_LINE_STATE_CHANGED
Chapter 2. API Reference

**CDC_EVENT_LINE_CODING_CHANGED**

**Header File**
- components/tinyusb/additions/include/tusb_console.h

**Functions**

- **esp_err_t esp_tusb_init_console** (int cdc_intf)
  Redirect output to the USB serial.
  
  **Return** esp_err_t - ESP_OK, ESP_FAIL or an error code
  **Parameters**
  - cdc_intf: - interface number of TinyUSB’s CDC

- **esp_err_t esp_tusb_deinit_console** (int cdc_intf)
  Switch log to the default output.
  
  **Return** esp_err_t
  **Parameters**
  - cdc_intf: - interface number of TinyUSB’s CDC

**Header File**
- components/tinyusb/additions/include/tusb_tasks.h

**Functions**

- **esp_err_t tusb_run_task** (void)
  This helper function creates and starts a task which wraps `tud_task()`.
  The wrapper function basically wraps `tud_task` and some log. Default parameters: stack size and priority as configured, argument = NULL, not pinned to any core. If you have more requirements for this task, you can create your own task which calls `tud_task` as the last step.
  
  **Return Value**
  - ESP_OK: run TinyUSB main task successfully
  - ESP_FAIL: run TinyUSB main task failed of internal error
  - ESP_ERR_INVALID_STATE: TinyUSB main task has been created before

- **esp_err_t tusb_stop_task** (void)
  This helper function stops and destroys the task created by `tusb_run_task()`
  
  **Return Value**
  - ESP_OK: stop and desroy TinyUSB main task successfully
  - ESP_ERR_INVALID_STATE: TinyUSB main task hasn’t been created yet

**Header File**
- components/tinyusb/additions/include/vfs_tinyusb.h

**Functions**

- **esp_err_t esp_vfs_tusb_cdc_register** (int cdc_intf, char const *path)
  Register TinyUSB CDC at VFS with path.
  
  **Return** esp_err_t ESP_OK or ESP_FAIL
  **Parameters**
  - cdc_intf: - interface number of TinyUSB’s CDC
  - path: - path where the CDC will be registered, `/dev/tusb_cdc` will be used if left NULL.

- **esp_err_t esp_vfs_tusb_cdc_unregister** (char const *path)
  Unregister TinyUSB CDC from VFS.
  
  **Return** esp_err_t ESP_OK or ESP_FAIL
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Parameters
- **path**: path where the CDC will be unregistered if NULL will be used /dev/tusb_cdc

2.3.24 USB Host

**Warning**: The USB Host Library API is a beta version thus is subject to change.

The document provides information regarding the USB Host Library. This document is split into the following sections:

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**Overview**

The USB Host Library (hereinafter referred to as the Host Library) is the lowest public facing API layer of the ESP-IDF USB Host Stack. In most cases, applications that require USB Host functionality will not need to interface with the Host Library directly. Instead, most applications will use the API provided by a host class driver that is implemented on top of the Host Library.

However, users may want to use the Host Library directly for some of (but not limited to) the following reasons:

- The user needs to implement a custom host class driver such as a vendor specific class driver
- The user has a requirement for a lower level of abstraction due to resource/latency requirements

**Features & Limitations**

The Host Library has the following features:

- Supports Full Speed (FS) and Low Speed (LS) Devices
- Supports all four transfer types (Control, Bulk, Interrupt, and Isochronous)
- Allows multiple class drivers to run simultaneously (i.e., multiple clients of the Host Library)
- A single device can be used by multiple clients simultaneously (e.g., composite devices)
- The Host Library itself (and the underlying Host Stack) does not internally instantiate any OS tasks. The number of tasks are entirely controlled by how the Host Library interface is used. However, a general rule of thumb regarding the number of tasks is *(the number of host class drivers running + 1)*.

Currently, the Host Library (and the underlying Host Stack) has the following limitations:

- Only supports a single device, but the Host Library’s API is designed for multiple device support.
- Only supports Asynchronous transfers
- Transfer timeouts are not supported yet

**Architecture**

The diagram above shows the key entities that are involved when implementing USB Host functionality. These entities are:

- The **Host Library**
- **Clients** of the Host Library
- **Devices**
The Host Library is the lowest public facing layer of the USB Host Stack. Any other IDF component (such as a class driver or a user component) that needs to communicate with a connected USB device can only do so using the Host Library API either directly or indirectly.

The Host Library’s API is split into two sub-sets, namely the **Library API** and **Client API**.

- The Client API handles the communication between a client of the Host Library and one or more USB devices. The Client API should only be called by registered clients of the Host Library.
- The Library API handles all of the Host Library processing that is not specific to a single client (e.g., device enumeration). Usually, the library API is called by a Host Library Daemon Task.

**Clients** A client of the Host Library is a software component (such as a host class driver or user component) that uses the Host Library to communicate with a USB device. Generally each client has a one-to-one relation with a task, meaning that for a particular client, all of its Client API calls should be done from the context of the same task.

By organizing the software components that use the Host Library’s into clients, the Host Library can delegate the handling of all client events (i.e., the events specific to that client) to the client’s task. In other words, each client task is responsible for all the required processing and event handling associated with the USB communication that the client initiates.

**Daemon Task** Although the Host Library delegates the handling of client events to the clients themselves, there are still Library events (i.e., events that are not specific to a client) that need to be handled. Library event handling can include things such as:

- Handling USB device connection, enumeration, and disconnection
- Rerouting control transfers to/from clients
- Forwarding events to clients

Therefore, in addition to the client tasks, the Host Library also requires a task (usually the Host Library Daemon Task) to handle all of the library events.
Devices  The Host Library hides the details of device handling (such as connection, memory allocation, and enumeration) from the clients. The clients are provided only with a list of already connected and enumerated devices to choose from. During enumeration, each device is configured to use configuration 1.

It is possible for a two or more clients to simultaneously communicate with the same device as long as they are not communicating to the same interface. However, multiple clients can simultaneously communicate with the same device’s default endpoint (EP0), which will result in their control transfers being serialized.

For a client to communicate with a device, the client must:

1. Open the device using the device’s address. This lets the Host Library know that the client is using that device.
2. Claim the interface(s) that will be used for communication. This prevents other clients from claiming the same interface(s).
3. Send transfers to the endpoints in the claimed interface. The client’s task is responsible for handling its own processing and events.

Usage

The Host Library (and the underlying Host Stack) will not create any tasks. All tasks (i.e., the client tasks and the Daemon Task) will need to be created by the class drivers or the user. Instead, the Host Library provides two event handler functions that will handle all of the required Host Library processing, thus these functions should be called repeatedly from the client tasks and the Daemon Task. Therefore, the implementation of client tasks and the Daemon Task will be the largely centered around the invocation of these event handler functions.

Host Library & Daemon Task

Basic Usage  The Host Library API provides `usb_host_lib_handle_events()` to handle library events. This function should be called repeatedly, typically from the daemon task. Some notable features regarding `usb_host_lib_handle_events()` are:

- The function can block until a library event needs handling
- Event flags are returned on each invocation. These event flags are useful for knowing when the Host Library can be uninstalled.

A bare-bones Daemon Task would resemble something like the following code snippet:

```c
#include "usb/usb_host.h"

void daemon_task(void *arg)
{
    ...  
    bool exit = false;
    while (!exit) {
        uint32_t event_flags;
        usb_host_lib_handle_events(portMAX_DELAY, &event_flags);
        if (event_flags & USB_HOST_LIB_EVENT_FLAGS_NO_CLIENTS) {
            ...  
        }
        if (event_flags & USB_HOST_LIB_EVENT_FLAGS_ALL_FREE) {
            ...  
        }
        ...  
    }
    ...  
}
```

Note:  See the peripherals/usb/host/usb_host_lib example for a full implementation of the Daemon Task
The graph above illustrates the typical lifecycle of the Host Library with multiple clients and devices. Specifically, the example involves:

- two registered clients (Client 1 and Client 2)
- two connected devices (Device 1 and Device 2), where Client 1 communicates with Device 1 and Client 2 communicates with Device 2.

With reference the graph above, the typical lifecycle involves the following key stages.

1. **The Host Library is installed by calling `usb_host_install()`**.
   - Installation must be done before any other Host Library API is called.
   - Where `usb_host_install()` is called (e.g., from the Daemon Task or another task) will depend on the synchronization logic between the Daemon Task, client tasks, and the rest of the system.

2. **Once the Host Library is installed, the clients can be registered by calling `usb_host_client_register()`**.
   - This is typically called from the client task (where the client task waits for a signal from the Daemon Task).
   - This can be called elsewhere if necessary as long it is called after `usb_host_install()`.

3. **Device 1 connects and is then enumerated**.
   - Each registered client (in this case Client 1 and Client 2) are notified of the new device by way of the `USB_HOST_CLIENT_EVENT_NEW_DEV` event.
   - Client 1 opens Device 1 and begins communication with it.

4. **Similarly Device 2 connects and is enumerated**.
   - Client 1 and 2 are notified of a new device (via a `USB_HOST_CLIENT_EVENT_NEW_DEV` event).
   - Client 2 opens Device 2 and begins communication with it.

5. **Device 1 suddenly disconnects**.
   - Client 1 is notified by way of `USB_HOST_CLIENT_EVENT_DEV_GONE` and begins its cleanup.
   - Client 2 is not notified as it has not opened Device 1.

6. **Client 1 completes its clean up and deregisters by calling `usb_host_client_deregister()`**.
   - This is typically called from the client task before the task exits.
   - This can be called elsewhere if necessary as long as Client 1 has already completed its clean up.

7. **Client 2 completes its communication with Device 2. Client 2 then closes Device 2 and deregisters itself**.
   - The Daemon Task is notified of the deregistration of all clients by way the `USB_HOST_LIB_EVENT_FLAGS_NO_CLIENTS` event flag as Client 2 is the last client to deregister.
   - Device 2 is still allocated (i.e., not freed) as it is still connected albeit not currently opened by any client.

8. **The Daemon Task decides to cleanup as there are no more clients**.
   - The Daemon Task must free Device 2 first by calling `usb_host_device_free_all()`.
   - If `usb_host_device_free_all()` was able to free all devices, the function will return `ESP_OK` indicating that all devices have been freed.
• If `usb_host_device_free_all()` was unable to free all devices (e.g., because the device is still opened by a client), the function will return `ESP_ERR_NOT_FINISHED`.
• The Daemon Task must wait for `usb_host_lib_handle_events()` to return the `USB_HOST_LIB_EVENT_FLAGS_ALL_FREE` event flag in order to know when all devices have been freed.

9. Once the Daemon Task has verified that all clients have deregistered and all devices have been freed, it can now uninstall the Host Library by calling `usb_host_uninstall()`.

Clients & Class Driver

**Basic Usage** The Host Library API provides `usb_host_client_handle_events()` to handle a particular client’s events. This function should be called repeatedly, typically from the client’s task. Some notable features regarding `usb_host_client_handle_events()` are:

- The function can block until a client event needs handling
- The function’s primary purpose is to call the various event handling callbacks when a client event occurs.

The following callbacks are called from within `usb_host_client_handle_events()` thus allowing the client task to be notified of events.

- The client event callback of type `usb_host_client_event_cb_t` which delivers client event messages to the client. Client event messages indicate events such as the addition or removal of a device.
- The USB transfer completion callback of type `usb_transfer_cb_t` which indicates that a particular USB transfer previously submitted by the client has completed.

**Note:** Given that the callbacks are called from within `usb_host_client_handle_events()`, users should avoid blocking from within the callbacks as this will result in `usb_host_client_handle_events()` being blocked as well, thus preventing other pending client events from being handled.

The following code snippet demonstrates a bare-bones host class driver and its client task. The code snippet contains:

- A simple client task function `client_task` that calls `usb_host_client_handle_events()` in a loop.
- Implementations of a client event callback and transfer completion callbacks.
- Implementation of a simple state machine for the class driver. The class driver simply opens a device, sends an OUT transfer to EP1, then closes the device.

```c
#include <string.h>
#include "usb/usb_host.h"

#define CLASS_DRIVER_ACTION_OPEN_DEV 0x01
#define CLASS_DRIVER_ACTION_TRANSFER 0x02
#define CLASS_DRIVER_ACTION_CLOSE_DEV 0x03

struct class_driver_control {
    uint32_t actions;
    uint8_t dev_addr;
    usb_host_client_handle_t client_hdl;
    usb_device_handle_t dev_hdl;
};

static void client_event_cb(const usb_host_client_event_msg_t *event_msg, void *arg) {
    struct class_driver_control *class_driver_obj = (struct class_driver_control *)arg;
    switch (event_msg->event) {
```
case USB_HOST_CLIENT_EVENT_NEW_DEV:
    class_driver_obj->actions |= CLASS_DRIVER_ACTION_OPEN_DEV;
    class_driver_obj->dev_addr = event_msg->new_dev.address; // Store the address of the new device
    break;

case USB_HOST_CLIENT_EVENT_DEV_GONE:
    class_driver_obj->actions |= CLASS_DRIVER_ACTION_CLOSE_DEV;
    break;

default:
    break;
}

static void transfer_cb(usb_transfer_t *transfer)
{
    // This is function is called from within usb_host_client_handle_events(). Don't block and try to keep it short
    struct class_driver_control *class_driver_obj = (struct class_driver_control_ * transfer->context;
    printf("Transfer status %d, actual number of bytes transferred %d\n", transfer->status, transfer->actual_num_bytes);
    class_driver_obj->actions |= CLASS_DRIVER_ACTION_CLOSE_DEV;
}

void client_task(void *arg)
{
    ... // Wait until Host Library is installed
    // Initialize class driver objects
    struct class_driver_control class_driver_obj = {0};
    // Register the client
    usb_host_client_config_t client_config = {
        .is_synchronous = false,
        .max_num_event_msg = 5,
        .async = {
            .client_event_callback = client_event_cb,
            .callback_arg = &class_driver_obj,
        },
    };
    usb_host_client_register(&client_config, &class_driver_obj.client_hdl);
    // Allocate a USB transfer
    usb_transfer_t *transfer;
    usb_host_transfer_alloc(1024, 0, &transfer);

    // Event handling loop
    bool exit = false;
    while (!exit) {
        // Call the client event handler function
        usb_host_client_handle_events(class_driver_obj.client_hdl, portMAX_DELAY);
        // Execute pending class driver actions
        if (class_driver_obj.actions & CLASS_DRIVER_ACTION_OPEN_DEV) {
            // Open the device and claim interface 1
            usb_host_device_open(class_driver_obj.client_hdl, class_driver_obj.dev_addr, &class_driver_obj.dev_hdl);
            usb_host_interface_claim(class_driver_obj.client_hdl, class_driver_obj.dev_hdl, 1, 0);
        }
        if (class_driver_obj.actions & CLASS_DRIVER_ACTION_TRANSFER) {
            // Send an OUT transfer to EP1
            memset(transfer->data_buffer, 0xAA, 1024);
            transfer->num_bytes = 1024;
            transfer->device_handle = class_driver_obj.dev_hdl;
        }
    }
}
transfer->bEndpointAddress = 0x01;
transfer->callback = transfer_cb;
transfer->context = (void *)&class_driver_obj;
usb_host_transfer_submit(transfer);
}
if (class_driver_obj.actions & CLASS_DRIVER_ACTION_CLOSE_DEV) {
    //Release the interface and close the device
    usb_host_interface_release(class_driver_obj.client_hdl, class_driver_obj.dev_hdl);
    usb_host_device_close(class_driver_obj.client_hdl, class_driver_obj.dev_hdl);
    exit = true;
}
... //Handle any other actions required by the class driver

//Cleanup class driver
usb_host_transfer_free(transfer);
usb_host_client_deregister(class_driver_obj.client_hdl);
... //Delete the task and any other signal Daemon Task if required

Note: An actual host class driver will likely supported many more features, thus will have a much more complex state machine. A host class driver will likely also need to:

- Be able to open multiple devices
- Parse an opened device’s descriptors to identify if the device is of the target class
- Communicate with multiple endpoints of an interface in a particular order
- Claim multiple interfaces of a device
- Handle various errors

Lifecycle The typical life cycle of a client task and class driver will go through the following stages:

1. Wait for some signal regarding the Host Library being installed.
2. Register the client via `usb_host_client_register()` and allocate any other class driver resources (e.g., allocating transfers using `usb_host_transfer_alloc()`).
3. For each new device that the class driver needs to communicate with:
   a. Check if the device is already connected via `usb_host_device_addr_list_fill()`.
   b. If the device is not already connected, wait for a USB_HOST_CLIENT_EVENT_NEW_DEV event from the client event callback.
   c. Open the device via `usb_host_device_open()`.
   d. Parse the device and configuration descriptors via `usb_host_get_device_descriptor()` and `usb_host_get_active_config_descriptor()` respectively.
   e. Claim the necessary interfaces of the device via `usb_host_interface_claim()`.
4. Submit transfers to the device via `usb_host_transfer_submit()` or `usb_host_transfer_submit_control()`.
5. Once an opened device is no longer needed by the class driver, or has disconnected (as indicated by a USB_HOST_CLIENT_EVENT_DEV_GONE event):
   a. Stop any previously submitted transfers to the device’s endpoints by calling `usb_host_endpoint_halt()` and `usb_host_endpoint_flush()` on those endpoints.
   b. Release all previously claimed interfaces via `usb_host_interface_release()`.
   c. Close the device via `usb_host_device_close()`.
6. Deregister the client via `usb_host_client_deregister()` and free any other class driver resources.
7. Delete the client task. Signal the Daemon Task if necessary.
Chapter 2. API Reference

Examples

Host Library Examples  The peripherals/usb/host/usb_host_lib demonstrates basic usage of the USB Host Library’s API to implement a pseudo class driver.

Class Driver Examples  The USB Host Stack provides a number of examples that implement host class drivers using the Host Library’s API.

CDC-ACM

• A host class driver for the Communication Device Class (Abstract Control Model) is currently implemented as an example component (found via peripherals/usb/host/cdc/common/cdc_acm_host).
• The peripherals/usb/host/cdc/cdc_acm_host example uses the CDC-ACM host driver component to communicate with CDC-ACM devices
• The peripherals/usb/host/cdc/cdc_acm_bg96 example uses the CDC-ACM host driver component to communicate with non-compliant CDC-ACM devices (i.e., vendor-specific classes that support a subset of CDC-ACM features) such as the Quectel BG96 modem.

MSC

• A host class driver for the Mass Storage Class (Bulk-Only Transport) is currently implemented as an example found via peripherals/usb/host/msc.

API Reference

The API of the USB Host Library is separated into the following header files. However, it is sufficient for applications to only #include "usb/usb_host.h" and all of USB Host Library headers will also be included.

• usb/include/usb/usb_host.h contains the functions and types of the USB Host Library
• usb/include/usb/usb_helpers.h contains various helper functions that are related to the USB protocol such as descriptor parsing.
• usb/include/usb/usb_types_stack.h contains types that are are used across multiple layers of the USB Host stack.
• usb/include/usb/usb_types_ch9.h contains types and macros related to Chapter 9 of the USB2.0 specification (i.e., descriptors and standard requests).

Header File

• components/usb/include/usb/usb_host.h

Functions

esp_err_t usb_host_install (const usb_host_config_t *config)
Install the USB Host Library.
• This function should only once to install the USB Host Library
• This function should be called before any other USB Host Library functions are called

Note  If skip_phy_setup is set in the install configuration, the user is responsible for ensuring that the underlying Host Controller is enabled and the USB PHY (internal or external) is already setup before this function is called.

Return  esp_err_t

Parameters
• [in] config: USB Host Library configuration

esp_err_t usb_host_uninstall (void)
Uninstall the USB Host Library.
• This function should be called to uninstall the USB Host Library, thereby freeing its resources
Chapter 2. API Reference

- All clients must have been deregistered before calling this function
- All devices must have been freed by calling usb_host_device_free_all() and receiving the USB_HOST_LIB_EVENT_FLAGS_ALL_FREE event flag

**Note** If skip_phy_setup was set when the Host Library was installed, the user is responsible for disabling the underlying Host Controller and USB PHY (internal or external).

**Return** esp_err_t

```c
esp_err_t usb_host_lib_handle_events (TickType_t timeout_ticks, uint32_t *event_flags_ret)
```

Handle USB Host Library events.

- This function handles all of the USB Host Library’s processing and should be called repeatedly in a loop
- Check event_flags_ret to see if an flags are set indicating particular USB Host Library events
- This function should never be called by multiple threads simultaneously

**Note** This function can block

**Return** esp_err_t

**Parameters**

- [in] timeout_ticks: Timeout in ticks to wait for an event to occur
- [out] event_flags_ret: Event flags that indicate what USB Host Library event occurred.

```c
esp_err_t usb_host_lib_unblock (void)
```

Unblock the USB Host Library handler.

- This function simply unblocks the USB Host Library event handling function (usb_host_lib_handle_events())

**Return** esp_err_t

```c
esp_err_t usb_host_lib_info (usb_host_lib_info_t *info_ret)
```

Get current information about the USB Host Library.

**Return** esp_err_t

**Parameters**

- [out] info_ret: USB Host Library Information

```c
esp_err_t usb_host_client_register (const usb_host_client_config_t *client_config,
                                 usb_host_client_handle_t *client_hdl_ret)
```

Register a client of the USB Host Library.

- This function registers a client of the USB Host Library
- Once a client is registered, its processing function usb_host_client_handle_events() should be called repeatedly

**Return** esp_err_t

**Parameters**

- [in] client_config: Client configuration
- [out] client_hdl_ret: Client handle

```c
esp_err_t usb_host_client_deregister (usb_host_client_handle_t client_hdl)
```

Deregister a USB Host Library client.

- This function deregisters a client of the USB Host Library
- The client must have closed all previously opened devices before attempting to deregister

**Return** esp_err_t

**Parameters**

- [in] client_hdl: Client handle

```c
esp_err_t usb_host_client_handle_events (usb_host_client_handle_t client_hdl, TickType_t timeout_ticks)
```

USB Host Library client processing function.

- This function handles all of a client’s processing and should be called repeatedly in a loop
- For a particular client, this function should never be called by multiple threads simultaneously

**Note** This function can block

**Return** esp_err_t
Chapter 2. API Reference

Parameters
  • [in] client_hdl: Client handle
  • [in] timeout_ticks: Timeout in ticks to wait for an event to occur

\texttt{esp_err_t usb_host_client_unblock(usb_host_client_handle_t client_hdl)}

Unblock a client.

  • This function simply unblocks a client if it is blocked on the usb_host_client_handle_events() function.
  • This function is useful when need to unblock a client in order to deregister it.

Return esp_err_t

Parameters
  • [in] client_hdl: Client handle

\texttt{esp_err_t usb_host_device_open(usb_host_client_handle_t client_hdl, uint8_t dev_addr, usb_device_handle_t *dev_hdl_ret)}

Open a device.

  • This function allows a client to open a device
  • A client must open a device first before attempting to use it (e.g., sending transfers, device requests etc.)

Return esp_err_t

Parameters
  • [in] client_hdl: Client handle
  • [in] dev_addr: Device’s address
  • [out] dev_hdl_ret: Device’s handle

\texttt{esp_err_t usb_host_device_close(usb_host_client_handle_t client_hdl, usb_device_handle_t dev_hdl)}

Close a device.

  • This function allows a client to close a device
  • A client must close a device after it has finished using the device (claimed interfaces must also be released)
  • A client must close all devices it has opened before deregistering

Note This function can block

Return esp_err_t

Parameters
  • [in] client_hdl: Client handle
  • [in] dev_hdl: Device handle

\texttt{esp_err_t usb_host_device_free_all(void)}

Indicate that all devices can be freed when possible.

  • This function marks all devices as waiting to be freed
  • If a device is not opened by any clients, it will be freed immediately
  • If a device is opened by at least one client, the device will be free when the last client closes that device.
  • Wait for the USB_HOST_LIB_EVENT_FLAGS_ALL_FREE flag to be set by usb_host_lib_handle_events() in order to know when all devices have been freed
  • This function is useful when cleaning up devices before uninstalling the USB Host Library

Return
  • ESP_ERR_NOT_FINISHED: There are one or more devices that still need to be freed. Wait for USB_HOST_LIB_EVENT_FLAGS_ALL_FREE event
  • ESP_OK: All devices already freed (i.e., there were no devices)
  • Other: Error

\texttt{esp_err_t usb_host_device_addr_list_fill(int list_len, uint8_t *dev_addr_list, int *num_dev_ret)}

Fill a list of device address.

  • This function fills an empty list with the address of connected devices
  • The Device addresses can then used in usb_host_device_open()
  • If there are more devices than the list_len, this function will only fill up to list_len number of devices

Return esp_err_t
Parameters
• [in] list_len: Length of the empty list
• [inout] dev_addr_list: Empty list to be filled
• [out] num_dev_ret: Number of devices

esp_err_t usb_host_device_info(usb_device_handle_t dev_hdl, usb_device_info_t *dev_info)
Get device’s information.
• This function gets some basic information of a device
• The device must be opened first before attempting to get its information

Note
This function can block
Return esp_err_t
Parameters
• [in] dev_hdl: Device handle
• [out] dev_info: Device information

Note
This function can block
Parameters
• [in] dev_hdl: Device handle
• [out] device_desc: Device descriptor

esp_err_t usb_host_get_active_config_descriptor(usb_device_handle_t dev_hdl, const usb_config_desc_t **config_desc)
Get device’s active configuration descriptor.
• A client must call usb_host_device_open() first
• No control transfer is sent. The device’s active configuration descriptor is cached on enumeration
• This function simple returns a pointer to the cached descriptor

Note
No control transfer is sent. A device’s active configuration descriptor is cached on enumeration
Return esp_err_t
Parameters
• [in] dev_hdl: Device handle
• [out] config_desc: Configuration descriptor

sp_err_t usb_host_interface_claim(usb_host_client_handle_t client_hdl, usb_device_handle_t dev_hdl, uint8_t bInterfaceNumber, uint8_t bAlternateSetting)
Function for a client to claim a device’s interface.
• A client must claim a device’s interface before attempting to communicate with any of its endpoints
• Once an interface is claimed by a client, it cannot be claimed by any other client.

Note
This function can block
Return esp_err_t
Parameters
• [in] client_hdl: Client handle
• [in] dev_hdl: Device handle
• [in] bInterfaceNumber: Interface number
• [in] bAlternateSetting: Interface alternate setting number

esp_err_t usb_host_interface_release(usb_host_client_handle_t client_hdl, usb_device_handle_t dev_hdl, uint8_t bInterfaceNumber)
Function for a client to release a previously claimed interface.
A client should release a device’s interface after it no longer needs to communicate with the interface.
A client must release all of its interfaces of a device it has claimed before being able to close the device.

**Note** This function can block

**Return** `esp_err_t`

**Parameters**
- `[in] client_hdl`: Client handle
- `[in] dev_hdl`: Device handle
- `[in] bInterfaceNumber`: Interface number

```c
esp_err_t usb_host_endpoint_halt(usb_device_handle_t dev_hdl, uint8_t bEndpointAddress)
```

Halt a particular endpoint.

- The device must have been opened by a client
- The endpoint must be part of an interface claimed by a client
- Once halted, the endpoint must be cleared using `usb_host_endpoint_clear()` before it can communicate again

**Note** This function can block

**Return** `esp_err_t`

**Parameters**
- `dev_hdl`: Device handle
- `bEndpointAddress`: Endpoint address

```c
esp_err_t usb_host_endpoint_flush(usb_device_handle_t dev_hdl, uint8_t bEndpointAddress)
```

Flush a particular endpoint.

- The device must have been opened by a client
- The endpoint must be part of an interface claimed by a client
- The endpoint must have been halted (either through a transfer error, or `usb_host_endpoint_halt()`)
- Flushing an endpoint will cause any queued up transfers to be canceled

**Note** This function can block

**Return** `esp_err_t`

**Parameters**
- `dev_hdl`: Device handle
- `bEndpointAddress`: Endpoint address

```c
esp_err_t usb_host_endpoint_clear(usb_device_handle_t dev_hdl, uint8_t bEndpointAddress)
```

Clear a halt on a particular endpoint.

- The device must have been opened by a client
- The endpoint must be part of an interface claimed by a client
- The endpoint must have been halted (either through a transfer error, or `usb_host_endpoint_halt()`)
- If the endpoint has any queued up transfers, clearing a halt will resume their execution

**Note** This function can block

**Return** `esp_err_t`

**Parameters**
- `dev_hdl`: Device handle
- `bEndpointAddress`: Endpoint address

```c
esp_err_t usb_host_transfer_alloc(size_t data_buffer_size, int num_isoc_packets, usb_transfer_t **transfer)
```

Allocate a transfer object.

- This function allocates a transfer object
- Each transfer object has a fixed sized buffer specified on allocation
- A transfer object can be re-used indefinitely
- A transfer can be submitted using `usb_host_transfer_submit()` or `usb_host_transfer_submit_control()`

**Return** `esp_err_t`

**Parameters**
- `[in] data_buffer_size`: Size of the transfer’s data buffer
Chapter 2. API Reference

- [in] num_isoc_packets: Number of isochronous packets in transfer (set to 0 for non-isochronous transfers)
- [out] transfer: Transfer object

```c
esp_err_t usb_host_transfer_free(usb_transfer_t *transfer)
```
Free a transfer object.

- Free a transfer object previously allocated using usb_host_transfer_alloc()
- The transfer must not be in-flight when attempting to free it
- If a NULL pointer is passed, this function will simply return ESP_OK

Return: esp_err_t
Parameters
- [in] transfer: Transfer object

```c
esp_err_t usb_host_transfer_submit(usb_transfer_t *transfer)
```
Submit a non-control transfer.

- Submit a transfer to a particular endpoint. The device and endpoint number is specified inside the transfer
- The transfer must be properly initialized before submitting
- On completion, the transfer’s callback will be called from the client’s usb_host_client_handle_events() function.

Return: esp_err_t
Parameters
- [in] transfer: Initialized transfer object

```c
esp_err_t usb_host_transfer_submit_control(usb_host_client_handle_t client_hdl, ush_transfer_t *transfer)
```
Submit a control transfer.

- Submit a control transfer to a particular device. The client must have opened the device first
- The transfer must be properly initialized before submitting. The first 8 bytes of the transfer’s data buffer should contain the control transfer setup packet
- On completion, the transfer’s callback will be called from the client’s usb_host_client_handle_events() function.

Return: esp_err_t
Parameters
- [in] client_hdl: Client handle
- [in] transfer: Initialized transfer object

Structures
```c
struct usb_host_client_event_msg_t
```
Client event message.

Client event messages are sent to each client of the USB Host Library in order to notify them of various USB Host Library events such as:

- Addition of new devices
- Removal of existing devices

Note: The event message structure has a union with members corresponding to each particular event. Based on the event type, only the relevant member field should be accessed.

Public Members
```c
usb_host_client_event_t event
```
Type of event

```c
uint8_t address
```
New device’s address
**usb_device_handle_t** `dev_hdl`

The handle of the device that was gone

**struct usb_host_lib_info_t**

Current information about the USB Host Library obtained via `usb_host_lib_info()`

**Public Members**

- `int num_devices`
  Current number of connected (and enumerated) devices
- `int num_clients`
  Current number of registered clients

**struct usb_host_config_t**

USB Host Library configuration.

Configuration structure of the USB Host Library. Provided in the `usb_host_install()` function

**Public Members**

- `bool skip_phy_setup`
  If set, the USB Host Library will not configure the USB PHY thus allowing the user to manually configure the USB PHY before calling `usb_host_install()`. Users should set this if they want to use an external USB PHY. Otherwise, the USB Host Library will automatically configure the internal USB PHY
- `int intr_flags`
  Interrupt flags for the underlying ISR used by the USB Host stack

**struct usb_host_client_config_t**

USB Host Library Client configuration.

Configuration structure for a USB Host Library client. Provided in `usb_host_client_register()`

**Public Members**

- `bool is_synchronous`
  Whether the client is asynchronous or synchronous or not. Set to false for now.
- `int max_num_event_msg`
  Maximum number of event messages that can be stored (e.g., 3)
- `usb_host_client_event_cb_t client_event_callback`
  Client’s event callback function
- `void *callback_arg`
  Event callback function argument

**Macros**

- `USB_HOST_LIB_EVENT_FLAGS_NO_CLIENTS`
  All clients have been deregistered from the USB Host Library
- `USB_HOST_LIB_EVENT_FLAGS_ALL_FREE`
  The USB Host Library has freed all devices

**Type Definitions**

- `typedef struct usb_host_client_handle_s *usb_host_client_handle_t`
  Handle to a USB Host Library asynchronous client.
  An asynchronous client can be registered using `usb_host_client_register()`

  **Note** Asynchronous API
typedef void (*usb_host_client_event_cb_t)(const usb_host_client_event_msg_t *event_msg, void *arg)

Client event callback.
• Each client of the USB Host Library must register an event callback to receive event messages from the USB Host Library.
• The client event callback is run from the context of the clients usb_host_client_handle_events() function

Enumerations
enum usb_host_client_event_t
The type event in a client event message.
Values:
USB_HOST_CLIENT_EVENT_NEW_DEV
A new device has been enumerated and added to the USB Host Library
USB_HOST_CLIENT_EVENT_DEV_GONE
A device opened by the client is now gone

Header File
• components/usb/include/usb/usb_helpers.h

Functions
const usb_standard_desc_t *usb_parse_next_descriptor(const usb_standard_desc_t *cur_desc, uint16_t wTotalLength, int *offset)
Get the next descriptor.
Given a particular descriptor within a full configuration descriptor, get the next descriptor within the configuration descriptor. This is a convenience function that can be used to walk each individual descriptor within a full configuration descriptor.

Return usb_standard_desc_t* Next descriptor, NULL if end of configuration descriptor reached

Parameters
• [in] cur_desc: Current descriptor
• [in] wTotalLength: Total length of the configuration descriptor
• [inout] offset: Byte offset relative to the start of the configuration descriptor. On input, it is the offset of the current descriptor. On output, it is the offset of the returned descriptor.

const usb_standard_desc_t *usb_parse_next_descriptor_of_type(const usb_standard_desc_t *cur_desc, uint16_t wTotalLength, uint8_t bDescriptorType, int *offset)
Get the next descriptor of a particular type.
Given a particular descriptor within a full configuration descriptor, get the next descriptor of a particular type (i.e., using the bDescriptorType value) within the configuration descriptor.

Return usb_standard_desc_t* Next descriptor, NULL if end descriptor is not found or configuration descriptor reached

Parameters
• [in] cur_desc: Current descriptor
• [in] wTotalLength: Total length of the configuration descriptor
• [in] bDescriptorType: Type of the next descriptor to get
• [inout] offset: Byte offset relative to the start of the configuration descriptor. On input, it is the offset of the current descriptor. On output, it is the offset of the returned descriptor.
### Chapter 2. API Reference

```c
int usb_parse_interface_number_of_alternate(const usb_config_desc_t *config_desc, uint8_t bInterfaceNumber)
```

Get the number of alternate settings for a bInterfaceNumber.

Given a particular configuration descriptor, for a particular bInterfaceNumber, get the number of alternate settings available for that interface (i.e., the max possible value of bAlternateSetting for that bInterfaceNumber).

**Return** int The number of alternate settings that the interface has, -1 if bInterfaceNumber not found

**Parameters**
- [in] config_desc: Pointer to the start of a full configuration descriptor
- [in] bInterfaceNumber: Interface number

```c
const usb_intf_desc_t *usb_parse_interface_descriptor(const usb_config_desc_t *config_desc, uint8_t bInterfaceNumber, uint8_t bAlternateSetting, int *offset)
```

Get a particular interface descriptor (using bInterfaceNumber and bAlternateSetting)

Given a full configuration descriptor, get a particular interface descriptor.

**Note** To get the number of alternate settings for a particular bInterfaceNumber, call `usb_parse_interface_number_of_alternate()`

**Return** const usb_intf_desc_t* Pointer to interface descriptor, NULL if not found.

**Parameters**
- [in] config_desc: Pointer to the start of a full configuration descriptor
- [in] bInterfaceNumber: Interface number
- [in] bAlternateSetting: Alternate setting number
- [out] offset: Byte offset of the interface descriptor relative to the start of the configuration descriptor. Can be NULL.

```c
const usb_ep_desc_t *usb_parse_endpoint_descriptor_by_index(const usb_intf_desc_t *intf_desc, int index, uint16_t wTotalLength, int *offset)
```

Get an endpoint descriptor within an interface descriptor.

Given an interface descriptor, get the Nth endpoint descriptor of the interface. The number of endpoints in an interface is indicated by the bNumEndpoints field of the interface descriptor.

**Note** If bNumEndpoints is 0, it means the interface uses the default endpoint only

**Return** const usb_ep_desc_t* Pointer to endpoint descriptor, NULL if not found.

**Parameters**
- [in] intf_desc: Pointer to the start of an interface descriptor
- [in] index: Endpoint index
- [in] wTotalLength: Total length of the containing configuration descriptor
- [inout] offset: Byte offset relative to the start of the configuration descriptor. On input, it is the offset of the interface descriptor. On output, it is the offset of the endpoint descriptor.

```c
const usb_ep_desc_t *usb_parse_endpoint_descriptor_by_address(const usb_config_desc_t *config_desc, uint8_t bInterfaceNumber, uint8_t bAlternateSetting, uint8_t bEndpointAddress, int *offset)
```

Get an endpoint descriptor based on an endpoint’s address.

Given a configuration descriptor, get an endpoint descriptor based on it’s bEndpointAddress, bAlternateSetting, and bInterfaceNumber.

**Return** const usb_ep_desc_t* Pointer to endpoint descriptor, NULL if not found.

**Parameters**
- [in] config_desc: Pointer to the start of a full configuration descriptor
• [in] bInterfaceNumber: Interface number
• [in] bAlternateSetting: Alternate setting number
• [in] bEndpointAddress: Endpoint address
• [out] offset: Byte offset of the endpoint descriptor relative to the start of the configuration descriptor. Can be NULL.

```c
void usb_print_device_descriptor(const usb_device_desc_t *devc_desc)
```

Print device descriptor.

**Parameters**
- devc_desc: Device descriptor

```c
void usb_print_config_descriptor(const usb_config_desc_t *cfg_desc,
                               print_class_descriptor_cb class_specific_cb)
```

Print configuration descriptor.

- This function prints the full contents of a configuration descriptor (including interface and endpoint descriptors)
- When a non-standard descriptor is encountered, this function will call the class_specific_cb if it is provided

**Parameters**
- cfg_desc: Configuration descriptor
- class_specific_cb: Class specific descriptor callback. Can be NULL

```c
void usb_print_string_descriptor(const usb_str_desc_t *str_desc)
```

Print a string descriptor.

- This function will only print ASCII characters of the UTF-16 encoded string

**Parameters**
- str_desc: String descriptor

```c
static int usb_round_up_to_mps(int num_bytes, int mps)
```

Round up to an integer multiple of endpoint’s MPS.

- This is a convenience function to round up a size/length to an endpoint’s MPS (Maximum packet size). This is useful when calculating transfer or buffer lengths of IN endpoints.
  - If MPS <= 0, this function will return 0
  - If num_bytes <= 0, this function will return 0

**Return**
- int Round up integer multiple of MPS

**Parameters**
- [in] num_bytes: Number of bytes
- [in] mps: MPS

**Type Definitions**

```c
typedef void (*print_class_descriptor_cb)(const usb_standard_desc_t *)
```

Print class specific descriptor callback.

- Optional callback to be provided to `usb_print_config_descriptor()` function. The callback is called when a non-standard descriptor is encountered. The callback should decode the descriptor as print it.

**Header File**

- components/usb/include/usb/usb_types_stack.h

**Structures**

```c
struct usb_device_info_t
```

Basic information of an enumerated device.
Public Members

```c
usb_speed_t speed
    Device’s speed
```

```c
uint8_t dev_addr
    Device’s address
```

```c
uint8_t bMaxPacketSize0
    The maximum packet size of the device’s default endpoint
```

```c
uint8_t bConfigurationValue
    Device’s current configuration number
```

```c
const usb_str_desc_t *str_desc_manufacturer
    Pointer to Manufacturer string descriptor (can be NULL)
```

```c
const usb_str_desc_t *str_desc_product
    Pointer to Product string descriptor (can be NULL)
```

```c
const usb_str_desc_t *str_desc_serial_num
    Pointer to Serial Number string descriptor (can be NULL)
```

```c
struct usb_isoc_packet_desc_t
    Isochronous packet descriptor.
```

If the number of bytes in an Isochronous transfer is larger than the MPS of the endpoint, the transfer is split into multiple packets transmitted at the endpoint’s specified interval. An array of Isochronous packet descriptors describes how an Isochronous transfer should be split into multiple packets.

Public Members

```c
int num_bytes
    Number of bytes to transmit/receive in the packet. IN packets should be integer multiple of MPS
```

```c
int actual_num_bytes
    Actual number of bytes transmitted/received in the packet
```

```c
usb_transfer_status_t status
    Status of the packet
```

```c
struct usb_transfer_s
```

Public Members

```c
uint8_t *const data_buffer
    Pointer to data buffer
```

```c
const size_t data_buffer_size
    Size of the data buffer in bytes
```

```c
int num_bytes
    Number of bytes to transfer. Control transfers should include the size of the setup packet. Isochronous transfer should be the total transfer size of all packets. For non-control IN transfers, num_bytes should be an integer multiple of MPS.
```

```c
int actual_num_bytes
    Actual number of bytes transferred
```

```c
uint32_t flags
    Transfer flags
```

```c
usb_device_handle_t device_handle
    Device handle
```
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```c
uint8_t bEndpointAddress
    Endpoint Address

usb_transfer_status_t status
    Status of the transfer

uint32_t timeout_ms
    Timeout (in milliseconds) of the packet (currently not supported yet)

usb_transfer_cb_t callback
    Transfer callback

void *context
    Context variable for transfer to associate transfer with something

const int num_isoc_packets
    Only relevant to Isochronous. Number of service periods (i.e., intervals) to transfer data buffer over.

usb_isoc_packet_desc_t isoc_packet_desc[]
    Descriptors for each Isochronous packet
```

### Macros

**USB_TRANSFER_FLAG_ZERO_PACK**

Terminate Bulk/Interrupt OUT transfer with a zero length packet.

OUT transfers normally terminate when the Host has transferred the exact amount of data it needs to the device. However, for bulk and interrupt OUT transfers, if the transfer size just happened to be a multiple of MPS, it will be impossible to know the boundary between two consecutive transfers to the same endpoint.

Therefore, this flag will cause the transfer to automatically add a zero length packet (ZLP) at the end of the transfer if the following conditions are met:

- The target endpoint is a Bulk/Interrupt OUT endpoint (Host to device)
- The transfer’s length (i.e., transfer.num_bytes) is a multiple of the endpoint’s MPS

Otherwise, this flag has no effect.

Users should check whether their target device’s class requires a ZLP, as not all Bulk/Interrupt OUT endpoints require them. For example:

- For MSC Bulk Only Transport class, the Host MUST NEVER send a ZLP. Bulk transfer boundaries are determined by the CBW and CSW instead
- For CDC Ethernet, the Host MUST ALWAYS send a ZLP if a segment (i.e., a transfer) is a multiple of MPS (See 3.3.1 Segment Delineation)

**Note** See USB2.0 specification 5.7.3 and 5.8.3 for more details

**Note** IN transfers normally terminate when the Host as receive the exact amount of data it needs (must be multiple of MPS) or the endpoint sends a short packet to the Host (For bulk OUT only). Indicates that a bulk OUT transfers should always terminate with a short packet, even if it means adding an extra zero length packet

### Type Definitions

```c
typedef struct usb_device_handle_s *usb_device_handle_t
    Handle of a USB Device connected to a USB Host.

typedef struct usb_transfer_s usb_transfer_t
    USB transfer structure.
```

This structure is used to represent a transfer from a software client to an endpoint over the USB bus. Some of the fields are made const on purpose as they are fixed on allocation. Users should call the appropriate USB Host Library function to allocate a USB transfer structure instead of allocating this structure themselves.

The transfer type is inferred from the endpoint this transfer is sent to. Depending on the transfer type, users should note the following:
• Bulk: This structure represents a single bulk transfer. If the number of bytes exceeds the endpoint’s MPS, the transfer will be split into multiple MPS sized packets followed by a short packet.
• Control: This structure represents a single control transfer. This first 8 bytes of the data_buffer must be filled with the setup packet (see `usb_setup_packet_t`). The num_bytes field should be the total size of the transfer (i.e., size of setup packet + wLength).
• Interrupt: Represents an interrupt transfer. If num_bytes exceeds the MPS of the endpoint, the transfer will be split into multiple packets, and each packet is transferred at the endpoint’s specified interval.

Note For Bulk/Control/Interrupt IN transfers, the num_bytes must be a integer multiple of the endpoint’s MPS

Note This structure should be allocated via `usb_host_transfer_alloc()`
Note Once the transfer has been submitted, users should not modify the structure until the transfer has completed

typedef void (*usb_transfer_cb_t)(usb_transfer_t *transfer)
USB transfer completion callback.

Enumerations
enum usb_speed_t
USB Standard Speeds.

Values:

USB_SPEED_LOW = 0
USB Low Speed (1.5 Mbit/s)

USB_SPEED_FULL
USB Full Speed (12 Mbit/s)

enum usb_transfer_type_t
The type of USB transfer.

Note The enum values need to match the bmAttributes field of an EP descriptor

Values:

USB_TRANSFER_TYPE_CTRL = 0
USB_TRANSFER_TYPE_ISOCHRONOUS

USB_TRANSFER_TYPE_BULK
USB_TRANSFER_TYPE_INTR

enum usb_transfer_status_t
The status of a particular transfer.

Values:

USB_TRANSFER_STATUS_COMPLETED
The transfer was successful (but may be short)

USB_TRANSFER_STATUS_ERROR
The transfer failed because due to excessive errors (e.g. no response or CRC error)

USB_TRANSFER_STATUS_TIMED_OUT
The transfer failed due to a time out

USB_TRANSFER_STATUS_CANCELED
The transfer was canceled
USB_TRANSFER_STATUSSTALL
The transfer was stalled

USB_TRANSFER_STATUS_OVERFLOW
The transfer as more data was sent than was requested

USB_TRANSFER_STATUS_SKIPPED
ISOC packets only. The packet was skipped due to system latency or bus overload

USB_TRANSFER_STATUS_NO_DEVICE
The transfer failed because the target device is gone

Header File

- components/usb/include/usb/usb_types_ch9.h

Unions

union usb_setup_packet_t
#include <usb_types_ch9.h> Structure representing a USB control transfer setup packet.

See Table 9-2 of USB2.0 specification for more details

Public Members

uint8_t bmRequestType
Characteristics of request

uint8_t bRequest
Specific request

uint16_t wValue
Word-sized field that varies according to request

uint16_t wIndex
Word-sized field that varies according to request; typically used to pass an index or offset

uint16_t wLength
Number of bytes to transfer if there is a data stage

struct usb_setup_packet_t::[anonymous] [anonymous]
uint8_t val[USB_SETUP_PACKET_SIZE]

union usb_standard_desc_t
#include <usb_types_ch9.h> USB standard descriptor.

All USB standard descriptors start with these two bytes. Use this type when traversing over configuration descriptors

Public Members

uint8_t bLength
Size of the descriptor in bytes

uint8_t bDescriptorType
Descriptor Type

struct usb_standard_desc_t::[anonymous] USB_DESC_ATTR
uint8_t val[USB_STANDARD_DESC_SIZE]

union usb_device_desc_t
#include <usb_types_ch9.h> Structure representing a USB device descriptor.

See Table 9-8 of USB2.0 specification for more details
Public Members

uint8_t \texttt{bLength}  
Size of the descriptor in bytes

uint8_t \texttt{bDescriptorType}  
DEVICE Descriptor Type

uint16_t \texttt{bcdUSB}  
USB Specification Release Number in Binary-Coded Decimal (i.e., 2.10 is 210H)

uint8_t \texttt{bDeviceClass}  
Class code (assigned by the USB-IF)

uint8_t \texttt{bDeviceSubClass}  
Subclass code (assigned by the USB-IF)

uint8_t \texttt{bDeviceProtocol}  
Protocol code (assigned by the USB-IF)

uint8_t \texttt{bMaxPacketSize0}  
Maximum packet size for endpoint zero (only 8, 16, 32, or 64 are valid)

uint16_t \texttt{idVendor}  
Vendor ID (assigned by the USB-IF)

uint16_t \texttt{idProduct}  
Product ID (assigned by the manufacturer)

uint16_t \texttt{bcdDevice}  
Device release number in binary-coded decimal

uint8_t \texttt{iManufacturer}  
Index of string descriptor describing manufacturer

uint8_t \texttt{iProduct}  
Index of string descriptor describing product

uint8_t \texttt{iSerialNumber}  
Index of string descriptor describing the device’s serial number

uint8_t \texttt{bNumConfigurations}  
Number of possible configurations

\begin{verbatim}
struct usb_device_desc_t::[anonymous] USB_DESC_ATTR

uint8_t val[USB_DEVICE_DESC_SIZE]
\end{verbatim}

union usb_config_desc_t

#include <usb_types_ch9.h> Structure representing a short USB configuration descriptor.

See Table 9-10 of USB2.0 specification for more details

Note The full USB configuration includes all the interface and endpoint descriptors of that configuration.

Public Members

uint8_t \texttt{bLength}  
Size of the descriptor in bytes

uint8_t \texttt{bDescriptorType}  
CONFIGURATION Descriptor Type

uint16_t \texttt{wTotalLength}  
Total length of data returned for this configuration

uint8_t \texttt{bNumInterfaces}  
Number of interfaces supported by this configuration
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uint8_t bConfigurationValue
    Value to use as an argument to the SetConfiguration() request to select this configuration

uint8_t iConfiguration
    Index of string descriptor describing this configuration

uint8_t bmAttributes
    Configuration characteristics

uint8_t bMaxPower
    Maximum power consumption of the USB device from the bus in this specific configuration when the
device is fully operational.

struct usb_config_desc_t::[anonymous] USB_DESC_ATTR
    uint8_t val[USB_CONFIG_DESC_SIZE]

union usb_iad_desc_t
    #include <usb_types_ch9.h> Structure representing a USB interface association descriptor.

Public Members

uint8_t bLength
    Size of the descriptor in bytes

uint8_t bDescriptorType
    INTERFACE ASSOCIATION Descriptor Type

uint8_t bFirstInterface
    Interface number of the first interface that is associated with this function

uint8_t bInterfaceCount
    Number of contiguous interfaces that are associated with this function

uint8_t bFunctionClass
    Class code (assigned by USB-IF)

uint8_t bFunctionSubClass
    Subclass code (assigned by USB-IF)

uint8_t bFunctionProtocol
    Protocol code (assigned by USB-IF)

uint8_t iFunction
    Index of string descriptor describing this function

struct usb_iad_desc_t::[anonymous] USB_DESC_ATTR
    uint8_t val[USB_IAD_DESC_SIZE]

union usb_intf_desc_t
    #include <usb_types_ch9.h> Structure representing a USB interface descriptor.

See Table 9-12 of USB2.0 specification for more details

Public Members

uint8_t bLength
    Size of the descriptor in bytes

uint8_t bDescriptorType
    INTERFACE Descriptor Type

uint8_t bInterfaceNumber
    Number of this interface.
uint8_t bAlternateSetting
   Value used to select this alternate setting for the interface identified in the prior field

uint8_t bNumEndpoints
   Number of endpoints used by this interface (excluding endpoint zero).

uint8_t bInterfaceClass
   Class code (assigned by the USB-IF)

uint8_t bInterfaceSubClass
   Subclass code (assigned by the USB-IF)

uint8_t bInterfaceProtocol
   Protocol code (assigned by the USB)

uint8_t iInterface
   Index of string descriptor describing this interface

struct usb_intf_desc_t::[anonymous] USB_DESC_ATTR

union usb_ep_desc_t
   #include <usb_types_ch9.h> Structure representing a USB endpoint descriptor.
   See Table 9-13 of USB2.0 specification for more details

Public Members

uint8_t bLength
   Size of the descriptor in bytes

uint8_t bDescriptorType
   ENDPOINT Descriptor Type

uint8_t bEndpointAddress
   The address of the endpoint on the USB device described by this descriptor

uint8_t bmAttributes
   This field describes the endpoint’s attributes when it is configured using the bConfigurationValue.

uint16_t wMaxPacketSize
   Maximum packet size this endpoint is capable of sending or receiving when this configuration is selected.

uint8_t bInterval
   Interval for polling Isochronous and Interrupt endpoints. Expressed in frames or microframes depending on the device operating speed (1 ms for Low-Speed and Full-Speed or 125 us for USB High-Speed and above).

struct usb_ep_desc_t::[anonymous] USB_DESC_ATTR

union usb_str_desc_t
   #include <usb_types_ch9.h> Structure representing a USB string descriptor.

Public Members

uint8_t bLength
   Size of the descriptor in bytes

uint8_t bDescriptorType
   STRING Descriptor Type

uint16_t wData[]
   UTF-16LE encoded


```c
struct usb_desc_t::[anonymous] USB_DESC_ATTR
uint8_t val[USB_STR_DESC_SIZE]
```

**Macros**

- **USB_DESC_ATTR**
  - Descriptor types from USB 2.0 specification table 9.5.
- **USB_BGR_DESCRIPTOR_TYPE_DEVICE**
- **USB_BGR_DESCRIPTOR_TYPE_CONFIGURATION**
- **USB_BGR_DESCRIPTOR_TYPE_STRING**
- **USB_BGR_DESCRIPTOR_TYPE_INTERFACE**
- **USB_BGR_DESCRIPTOR_TYPE_ENDPOINT**
- **USB_BGR_DESCRIPTOR_TYPE_DEVICE_QUALIFIER**
- **USB_BGR_DESCRIPTOR_TYPE_OTHER_SPEED_CONFIGURATION**
- **USB_BGR_DESCRIPTOR_TYPE_INTERFACE_POWER**
- **USB_BGR_DESCRIPTOR_TYPE_OTG**
  - Descriptor types from USB 2.0 ECN.
- **USB_BGR_DESCRIPTOR_TYPE_DEBUG**
- **USB_BGR_DESCRIPTOR_TYPE_INTERFACE_ASSOCIATION**
- **USB_BGR_DESCRIPTOR_TYPE_SECURITY**
  - Descriptor types from Wireless USB spec.
- **USB_BGR_DESCRIPTOR_TYPE_KEY**
- **USB_BGR_DESCRIPTOR_TYPE_ENCRYPTION_TYPE**
- **USB_BGR_DESCRIPTOR_TYPE_BOS**
- **USB_BGR_DESCRIPTOR_TYPE_DEVICE_CAPABILITY**
- **USB_BGR_DESCRIPTOR_TYPE_WIRELESS_ENDPOINT_COMP**
- **USB_BGR_DESCRIPTOR_TYPE_WIRE_ADAPTER**
- **USB_BGR_DESCRIPTOR_TYPE_RPIPE**
- **USB_BGR_DESCRIPTOR_TYPE_CS_RADIO_CONTROL**
- **USB_BGR_DESCRIPTOR_TYPE_PIPE_USAGE**
  - Descriptor types from UAS specification.
- **USB_SETUP_PACKET_SIZE**
  - Size of a USB control transfer setup packet in bytes.
- **USB_BGR_REQUEST_TYPE_DIR_OUT**
  - Bit masks belonging to the bmRequestType field of a setup packet.
- **USB_BGR_REQUEST_TYPE_DIR_IN**
- **USB_BGR_REQUEST_TYPE_TYPE_STANDARD**
- **USB_BGR_REQUEST_TYPE_TYPE_CLASS**
- **USB_BGR_REQUEST_TYPE_TYPE_VENDOR**
- **USB_BGR_REQUEST_TYPE_TYPE_RESERVED**
- **USB_BGR_REQUEST_TYPE_TYPE_MASK**
- **USB_BGR_REQUEST_TYPE_RECIP_DEVICE**
- **USB_BGR_REQUEST_TYPE_RECIP_INTERFACE**
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USB_BM_REQUEST_TYPE_RECIP_ENDPOINT
USB_BM_REQUEST_TYPE_RECIP_OTHER
USB_BM_REQUEST_TYPE_RECIP_MASK
USB_B_REQUEST_GET_STATUS
   Bitmasks belonging to the bRequest field of a setup packet.
USB_B_REQUEST_CLEAR_FEATURE
USB_B_REQUEST_SET_FEATURE
USB_B_REQUEST_SET_ADDRESS
USB_B_REQUEST_GET_DESCRIPTOR
USB_B_REQUEST_SET_DESCRIPTOR
USB_B_REQUEST_GET_CONFIGURATION
USB_B_REQUEST_SET_CONFIGURATION
USB_B_REQUEST_GET_INTERFACE
USB_B_REQUEST_SET_INTERFACE
USB_B_REQUEST_SYNCH_FRAME
USB_W_VALUE_DT_DEVICE
   Bitmasks belonging to the wValue field of a setup packet.
USB_W_VALUE_DT_CONFIG
USB_W_VALUE_DT_STRING
USB_W_VALUE_DT_INTERFACE
USB_W_VALUE_DT_ENDPOINT
USB_W_VALUE_DT_DEVICE_QUALIFIER
USB_W_VALUE_DT_OTHER_SPEED_CONFIG
USB_W_VALUE_DT_INTERFACE_POWER
USB_SETUP_PACKET_INIT_SET_ADDR (setup_pkt_ptr, addr)
  Initializer for a SET_ADDRESS request.
   Sets the address of a connected device
USB_SETUP_PACKET_INIT_GET_DEVICE_DESC (setup_pkt_ptr)
  Initializer for a request to get a device’s device descriptor.
USB_SETUP_PACKET_INIT_GET_CONFIG (setup_pkt_ptr)
  Initializer for a request to get a device’s current configuration number.
USB_SETUP_PACKET_INIT_GET_CONFIG_DESC (setup_pkt_ptr, desc_index, desc_len)
   Initializer for a request to get one of the device’s current configuration descriptor.
   • desc_index indicates the configuration’s index number
   • Number of bytes of the configuration descriptor to get
USB_SETUP_PACKET_INIT_SET_CONFIG (setup_pkt_ptr, config_num)
   Initializer for a request to set a device’s current configuration number.
USB_SETUP_PACKET_INIT_SET_INTERFACE (setup_pkt_ptr, intf_num, alt_setting_num)
   Initializer for a request to set an interface’s alternate setting.
USB_SETUP_PACKET_INIT_GET_STR_DESC (setup_pkt_ptr, string_index, lang_id, desc_len)
   Initializer for a request to get a string descriptor.
USB_STANDARD_DESC_SIZE
   Size of dummy USB standard descriptor.
USB_DEVICE_DESC_SIZE
  Size of a USB device descriptor in bytes.

USB_CLASS_PER_INTERFACE
  Possible base class values of the bDeviceClass field of a USB device descriptor.

USB_CLASS_AUDIO
USB_CLASS_COMM
USB_CLASS_HID
USB_CLASS_PHYSICAL
USB_CLASS_STILL_IMAGE
USB_CLASS_PRINTER
USB_CLASS_MASS_STORAGE
USB_CLASS_HUB
USB_CLASS_CDC_DATA
USB_CLASS_CSCID
USB_CLASSCONTENT_SEC
USB_CLASS_VIDEO
USB_CLASS_WIRELESS_CONTROLLER
USB_CLASS_PERSONAL_HEALTHCARE
USB_CLASS_AUDIO_VIDEO
USB_CLASS_BILLBOARD
USB_CLASS_USB_TYPE_C_BRIDGE
USB_CLASS_MISC
USB_CLASS_APP_SPEC
USB_CLASS_VENDOR_SPEC
USB_SUBCLASS_VENDOR_SPEC
  Vendor specific subclass code.

USB_CONFIG_DESC_SIZE
  Size of a short USB configuration descriptor in bytes.

  Note  The size of a full USB configuration includes all the interface and endpoint descriptors of that configuration.

USB_BM_ATTRIBUTES_ONE
  Bit masks belonging to the bmAttributes field of a configuration descriptor.

USB_BM_ATTRIBUTES_SELFPOWER
USB_BM_ATTRIBUTES_WAKEUP
USB_BM_ATTRIBUTES_BATTERY

USB_IAD_DESC_SIZE
  Size of a USB interface association descriptor in bytes.

USB_INTF_DESC_SIZE
  Size of a USB interface descriptor in bytes.

USB_EP_DESC_SIZE
  Size of a USB endpoint descriptor in bytes.
USB_B_ENDPOINT_ADDRESS_EP_NUM_MASK
Bit masks belonging to the bEndpointAddress field of an endpoint descriptor.

USB_B_ENDPOINT_ADDRESS_EP_DIR_MASK

USB_BM_ATTRIBUTES_XFERTYPE_MASK
Bit masks belonging to the bmAttributes field of an endpoint descriptor.

USB_BM_ATTRIBUTES_XFER_CONTROL
USB_BM_ATTRIBUTES_XFER_ISOC
USB_BM_ATTRIBUTES_XFER_BULK
USB_BM_ATTRIBUTES_XFER_INT
USB_B_M_ATTRIBUTES_SYNCTYPE_MASK
USB_BM_ATTRIBUTES_SYNC_NONE
USB_BM_ATTRIBUTES_SYNC_ASYNC
USB_BM_ATTRIBUTES_SYNC_ADAPTIVE
USB_BM_ATTRIBUTES_SYNC_SYNC
USB_BM_ATTRIBUTES_USAGETYPE_MASK
USB_BM_ATTRIBUTES_USAGE_DATA
USB_BM_ATTRIBUTES_USAGE_FEEDBACK
USB_BM_ATTRIBUTES_USAGE_IMPLICIT_FB

USB_EP_DESC_GET_XFERTYPE (desc_ptr)
Macro helper to get information about an endpoint from its descriptor.

USB_EP_DESC_GET_EP_NUM (desc_ptr)
USB_EP_DESC_GET_EP_DIR (desc_ptr)
USB_EP_DESC_GET_MPS (desc_ptr)

USB_STR_DESC_SIZE
Size of a short USB string descriptor in bytes.

Enumerations

enum usb_device_state_t
USB2.0 device states.

See Table 9-1 of USB2.0 specification for more details

Note The USB_DEVICE_STATE_NOT_ATTACHED is not part of the USB2.0 specification, but is a catch
all state for devices that need to be cleaned up after a sudden disconnection or port error.

Values:

USB_DEVICE_STATE_NOT_ATTACHED
The device was previously configured or suspended, but is no longer attached (either suddenly discon-
nected or a port error)

USB_DEVICE_STATE_ATTACHED
Device is attached to the USB, but is not powered.

USB_DEVICE_STATEPOWERED
Device is attached to the USB and powered, but has not been reset.

USB_DEVICE_STATE_DEFAULT
Device is attached to the USB and powered and has been reset, but has not been assigned a unique address.
Device responds at the default address.
**USB_DEVICE_STATE_ADDRESS**
Device is attached to the USB, powered, has been reset, and a unique device address has been assigned. Device is not configured.

**USB_DEVICE_STATE_CONFIGURED**
Device is attached to the USB, powered, has been reset, has a unique address, is configured, and is not suspended. The host may now use the function provided by the device.

**USBDEVICE_STATE_SUSPENDED**
Device is, at minimum, attached to the USB and is powered and has not seen bus activity for 3 ms. It may also have a unique address and be configured for use. However, because the device is suspended, the host may not use the device’s function.

Code examples for this API section are provided in the peripherals directory of ESP-IDF examples.

### 2.4 Application Protocols

#### 2.4.1 ASIO port

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

**ASIO documentation** Please refer to the original asio documentation at https://think-async.com/Asio/Documentation. Asio also comes with a number of examples which could be found under Documentation/Examples on that web site.

**Supported features** ESP platform port currently supports only network asynchronous socket operations; does not support serial port. SSL/TLS support is disabled by default and could be enabled in component configuration menu by choosing TLS library from
- mbedTLS with OpenSSL translation layer (default option)
- wolfSSL

SSL support is very basic at this stage and it does include following features:
- Verification callbacks
- DH property files
- Certificates/private keys file APIs

Internal asio settings for ESP include
- EXCEPTIONS are enabled in ASIO if enabled in menuconfig
- TYPEID is enabled in ASIO if enabled in menuconfig

**Application Example**

ESP examples are based on standard asio protocols/asio:

- protocols/asio/udp_echo_server
- protocols/asio/tcp_echo_server
- protocols/asio/asio_chat
- protocols/asio/ssl_client_server

Please refer to the specific example README.md for details.


2.4.2 ESP-MQTT

Overview

ESP-MQTT is an implementation of MQTT protocol client (MQTT is a lightweight publish/subscribe messaging protocol).

Features

- Supports MQTT over TCP, SSL with mbedtls, MQTT over Websocket, 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 QoS levels (it should be a fully functional client).

Application Example

- protocols/mqtt/tcp: MQTT over tcp, default port 1883
- protocols/mqtt/ssl: MQTT over tcp, default port 8883
- protocols/mqtt/ssl_psk: MQTT over tcp 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

Configuration

URI

- 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
- MQTT over Websocket Secure samples:
  - wss://mqtt.eclipseprojects.io:443/mqtt
- Minimal configurations:

```c
const esp_mqtt_client_config_t mqtt_cfg = {
  .uri = "mqtt://mqtt.eclipseprojects.io",
  // .user_context = (void *)your_context
};
esp_mqtt_client_handle_t client = esp_mqtt_client_init(&mqtt_cfg);
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.)
SSL

- Get certificate from server, example: `mqtt.eclipseprojects.io openssl s_client -showcerts -connect mqtt.eclipseprojects.io:8883 </dev/null 2>/dev/null x509 -outform PEM >mqtt_eclipse_org.pem`
- Check the sample application: `examples/mqtt_ssl`
- Configuration:

```c
const esp_mqtt_client_config_t mqtt_cfg = {
    .uri = "mqtts://mqtt.eclipseprojects.io:8883",
    .event_handle = mqtt_event_handler,
    .cert_pem = (const char *)mqtt_eclipse_org_pem_start,
};
```

If the certificate is not null-terminated then `cert_len` should also be set. Other SSL related configuration parameters are:

- `use_global_ca_store`: use the global certificate store to verify server certificate, see esp-tls.h for more information
- `client_cert_pem`: pointer to certificate data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed.
- `client_cert_len`: length of the buffer pointed to by `client_cert_pem`. May be 0 for null-terminated pem.
- `client_key_pem`: pointer to private key data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed.
- `client_key_len`: length of the buffer pointed to by `client_key_pem`. May be 0 for null-terminated pem.
- `psk_hint_key`: pointer to PSK struct defined in esp_tls.h to enable PSK authentication (as alternative to certificate verification). If not NULL and server/client certificates are NULL, PSK is enabled
- `alpn_protos`: NULL-terminated list of protocols to be used for ALPN.

**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 `esp_mqtt_client_config_t` struct.

- `lwt_topic`: pointer to the LWT message topic
- `lwt_msg`: pointer to the LWT message
- `lwt_msg_len`: length of the LWT message, required if `lwt_msg` is not null-terminated
- `lwt_qos`: quality of service for the LWT message
- `lwt_retain`: specifies the retain flag of the LWT message

**Other Configuration Parameters**

- `disable_clean_session`: determines the clean session flag for the connect message, defaults to a clean session
- `keepalive`: determines how many seconds the client will wait for a ping response before disconnecting, default is 120 seconds.
- `disable_auto_reconnect`: enable to stop the client from reconnecting to server after errors or disconnects
- `user_context`: custom context that will be passed to the event handler
- `task_prio`: MQTT task priority, defaults to 5
- `task_stack`: MQTT task stack size, defaults to 6144 bytes, setting this will override setting from menu-config
- `buffer_size`: size of MQTT send/receive buffer, default is 1024 bytes
- `username`: pointer to the username used for connecting to the broker
- `password`: pointer to the password used for connecting to the broker
- `client_id`: pointer to the client id, defaults to ESP32_%CHIPID% where %CHIPID% are the last 3 bytes of MAC address in hex format
- `host`: MQTT broker domain (ipv4 as string), setting the uri will override this
- `port`: MQTT broker port, specifying the port in the uri will override this
- `transport`: sets the transport protocol, setting the uri will override this
API Reference

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- refresh_connection_after_ms: refresh connection after this value (in milliseconds)
- event_handle: handle for MQTT events as a callback in legacy mode
- event_loop_handle: handle for MQTT event loop library

For more options on esp_mqtt_client_config_t, please refer to API reference below

**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`: Enables 3.1.1 version of MQTT protocol
- `CONFIG_MQTT_TRANSPORT_SSL, CONFIG_MQTT_TRANSPORT_WEBSOCKET`: Enables specific MQTT transport layer, such as SSL, WEBSOCKET, WEBSOCKET_SECURE
- `CONFIG_MQTT_CUSTOM_OUTBOX`: Disables 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 Quality of Service 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. `esp_mqtt_error_type_t` from `error_handle` in the event data can be used to further determine the type of 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**

```c
esp_mqtt_client_handle_t esp_mqtt_client_init(const esp_mqtt_client_config_t *config)
```

Creates mqtt client handle based on the configuration.

- `Return` mqtt_client_handle if successfully created, NULL on error
- `Parameters`
  - `config`: mqtt configuration structure

```c
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`.

- `Return` ESP_FAIL if URI parse error, ESP_OK on success
- `Parameters`

---

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- client: mqtt client handle
- uri:

```c
esp_err_t esp_mqtt_client_start(esp_mqtt_client_handle_t client)
```
Starts mqtt client with already created client handle.

**Return** ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL on other error

**Parameters**
- client: mqtt client handle

```c
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.

**Return** ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL if client is in invalid state

**Parameters**
- client: mqtt client handle

```c
esp_err_t esp_mqtt_client_disconnect(esp_mqtt_client_handle_t client)
```
This api is typically used to force disconnection from the broker.

**Return** ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization

**Parameters**
- client: mqtt client handle

```c
esp_err_t esp_mqtt_client_stop(esp_mqtt_client_handle_t client)
```
Stops mqtt client tasks.

- Notes:
  - Cannot be called from themqtt event handler

**Return** ESP_OK on success ESP_ERR_INVALID_ARG on wrong initialization ESP_FAIL if client is in invalid state

**Parameters**
- client: mqtt client handle

```c
int esp_mqtt_client_subscribe(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.

**Return** message_id of the subscribe message on success -1 on failure

**Parameters**
- client: mqtt client handle
- topic:
- qos:

```c
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 for details

**Return** message_id of the subscribe message on success -1 on failure

**Parameters**
- client: mqtt client handle
- topic:

```c
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, enqueuing 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

Return message_id of the publish message (for QoS 0 message_id will always be zero) on success. -1 on failure.

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

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().

Return message_id if queued successfully, -1 otherwise

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 qos1 and qos 2 are enqueued

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

Return ESP_OK ESP_ERR_INVALID_ARG on wrong initialization

Parameters
- client: mqtt client handle

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.

Return ESP_ERR_NO_MEM if failed to allocate ESP_ERR_INVALID_ARG if conflicts on transport configuration. ESP_OK on success

Parameters
- client: mqtt client handle
- config: mqtt configuration structure

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.
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**Return** ESP_ERR_NO_MEM if failed to allocate ESP_ERR_INVALID_ARG on wrong initialization
ESP_OK on success

**Parameters**
- `client`: mqtt client handle
- `event`: event type
- `event_handler`: handler callback
- `event_handler_arg`: handlers context

int `esp_mqtt_client_get_outbox_size` (esp_mqtt_client_handle_t client)

Get outbox size.

**Return** outbox size 0 on wrong initialization

**Parameters**
- `client`: mqtt client handle

**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:

<table>
<thead>
<tr>
<th>error_type</th>
<th>related member variables</th>
<th>note</th>
<th>related to source of error</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQTT_ERROR_TYPE_TCP_TRANSPORT</td>
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<td>Internal error reported from MQTT broker on connection</td>
<td></td>
</tr>
</tbody>
</table>

**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`
erno 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
void *user_context
    User context passed from MQTT client config

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

struct esp_mqtt_client_config_t
    MQTT client configuration structure

Public Members

mqtt_event_callback_t event_handle
    handle for MQTT events as a callback in legacy mode

.exp_event_loop_handle_t event_loop_handle
    handle for MQTT event loop library

const char *host
    MQTT server domain (ipv4 as string)

const char *uri
    Complete MQTT broker URI

uint32_t port
    MQTT server port

bool set_null_client_id
    Selects a NULL client id

const char *client_id
    Set client id. 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
**const** char *username
MQTT username

**const** char *password
MQTT password

**const** char *lwt_topic
LWT (Last Will and Testament) message topic (NULL by default)

**const** char *lwt_msg
LWT message (NULL by default)

int lwt_qos
LWT message qos

int lwt_retain
LWT retained message flag

int lwt_msg_len
LWT message length

**int** disable_clean_session
mqqt clean session, default clean_session is true

**int** keepalive
mqqt keepalive, default is 120 seconds

**bool** disable_auto_reconnect
this mqtt client will reconnect to server (when errors/disconnect). Set disable_auto_reconnect=true to disable

void *user_context
pass user context to this option, then can receive that context in event->user_context

**int** task_prio
MQTT task priority, default is 5, can be changed in make menuconfig

**int** task_stack
MQTT task stack size, default is 6144 bytes, can be changed in make menuconfig

**int** buffer_size
size of MQTT send/receive buffer, default is 1024 (only receive buffer size if out_buffer_size defined)

**const** char *cert_pem
Pointer to certificate data in PEM or DER format for server verify (with SSL), default is NULL, not required to verify the server. PEM-format must have a terminating NULL-character. DER-format requires the length to be passed in cert_len.

**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
Pointer to certificate data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed. If it is not NULL, also client_key_pem has to be provided. PEM-format must have a terminating NULL-character. DER-format requires the length to be passed in client_cert_len.

**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
Pointer to private key data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed. If it is not NULL, also client_cert_pem has to be provided. PEM-format must have a terminating NULL-character. DER-format requires the length to be passed in client_key_len
size_t client_key_len
  Length of the buffer pointed to by client_key_pem. May be 0 for null-terminated pem

esp_mqtt_transport_t transport
  overrides URI transport

int refresh_connection_after_ms
  Refresh connection after this value (in milliseconds)

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). If not NULL and server/client certificates are NULL, PSK is enabled

bool use_global_ca_store
  Use a global ca_store for all the connections in which this bool is set.

esp_err_t (*crt_bundle_attach)(void *conf)
  Pointer to ESP x509 Certificate Bundle attach function for the usage of certification bundles in mqtt

int reconnect_timeout_ms
  Reconnect to the broker after this value in miliseconds if auto reconnect is not disabled (defaults to 10s)

const char **alpn_protos
  NULL-terminated list of supported application protocols to be used for ALPN

const char *clientkey_password
  Client key decryption password string

int clientkey_password_len
  String length of the password pointed to by clientkey_password

esp_mqtt_protocol_ver_t protocol_ver
  MQTT protocol version used for connection, defaults to value from menuconfig

int out_buffer_size
  size of MQTT output buffer. If not defined, both output and input buffers have the same size defined as buffer_size

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

bool use_secure_element
  enable secure element for enabling SSL connection

void *ds_data
  carrier of handle for digital signature parameters

int network_timeout_ms
  Abort network operation if it is not completed after this value, in milliseconds (defaults to 10s)

bool disable_keepalive
  Set disable_keepalive=true to turn off keep-alive mechanism, false by default (keepalive is active by default). Note: setting the config value keepalive to 0 doesn’t disable keepalive feature, but uses a default keepalive period

const char *path
  Path in the URI

int message_retransmit_timeout
  timeout for retransmit of faulded packet

Macros
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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

Type Definitions
typedef struct esp_mqtt_client * esp_mqtt_client_handle_t
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:

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typedef esp_mqtt_event_t * esp_mqtt_event_handle_t

typedef esp_err_t (* esp_mqtt_event_callback_t)(esp_mqtt_event_handle_t event)

Enumerations
typedef enum esp_mqtt_event_id_t
MQTT event types.

User event handler receives context data in esp_mqtt_event_t structure with

• user_context - user data from esp_mqtt_client_config_t
• client - mqtt client handle
• various other data depending on event type

Values:

MQTT_EVENT_ANY = -1
MQTT_EVENT_ERROR = 0
on error event, additional context: connection return code, error handle from esp_tls (if supported)

MQTT_EVENT_CONNECTED
connected event, additional context: session_present flag

MQTT_EVENT_DISCONNECTED
disconnected event

MQTT_EVENT_SUBSCRIBED
subscribed event, additional context:
• msg_id message id
• data pointer to the received data
• data_len length of the data for this event

MQTT_EVENT_UNSUBSCRIBED
unsubscribed event

MQTT_EVENT_PUBLISHED
published event, additional context: msg_id

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.

**MQTT_EVENT_BEFORE_CONNECT**
The event occurs before connecting

**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).

**enum esp_mqtt_connect_return_code_t**
MQTT connection error codes propagated via ERROR event

*Values:*

- **MQTT_CONNECTION_ACCEPTED** = 0
  Connection accepted

- **MQTT_CONNECTION_REFUSE_PROTOCOL**
  MQTT connection refused reason: Wrong protocol

- **MQTT_CONNECTION_REFUSE_ID_REJECTED**
  MQTT connection refused reason: ID rejected

- **MQTT_CONNECTION_REFUSE_SERVER_UNAVAILABLE**
  MQTT connection refused reason: Server unavailable

- **MQTT_CONNECTION_REFUSE_BAD_USERNAME**
  MQTT connection refused reason: Wrong user

- **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:*

- **MQTT_ERROR_TYPE_NONE** = 0
- **MQTT_ERROR_TYPE_TCP_TRANSPORT**
- **MQTT_ERROR_TYPE_CONNECTION_REFUSED**

**enum esp_mqtt_transport_t**

*Values:*

- **MQTT_TRANSPORT_UNKNOWN** = 0x0
- **MQTT_TRANSPORT_OVER_TCP**
  MQTT over TCP, using scheme: mqtt
- **MQTT_TRANSPORT_OVER_SSL**
  MQTT over SSL, using scheme: mqtts
2.4.3 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_conn_new(): for opening a new 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.
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- **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](https://github.com/espressif/esp-wolfssl).

- **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.

**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.

| Note: | As the library options are internal to ESP-TLS, switching the libraries will not change ESP-TLS specific code for a 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:\n
   ```
   (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.

Digital Signature with ESP-TLS

ESP-TLS provides support for using the Digital Signature (DS) with ESP32-S3. Use of the DS for TLS is supported only when ESP-TLS is used with mbedtls (default stack) as its underlying SSL/TLS stack. For more details on Digital Signature, please refer to the Digital Signature Documentation. The technical details of Digital Signature such as how to calculate private key parameters can be found in ESP32-S3 Technical Reference Manual > Digital Signature (DS) [PDF]. The DS peripheral must be configured before it can be used to perform Digital Signature, see Configure the DS Peripheral in Digital Signature.

The DS peripheral must be initialized with the required encrypted private key parameters (obtained when the DS peripheral is configured). ESP-TLS internally initializes the DS peripheral when provided with the required DS context (DS parameters). Please see the below code snippet for passing the DS context to esp-tls context. The DS context passed to the esp-tls context should not be freed till the TLS connection is deleted.

```c
#include "esp_tls.h"
esp_ds_data_ctx_t *ds_ctx;
/* initialize ds_ctx with encrypted private key parameters, which can be read from...
..the nvs or provided through the application code */
esp_tls_cfg_t cfg = {
    .clientcert_buf = /* the client cert */,
    .clientcert_bytes = /* length of the client cert */,
    /* other configurations options */
    .ds_data = (void *)ds_ctx,
};
```

**Note:** When using Digital Signature for the TLS connection, along with the other required params, only the client cert (clientcert_buf) and the DS params (ds_data) are required and the client key (clientkey_buf) can be set to NULL.

- An example of mutual authentication with the DS peripheral can be found at ssl mutual auth which internally uses (ESP-TLS) for the TLS connection.

API Reference

Header File

- components/esp-tls/esp_tls.h
Functions

*esp_tls_t* esp_tls_init (void)

Create TLS connection.

Return: tls Pointer to esp-tls as esp-tls handle if successfully initialized, NULL if allocation error

*esp_tls_t* esp_tls_conn_new (const char *hostname, int hostlen, int port, const esp_tls_cfg_t *cfg)

Create a new blocking TLS/SSL connection.

This function establishes a TLS/SSL connection with the specified host in blocking manner.

Note: This API is present for backward compatibility reasons. Alternative function with the same functionality is esp_tls_conn_new_sync (and its asynchronous version esp_tls_conn_new_async)

Return: pointer to esp_tls_t, or NULL if connection couldn’t be opened.

Parameters
- [in] hostname: Hostname of the host.
- [in] port: Port number of the host.
- [in] cfg: 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.

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.

Return
- -1 If connection establishment fails.
- 1 If connection establishment is successful.
- 0 If connection state is in progress.

Parameters
- [in] hostname: Hostname of the host.
- [in] port: Port number of the host.
- [in] cfg: 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.
- [in] tls: Pointer to esp-tls as esp-tls handle.

*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.

The behaviour is same as esp_tls_conn_new() API. However this API accepts host’s url.

Return: pointer to esp_tls_t, or NULL if connection couldn’t be opened.

Parameters
- [in] url: url of host.
- [in] cfg: 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.

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.

Return
- -1 If connection establishment fails.
- 0 If connection establishment is in progress.
Chapter 2. API Reference

• If connection establishment is successful.

Parameters
- [in] hostname: Hostname of the host.
- [in] port: Port number of the host.
- [in] cfg: TLS configuration as esp_tls_cfg_t. non_block member of this structure should be set to be true.
- [in] tls: pointer to esp-tls as esp-tls handle.

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() API. However this API accepts host’s url.

Return
- -1 If connection establishment fails.
- 0 If connection establishment is in progress.
- 1 If connection establishment is successful.

Parameters
- [in] url: url of host.
- [in] cfg: TLS configuration as esp_tls_cfg_t.
- [in] tls: pointer to esp-tls as esp-tls handle.

static ssize_t esp_tls_conn_write(esp_tls_t *tls, void *data, size_t datalen)
Write from buffer ‘data’ into specified tls connection.

Return
- >=0 if write operation was successful, the return value is the number of bytes actually written to the TLS/SSL connection.
- <0 if write operation was not successful, because either an error occured 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.

Parameters
- [in] tls: pointer to esp-tls as esp-tls handle.
- [in] data: Buffer from which data will be written.
- [in] datalen: Length of data buffer.

static ssize_t esp_tls_conn_read(esp_tls_t *tls, void *data, size_t datalen)
Read from specified tls connection into the buffer ‘data’.

Return
- >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 occured or an action must be taken by the calling process.

Parameters
- [in] tls: pointer to esp-tls as esp-tls handle.
- [in] data: Buffer to hold read data.
- [in] datalen: Length of data buffer.

void esp_tls_conn_delete(esp_tls_t *tls)
Compatible version of esp_tls_conn_destroy() to close the TLS/SSL connection.

Parameters
- [in] tls: pointer to esp-tls as esp-tls handle.

int esp_tls_conn_destroy(esp_tls_t *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() or esp_tls_conn_http_new() APIs.
Chapter 2. API Reference

Return - 0 on success
   • -1 if socket error or an invalid argument

Parameters
   • [in] tls: pointer to esp-tls as esp-tls handle.

ssize_t esp_tls_get_bytes_avail(esp_tls_t *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.

Return
   • -1 in case of invalid arg
   • bytes available in the application data record read buffer

Parameters
   • [in] tls: pointer to esp-tls as esp-tls handle.

esp_err_t esp_tls_get_conn_sockfd(esp_tls_t *tls, int *sockfd)
Returns the connection socket file descriptor from esp_tls session.

Return
   • 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)

Parameters
   • [in] tls: handle to esp_tls context
   • [out] sockfd: int pointer to sockfd value.

esp_err_t esp_tls_init_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().

Return
   • 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().

Return
   • ESP_OK if adding certificates was successful.
   • Other if an error occurred or an action must be taken by the calling process.

Parameters
   • [in] cacert_pem_buf: 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.

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.

Return
   • ESP_ERR_INVALID_STATE if invalid parameters
Chapter 2. API Reference

- ESP_OK (0) if no error occurred
- specific error code (based on ESP_ERR_ESP_TLS_BASE) otherwise

**Parameters**
- [in] `h`: esp-tls error handle.
- [out] `esp_tls_code`: 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
- [out] `esp_tls_flags`: last certification verification flags (set to zero if none) This pointer could be NULL if caller does not care about esp_tls_code

```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.

**Return**
- ESP_ERR_INVALID_STATE if invalid parameters
- ESP_OK if a valid error returned and was cleared

**Parameters**
- [in] `h`: esp-tls error handle.
- [in] `err_type`: specific error type
- [out] `error_code`: 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

```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.

**Return**
- 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.

**Return** ESP_OK on success ESP_ERR_INVALID_ARG if invalid output parameters ESP-TLS based error codes on failure

**Parameters**
- [in] `host`: Hostname of the host.
- [in] `port`: Port number of the host.
- [in] `cfg`: ESP-TLS configuration as esp_tls_cfg_t.
- [out] `error_handle`: ESP-TLS error handle holding potential errors occurred during connection
- [out] `sockfd`: Socket descriptor if successfully connected on TCP layer

**Structures**

```c
struct psk_key_hint
```

ESP-TLS preshared key and hint structure.

**Public Members**

```c
cconst uint8_t* key
```

key in PSK authentication mode in binary format

```c
cconst 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 mbedtls-
  support 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 mbedtls-support This buffer
  should be NULL terminated in case of PEM

const unsigned char *clientcert_pem_buf
  Client certificate legacy name
unsigned int \texttt{clientcert\_bytes}
Size of client certificate pointed to by \texttt{clientcert\_pem\_buf} (including NULL-terminator in case of PEM format)

unsigned int \texttt{clientcert\_pem\_bytes}
Size of client certificate legacy name

\texttt{const unsigned char *clientkey\_buf}
Client key in a buffer Format may be PEM or DER, depending on mbedtls-support This buffer should be NULL terminated in case of PEM

\texttt{const unsigned char *clientkey\_pem\_buf}
Client key legacy name

unsigned int \texttt{clientkey\_bytes}
Size of client key pointed to by \texttt{clientkey\_pem\_buf} (including NULL-terminator in case of PEM format)

unsigned int \texttt{clientkey\_pem\_bytes}
Size of client key legacy name

\texttt{const unsigned char *clientkey\_password}
Client key decryption password string

unsigned int \texttt{clientkey\_password\_len}
String length of the password pointed to by \texttt{clientkey\_password}

\texttt{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

\texttt{bool use\_secure\_element}
Enable this option to use secure element or atecc608a chip (Integrated with ESP32-WROOM-32SE)

\texttt{int timeout\_ms}
Network timeout in milliseconds

\texttt{bool use\_global\_ca\_store}
Use a global ca_store for all the connections in which this bool is set.

\texttt{const char *common\_name}
If non-NULL, server certificate CN must match this name. If NULL, server certificate CN must match hostname.

\texttt{bool skip\_common\_name}
Skip any validation of server certificate CN field

\texttt{tls\_keep\_alive\_cfg\_t *keep\_alive\_cfg}
Enable TCP keep-alive timeout for SSL connection

\texttt{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

\texttt{esp\_err\_t (*crt\_bundle\_attach) (void *conf)}
Function pointer to \texttt{esp\_crt\_bundle\_attach}. Enables the use of certification bundle for server verification, must be enabled in menuconfig

\texttt{void *ds\_data}
Pointer for digital signature peripheral context

\texttt{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 \texttt{esp\_tls\_plain\_tcp\_connect()} API

\texttt{struct ifreq *if\_name}
The name of interface for data to go through. Use the default interface without setting
struct esp_tls
ESP-TLS Connection Handle.

Public Members

mbedtls_ssl_context ssl
TLS/SSL context

mbedtls_entropy_context entropy
mbedTLS entropy context structure

mbedtls_ctr_drbg_context ctr_drbg
mbedTLS ctr drbg context structure. CTR_DRBG is deterministic random bit generation based on AES-256

mbedtls_ssl_config conf
TLS/SSL configuration to be shared between mbedtls_ssl_context structures

mbedtls_net_context server_fd
mbedTLS wrapper type for sockets

mbedtls_x509_crt cacert
Container for the X.509 CA certificate

mbedtls_x509_crt *cacert_ptr
Pointer to the cacert being used.

mbedtls_x509_crt clientcert
Container for the X.509 client certificate

mbedtls_pk_context clientkey
Container for the private key of the client certificate

int sockfd
Underlying socket file descriptor.

ssize_t (*read)(struct esp_tls *tls, char *data, size_t datalen)
Callback function for reading data from TLS/SSL connection.

ssize_t (*write)(struct esp_tls *tls, const char *data, size_t datalen)
Callback function for writing data to TLS/SSL connection.

esp_tls_conn_state_t conn_state
ESP-TLS Connection state

fd_set rset
read file descriptors

fd_set wset
write file descriptors

bool is_tls
indicates connection type (TLS or NON-TLS)

esp_tls_role_t role
esp-tls role

  • ESP_TLS_CLIENT
  • ESP_TLS_SERVER

esp_tls_error_handle_t error_handle
handle to error descriptor
Type Definitions

typedef enum esp_tls_conn_state esp_tls_conn_state_t
    ESP-TLS Connection State.

typedef enum esp_tls_role esp_tls_role_t

typedef struct psk_key_hint psk_hint_key_t
    ESP-TLS pre-shared key and hint structure.

typedef struct tls_keep_alive_cfg tls_keep_alive_cfg_t
    esp-tls client session ticket ctx
    Keep alive parameters structure

typedef struct esp_tls_cfg 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 esp_tls esp_tls_t
    ESP-TLS Connection Handle.

Enumerations

enum esp_tls_conn_state
    ESP-TLS Connection State.
    Values:
    ESP_TLS_INIT = 0
    ESP_TLS_CONNECTING
    ESP_TLS_HANDSHAKE
    ESP_TLS_FAIL
    ESP_TLS_DONE

enum esp_tls_role
    Values:
    ESP_TLS_CLIENT = 0
    ESP_TLS_SERVER

2.4.4 OpenSSL-APIs

Note: The OpenSSL-API will be discontinued in ESP-IDF from v5.0. Please use ESP-TLS <esp_tls> instead.

The code of this API (located in openssl directory), does not contain OpenSSL itself but is intended as a wrapper for applications using the OpenSSL API. It uses mbedTLS to do the actual work, so anyone compiling openssl code needs the mbedtls library and header file.

OpenSSL APIs not mentioned in this article are not open to public for the time, also do not have the corresponding function. If user calls it directly, it will always return an error or may show cannot link at compiling time.
## Chapter Introduction

- Chapter 1. SSL Context Method Create
- Chapter 2. SSL Context Function
- Chapter 3. SSL Function
- Chapter 4. SSL X509 Certification and Private Key Function

## Chapter 1. SSL Context Method Create

### 1.1 const SSL_METHOD* SSLv3_client_method (void)

**Arguments:**

```
none
```

**Return:**

SSLV3.0 version SSL context client method point

**Description:**

create the target SSL context method

**Example:**

```c
void example(void)
{
    const SSL_METHOD *method = SSLv3_client_method();
    ...
}
```

### 1.2 const SSL_METHOD* TLSv1_client_method (void)

**Arguments:**

```
none
```

**Return:**

TLSV1.0 version SSL context client method point

**Description:**

create the target SSL context method

**Example:**

```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_client_method();
    ...
}
```

### 1.3 const SSL_METHOD* TLSv1_1_client_method (void)

**Arguments:**

```
none
```

**Return:**

...
Chapter 2. API Reference

### TLSV1.1 version SSL context client method point

**Description:**
create the target SSL context method

**Example:**
```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_1_client_method();
    ...
}
```

#### 1.4 const SSL_METHOD* TLSv1_2_client_method (void)

**Arguments:**
one

**Return:**
TLSV1.2 version SSL context client method point

**Description:**
create the target SSL context method

**Example:**
```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_2_client_method();
    ...
}
```

#### 1.5 const SSL_METHOD* TLS_client_method (void)

**Arguments:**
one

**Return:**
TLSV1.2 version SSL context client method point

**Description:**
create the default SSL context method, it's always to be TLSV1.2

**Example:**
```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_2_client_method();
    ...
}
```

#### 1.6 const SSL_METHOD* SSLv3_server_method (void)
Arguments:

none

Return:

SSLV3.0 version SSL context server method point

Description:

create the target SSL context method

Example:

```c
void example(void)
{
    const SSL_METHOD *method = SSLv3_server_method();
    ...
}
```

1.7 const SSL_METHOD* TLSv1_server_method (void)

Arguments:

none

Return:

TLSV1.0 version SSL context server method point

Description:

create the target SSL context method

Example:

```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_server_method();
    ...
}
```

1.8 const SSL_METHOD* TLSv1_1_server_method (void)

Arguments:

none

Return:

TLSV1.1 version SSL context server method point

Description:

create the target SSL context method

Example:

```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_1_server_method();
    ...
}
```
1.9 const SSL_METHOD* TLSv1_2_server_method (void)

Arguments:
none

Return:
TLSV1.2 version SSL context server method point

Description:
create the target SSL context method

Example:

```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_2_server_method();
    ...
}
```

1.10 const SSL_METHOD* TLS_server_method (void)

Arguments:
none

Return:
TLSV1.2 version SSL context server method point

Description:
create the default SSL context method, it's always to be TLSv1.2

Example:

```c
void example(void)
{
    const SSL_METHOD *method = TLSv1_2_server_method();
    ...
}
```
context point

Description:
create a SSL context

Example:

```c
void example(void)
{
    SSL_CTX *ctx = SSL_CTX_new(SSLv3_server_method());
    ...
}
```

2.2 void SSL_CTX_free (SSL_CTX * ctx)

Arguments:
ctx - the SSL context point

Return:
none

Description:
free a SSL context

Example:

```c
void example(void)
{
    SSL_CTX *ctx;
    ...
    SSL_CTX_free(ctx);
}
```

2.3 int SSL_CTX_set_ssl_version (SSL_CTX * ctx, const SSL_METHOD * meth)

Arguments:
ctx - SSL context point
meth - SSL method point

Return:
1 : OK
0 : failed

Description:
set the SSL context version

Example:

```c
void example(void)
{
    SSL_CTX *ctx;
    const SSL_METHOD *meth;
    ...
}
```
... ... 
SSL_CTX_set_ssl_version(ctx, meth);
}

2.4 const SSL_METHOD* SSL_CTX_get_ssl_method (SSL_CTX * ctx)

Arguments:
ctx - SSL context point

Return:
SSL context method

Description:
get the SSL context method

Example:

```c
void example(void)
{
    const SSL_METHOD *method;
    SSL_CTX *ctx;
    ...
    method = SSL_CTX_get_ssl_method(ctx);
}
```

Chapter 3. SSL Function

3.1 SSL* SSL_new (SSL_CTX * ctx)

Arguments:
ctx - SSL context point

Return:
SSL method

Description:
create a SSL

Example:

```c
void example(void)
{
    SSL *ssl;
    SSL_CTX *ctx;
    ...
    ssl = SSL_new(ctx);
}
```

3.2 void SSL_free (SSL * ssl)
Arguments:
ssl - SSL point

Return:
none

Description:
free SSL

Example:
void example(void)
{
    SSL *ssl;
    ...
    SSL_free(ssl);
}

3.3 int SSL_do_handshake (SSL * ssl)

Arguments:
ssl - SSL point

Return:
1 : OK
0 : failed, connect is close by remote
-1 : a error catch

Description:
perform the SSL handshake

Example:
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_do_handshake(ssl);
}

3.4 int SSL_connect (SSL * ssl)

Arguments:
ssl - SSL point

Return:
1 : OK
0 : failed, connect is close by remote
-1 : a error catch

Description:
connect to the remote SSL server

Example:

```c
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_connect(ssl);
}
```

3.5 int SSL_accept (SSL * ssl)

Arguments:

ssl - SSL point

Return:

1 : OK
0 : failed, connect is close by remote
-1 : a error catch

Description:

accept the remote connection

Example:

```c
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_accept(ssl);
}
```

3.6 int SSL_shutdown (SSL * ssl)

Arguments:

ssl - SSL point

Return:

1 : OK
0 : failed, connect is close by remote
-1 : a error catch

Description:

shutdown the connection

Example:

```c
void example(void)
{
    ...
}
```

(continues on next page)
Chapter 2. API Reference

3.7 int SSL_clear (SSL * ssl)

Arguments:

ssl - SSL point

Return:

1 : OK
0 : failed

Description:

shutdown the connection

Example:

```c
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_clear(ssl);
}
```

3.8 int SSL_read (SSL * ssl, void * buffer, int len)

Arguments:

ssl - point
buffer - data buffer point
len - data length

Return:

> 0 : OK, and return received data bytes
= 0 : no data received or connection is closed
< 0 : an error catch

Description:

read data from remote

Example:

```c
void example(void)
{
    SSL *ssl;
    char *buf;
    int len;
    int ret;
    ...
    ret = SSL_read(ssl, buf, len);
}
```
... ...
ret = SSL_read(ssl, buf, len);
}

3.9 int SSL_write (SSL * ssl, const void * buffer, int len)
Arguments:

ssl  - SSL point
buffer - data buffer point
len   - data length

Return:

> 0 : OK, and return received data bytes
= 0 : no data sent or connection is closed
< 0 : an error catch

Description:

send the data to remote

Example:

```c
void example(void)
{
SSL *ssl;
char *buf;
int len;
int ret;
...
ret = SSL_write(ssl, buf, len);
}
```

3.10 SSL_CTX *SSL_get_SSL_CTX (const SSL * ssl)
Arguments:

ssl - SSL point

Return:

SSL context

Description:

get SSL context of the SSL

Example:

```c
void example(void)
{
SSL *ssl;
SSL_CTX *ctx;
...
...
```
3.11 `int SSL_get_shutdown (const SSL * ssl)`

**Arguments:**
- `ssl` - SSL point

**Return:**
- shutdown mode

**Description:**
get SSL shutdown mode

**Example:**

```c
void example(void)
{
    SSL *ssl;
    int mode;
    ...
    mode = SSL_get_SSL_CTX(ssl);
}
```

3.12 `void SSL_set_shutdown (SSL * ssl, int mode)`

**Arguments:**
- `ssl` - SSL point

**Return:**
- shutdown mode

**Description:**
set SSL shutdown mode

**Example:**

```c
void example(void)
{
    SSL *ssl;
    int mode = 0;
    ...
    SSL_set_shutdown(ssl, mode);
}
```

3.13 `const SSL_METHOD* SSL_get_ssl_method (SSL * ssl)`

**Arguments:**
- `ssl` - SSL point

**Return:**
- SSL METHOD
Chapter 2. API Reference

SSL method

Description:
set SSL shutdown mode

Example:

```c
void example(void)
{
    SSL *ssl;
    const SSL_METHOD *method;
    ...
    method = SSL_get_ssl_method(ssl);
}
```

3.14 int SSL_set_ssl_method (SSL * ssl, const SSL_METHOD * method)

Arguments:

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssl</td>
<td>SSL point</td>
</tr>
<tr>
<td>meth</td>
<td>SSL method point</td>
</tr>
</tbody>
</table>

Return:

- 1 : OK
- 0 : failed

Description:
set the SSL method

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    const SSL_METHOD *method;
    ...
    ret = SSL_set_ssl_method(ssl, method);
}
```

3.15 int SSL_pending (const SSL * ssl)

Arguments:

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssl</td>
<td>SSL point</td>
</tr>
</tbody>
</table>

Return:

data bytes

Description:
get received data bytes

Example:
void example(void)
{
    int ret;
    SSL *ssl;
    ...
    ret = SSL_pending(ssl);
}

3.16 int SSL_has_pending (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

1 : Yes
0 : No

Description:

check if data is received

Example:

void example(void)
{
    int ret;
    SSL *ssl;
    ...
    ret = SSL_has_pending(ssl);
}

3.17 int SSL_get_fd (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

>= 0 : socket id
< 0 : a error catch

Description:

get the socket of the SSL

Example:

void example(void)
{
    int ret;
    SSL *ssl;
    ...
    ret = SSL_get_fd(ssl);
}
3.18 int SSL_get_rfd (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

>= 0 : socket id
< 0 : an error catch

Description:

get the read only socket of the SSL

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    ...
    ret = SSL_get_rfd(ssl);
}
```

3.19 int SSL_get_wfd (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

>= 0 : socket id
< 0 : an error catch

Description:

get the write only socket of the SSL

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    ...
    ret = SSL_get_wfd(ssl);
}
```

3.20 int SSL_set_fd (SSL * ssl, int fd)

Arguments:

ssl - SSL point
fd - socket id

Return:
Chapter 2. API Reference

1: OK
0: failed

Description:
set socket to SSL

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    int socket;
    ...
    ret = SSL_set_fd(ssl, socket);
}
```

3.21 `int SSL_set_rfd (SSL * ssl, int fd)`

Arguments:

<table>
<thead>
<tr>
<th>SSL</th>
<th>SSL point</th>
</tr>
</thead>
<tbody>
<tr>
<td>fd</td>
<td>socket id</td>
</tr>
</tbody>
</table>

Return:

1: OK
0: failed

Description:
set read only socket to SSL

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    int socket;
    ...
    ret = SSL_set_rfd(ssl, socket);
}
```

3.22 `int SSL_set_wfd (SSL * ssl, int fd)`

Arguments:

<table>
<thead>
<tr>
<th>SSL</th>
<th>SSL point</th>
</tr>
</thead>
<tbody>
<tr>
<td>fd</td>
<td>socket id</td>
</tr>
</tbody>
</table>

Return:

1: OK
0: failed

Description:
set write only socket to SSL

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    int socket;
    ...
    ret = SSL_set_wfd(ssl, socket);
}
```

### 3.23 int SSL_version (const SSL * ssl)

**Arguments:**

ssl - SSL point

**Return:**

SSL version

**Description:**

get SSL version

**Example:**

```c
void example(void)
{
    int version;
    SSL *ssl;
    ...
    version = SSL_version(ssl);
}
```

### 3.24 const char* SSL_get_version (const SSL * ssl)

**Arguments:**

ssl - SSL point

**Return:**

SSL version string

**Description:**

get the SSL current version string

**Example:**

```c
void example(void)
{
    char *version;
    SSL *ssl;
    ...

    version = SSL_get_version(ssl);
}
```
... ...  
    version = SSL_get_version(ssl);  
}

3.25 OSSL_HANDSHAKE_STATE SSL_get_state (const SSL * ssl)

Arguments:
ssl - SSL point

Return:
SSL state

Description:
get the SSL state

Example:

```c
void example(void)
{
    OSSL_HANDSHAKE_STATE state;
    SSL *ssl;
    ... ...
    state = SSL_get_state(ssl);
}
```

3.26 const char* SSL_alert_desc_string (int value)

Arguments:
value - SSL description

Return:
alert value string

Description:
get alert description string

Example:

```c
void example(void)
{
    int val;
    char *str;
    ... ...
    str = SSL_alert_desc_string(val);
}
```

3.27 const char* SSL_alert_desc_string_long (int value)

Arguments:
value - SSL description

Return:

alert value long string

Description:

get alert description long string

Example:

```c
void example(void)
{
    int val;
    char *str;
    ...
    str = SSL_alert_desc_string_long(val);
}
```

3.28 `const char* SSL_alert_type_string (int value)`

Arguments:

value - SSL type description

Return:

alert type string

Description:

get alert type string

Example:

```c
void example(void)
{
    int val;
    char *str;
    ...
    str = SSL_alert_type_string(val);
}
```

3.29 `const char* SSL_alert_type_string_long (int value)`

Arguments:

value - SSL type description

Return:

alert type long string

Description:

get alert type long string

Example:
Chapter 2. API Reference

```c
void example(void)
{
    int val;
    char *str;
    ...
    str = SSL_alert_type_string_long(val);
}
```

### 3.30 const char* SSL_rstate_string (SSL * ssl)

**Arguments:**

- ssl - SSL point

**Return:**

- state string

**Description:**

get the state string where SSL is reading

**Example:**

```c
void example(void)
{
    SSL *ssl;
    char *str;
    ...
    str = SSL_rstate_string(ssl);
}
```

### 3.31 const char* SSL_rstate_string_long (SSL * ssl)

**Arguments:**

- ssl - SSL point

**Return:**

- state long string

**Description:**

get the state long string where SSL is reading

**Example:**

```c
void example(void)
{
    SSL *ssl;
    char *str;
    ...
    str = SSL_rstate_string_long(ssl);
}
```

### 3.32 const char* SSL_state_string (const SSL * ssl)
Chapter 2. API Reference

### 3.33 `char* SSL_state_string_long (const SSL *ssl)`

**Arguments:**

- `ssl` - SSL point

**Return:**

- state long string

**Description:**

get the state long string

**Example:**

```c
void example(void)
{
  SSL *ssl;
  const char *str;
  ...
  str = SSL_state_string_long(ssl);
}
```

### 3.34 `int SSL_get_error (const SSL *ssl, int ret_code)`

**Arguments:**

- `ssl` - SSL point
- `ret_code` - SSL return code

**Return:**

- SSL error number

**Description:**

get the error number
get SSL error code

Example:

```c
void example(void)
{
    SSL *ssl;
    int ret;
    int err;
    ...
    err = SSL_get_error(ssl, ret);
}
```

3.35 int SSL_want (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

specific statement

Description:

going the SSL specific statement

Example:

```c
void example(void)
{
    SSL *ssl;
    int state;
    ...
    state = SSL_want(ssl);
}
```

3.36 int SSL_want_nothing (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>false</td>
</tr>
<tr>
<td>1</td>
<td>true</td>
</tr>
</tbody>
</table>

Description:

check if SSL want nothing

Example:

```c
void example(void)
{
    SSL *ssl;
    int ret;
    ... ...
    ret = SSL_want_nothing(ssl);
}
```
... ...
ret = SSL_want(ssl);
}

3.37 int SSL_want_read (const SSL * ssl)

Arguments:
ssl - SSL point

Return:
0 : false
1 : true

Description:
check if SSL want to read

Example:
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_want_read(ssl);
}

3.38 int SSL_want_write (const SSL * ssl)

Arguments:
ssl - SSL point

Return:
0 : false
1 : true

Description:
check if SSL want to write

Example:
void example(void)
{
    SSL *ssl;
    int ret;
    ...
    ret = SSL_want_write(ssl);
}
Chapter 4. SSL X509 Certification and Private Key Function

4.1 X509 * d2i_X509 (X509 ** cert, const unsigned char * buffer, long len)

Arguments:

 cert - a point pointed to X509 certification
 buffer - a point pointed to the certification context memory point
 length - certification bytes

Return:

 X509 certification object point

Description:

load a character certification context into system context. If '*cert' is
→ pointed to the certification, then load certification into it. Or create a new X509-
→ certification object

Example:

```c
void example(void)
{
    X509 *new;
    X509 *cert;
    unsigned char *buffer;
    long len;
    ...
    new = d2i_X509(&cert, buffer, len);
}
```

4.2 int SSL_add_client_CA (SSL * ssl, X509 * x)

Arguments:

 ssl - SSL point
 x   - CA certification point

Return:

 1 : OK
 0 : failed

Description:

add CA client certification into the SSL

Example:

```c
void example(void)
{
    int ret;
    SSL *ssl;
    X509 *new;
    ...
    ret = SSL_add_client_CA(ssl, new);
}
```

4.3 int SSL_CTX_add_client_CA (SSL_CTX * ctx, X509 * x)
Arguments:

ctx - SSL context point
x - CA certification point

Return:

1 : OK
0 : failed

Description:

add CA client certification into the SSL context

Example:

```c
void example(void)
{
    int ret;
    SSL_CTX *ctx;
    X509 *new;
    ...
    ret = SSL_add_client_CA(ctx, new);
}
```

4.4 **X509**

4.4 X509* SSL_get_certificate (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

SSL certification point

Description:

get the SSL certification point

Example:

```c
void example(void)
{
    SSL *ssl;
    X509 *cert;
    ...
    cert = SSL_get_certificate(ssl);
}
```

4.5 **long** SSL_get_verify_result (const SSL * ssl)

Arguments:

ssl - SSL point

Return:

the result of verifying

Description:
get the verifying result of the SSL certification

Example:

```c
void example(void)
{
    SSL *ssl;
    long ret;
    ...
    ret = SSL_get_verify_result(ssl);
}
```

4.6 int SSL_CTX_use_certificate (SSL_CTX * ctx, X509 * x)

Arguments:

cxt - the SSL context point
pkey - certification object point

Return:

1 : OK
0 : failed

Description:

load the certification into the SSL_CTX or SSL object

Example:

```c
void example(void)
{
    int ret;
    SSL_CTX *ctx
    X509 *new;
    ...
    ret = SSL_CTX_use_certificate(ctx, new);
}
```

4.7 int SSL_CTX_use_certificate_ASN1 (SSL_CTX * ctx, int len, const unsigned char * d)

Arguments:

cxt - SSL context point
len - certification length
d - data point

Return:

1 : OK
0 : failed

Description:

load the ASN1 certification into SSL context

Example:
void example(void)
{
    int ret;
    SSL_CTX *ctx;
    const unsigned char *buf;
    int len;
    ...
    ret = SSL_CTX_use_certificate_ASN1(ctx, len, buf);
}

4.8 int SSL_CTX_use_PrivateKey (SSL_CTX *ctx, EVP_PKEY *pkey)

Arguments:
- ctx - SSL context point
- pkey - private key object point

Return:
- 1 : OK
- 0 : failed

Description:
load the private key into the context object

Example:
void example(void)
{
    int ret;
    SSL_CTX *ctx;
    EVP_PKEY *pkey;
    ...
    ret = SSL_CTX_use_PrivateKey(ctx, pkey);
}

4.9 int SSL_CTX_use_PrivateKey_ASN1 (int pk, SSL_CTX *ctx, const unsigned char *d, long len)

Arguments:
- ctx - SSL context point
- d - data point
- len - private key length

Return:
- 1 : OK
- 0 : failed

Description:
load the ASN1 private key into SSL context

Example:
void example(void)
{
    (continues on next page)
4.10 int SSL_CTX_use_RSAPrivateKey_ASN1 (SSL_CTX * ctx, const unsigned char * d, long len)

Arguments:

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ctx</td>
<td>SSL context point</td>
</tr>
<tr>
<td>d</td>
<td>data point</td>
</tr>
<tr>
<td>len</td>
<td>private key length</td>
</tr>
</tbody>
</table>

Return:

<table>
<thead>
<tr>
<th>Return Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OK</td>
</tr>
<tr>
<td>0</td>
<td>failed</td>
</tr>
</tbody>
</table>

Description:

load the RSA ASN1 private key into SSL context

Example:

```c
void example(void)
{
    int ret;
    SSL_CTX *ctx;
    const unsigned char *buf;
    long len;
    ...
    ret = SSL_CTX_use_RSAPrivateKey_ASN1(pk, ctx, buf, len);
}
```

4.11 int SSL_use_certificate_ASN1 (SSL * ssl, int len, const unsigned char * d)

Arguments:

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ssl</td>
<td>SSL point</td>
</tr>
<tr>
<td>len</td>
<td>data bytes</td>
</tr>
<tr>
<td>d</td>
<td>data point</td>
</tr>
</tbody>
</table>

Return:

<table>
<thead>
<tr>
<th>Return Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>OK</td>
</tr>
<tr>
<td>0</td>
<td>failed</td>
</tr>
</tbody>
</table>

Description:

load certification into the SSL

Example:
void example(void)
{
    int ret;
    SSL *ssl;
    const unsigned char *buf;
    long len;
    ...
    ret = SSL_use_certificate_ASN1(ssl, len, buf);
}

4.12 X509\* SSL_get_peer_certificate (const SSL\* ssl)

Arguments:

ssl - SSL point

Return:

peer certification

Description:

get peer certification

Example:

void example(void)
{
    SSL *ssl;
    X509 *peer;
    ...
    peer = SSL_get_peer_certificate(ssl);
}

2.4.5 ESP HTTP Client

Overview

esp_http_client provides an API for making HTTP/S requests from ESP-IDF applications. The steps to use this API are as follows:

• esp_http_client_init(): Creates an esp_http_client_config_t instance i.e. a 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 until 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 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.

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_ENABLEHTTPS` (enabled by default).

**Note:** While making HTTPS requests, if server verification is needed, additional root certificate (in PEM format) needs to be provided to the `cert_pem` member in `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. (Implementation details of the above note are found here)

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 1 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 2 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,
};
```

API Reference

Header File

- components/esp_http_client/include/esp_http_client.h

Functions

```c
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 a 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.

**Return**

- esp_http_client_handle_t
- NULL if any errors

**Parameters**

- [in] config: The configurations, see http_client_config_t

```c
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 API performs request 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 invocations 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.

**Return**
- ESP_OK on successful
- ESP_FAIL on error

**Parameters**
- client: The esp_http_client handle

```c
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.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- [in] client: The esp_http_client handle
- [in] url: The url

```c
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.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- [in] client: The esp_http_client handle
- [in] data: post data pointer
- [in] len: post length

```c
int esp_http_client_get_post_field (esp_http_client_handle_t client, char **data)
```
Get current post field information.

**Return** Size of post data

**Parameters**
- [in] client: The client
- [out] data: Point to post data pointer

```c
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.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- [in] client: The esp_http_client handle
- [in] key: The header key
- [in] value: The header value

```c
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`.

**Return**
- ESP_OK
- ESP_FAIL

**Parameters**
- [in] client: The esp_http_client handle
- [in] key: The header key
- [out] value: The header value

```c
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`.

**Return**
- ESP_OK
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] client: The esp_http_client handle
- [out] value: The username value

```c
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.

**Return**
- ESP_OK
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] client: The esp_http_client handle
- [in] username: The username value

```c
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`.

**Return**
- ESP_OK
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] client: The esp_http_client handle
- [out] value: The password value

```c
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.

**Return**
- ESP_OK
- ESP_ERR_INVALID_ARG

**Parameters**
- [in] client: The esp_http_client handle
- [in] password: The password value

```c
esp_err_t esp_http_client_set_authtype(esp_http_client_handle_t client, esp_http_client_auth_type_t auth_type)
```

Set http request auth_type.

**Return**
- ESP_OK
- ESP_ERR_INVALID_ARG
Parameters
- \([\text{in}]\) client: The esp_http_client handle
- \([\text{in}]\) auth_type: The esp_http_client auth type

\textbf{int esp_http_client_get_errno (esp_http_client_handle_t client)}

Get HTTP client session errno.

\textbf{Return}
- (-1) if invalid argument
- errno

\textbf{Parameters}
- \([\text{in}]\) client: The esp_http_client handle

\textbf{esp_err_t esp_http_client_set_method (esp_http_client_handle_t client, esp_http_client_method_t method)}

Set http request method.

\textbf{Return}
- ESP_OK
- ESP_ERR_INVALID_ARG

\textbf{Parameters}
- \([\text{in}]\) client: The esp_http_client handle
- \([\text{in}]\) method: The method

\textbf{esp_err_t esp_http_client_set_timeout_ms (esp_http_client_handle_t client, int timeout_ms)}

Set http request timeout.

\textbf{Return}
- ESP_OK
- ESP_ERR_INVALID_ARG

\textbf{Parameters}
- \([\text{in}]\) client: The esp_http_client handle
- \([\text{in}]\) timeout_ms: The timeout value

\textbf{esp_err_t esp_http_client_delete_header (esp_http_client_handle_t client, const char* key)}

Delete http request header.

\textbf{Return}
- ESP_OK
- ESP_FAIL

\textbf{Parameters}
- \([\text{in}]\) client: The esp_http_client handle
- \([\text{in}]\) key: The key

\textbf{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.

\textbf{Return}
- ESP_OK
- ESP_FAIL

\textbf{Parameters}
- \([\text{in}]\) client: The esp_http_client handle
- \([\text{in}]\) write_len: HTTP Content length need to write to the server

\textbf{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().

\textbf{Return}
- (-1) if any errors
- Length of data written

\textbf{Parameters}
- \([\text{in}]\) client: The esp_http_client handle
- buffer: The buffer
Chapter 2. API Reference

- [in] len: This value must not be larger than the write_len parameter provided to esp_http_client_open()

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.

Return
- (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
- Download data length defined by content-length header

Parameters
- [in] client: The esp_http_client handle

bool esp_http_client_is_chunked_response (esp_http_client_handle_t client)

Check response data is chunked.

Return true or false

Parameters
- [in] client: The esp_http_client handle

int esp_http_client_read (esp_http_client_handle_t client, char* buffer, int len)

Read data from http stream.

Return
- (-1) if any errors
- Length of data was read

Parameters
- [in] client: The esp_http_client handle
- buffer: The buffer
- [in] len: The length

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

Return Status code

Parameters
- [in] client: The esp_http_client handle

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

Return
- (-1) Chunked transfer
- Content-Length value as bytes

Parameters
- [in] client: The esp_http_client handle

esp_err_t esp_http_client_close (esp_http_client_handle_t client)

Close http connection, still kept all http request resources.

Return
- ESP_OK
- ESP_FAIL

Parameters
- [in] client: The esp_http_client handle

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.

Return
API Reference

- ESP_OK
- ESP_FAIL

**Parameters**

- [in] client: The esp_http_client handle

 construed to ESP_OK or ESP_FAIL.

**esp_http_client_transport_t esp_http_client_get_transport_type (esp_http_client_handle_t client)**

Get transport type.

**Return**

- HTTP_TRANSPORT_UNKNOWN
- HTTP_TRANSPORT_OVER_TCP
- HTTP_TRANSPORT_OVER_SSL

**Parameters**

- [in] client: The esp_http_client handle

**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.

**Return**

- ESP_OK
- ESP_FAIL

**Parameters**

- [in] client: The esp_http_client handle

**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**

- [in] client: The esp_http_client handle

**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.

**Return**

- true
- false

**Parameters**

- [in] client: The esp_http_client handle

**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.

**Return**

- Length of data was read

**Parameters**

- [in] client: The esp_http_client handle
- buffer: The buffer
- [in] len: The buffer length

**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 preferrable to esp_http_client_read_response in situations where the content of the response may be ignored.

**Return**

- 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

Parameters
• [in] client: The esp_http_client handle
• len: Length of data discarded

esp_err_t esp_http_client_get_url (esp_http_client_handle_t client, char *url, const int len)
Get URL from client.

Return
• ESP_OK
• ESP_FAIL

Parameters
• [in] client: The esp_http_client handle
• [inout] url: The buffer to store URL
• [in] len: The buffer length

esp_err_t esp_http_client_get_chunk_length (esp_http_client_handle_t client, int *len)
Get Chunk-Length from client.

Return
• 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

Parameters
• [in] client: The esp_http_client handle
• [out] len: Variable to store length

Structures

struct esp_http_client_event
HTTP Client events data.

Public Members

esp_http_client_event_id_t event_id
event_id, to know the cause of the event

esp_http_client_handle_t client
esp_http_client_handle_t context

void *data
data of the event

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_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

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 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:

HTTP_EVENT_ERROR = 0
This event occurs when there are any errors during execution

HTTP_EVENT_ON_CONNECTED
Once the HTTP has been connected to the server, no data exchange has been performed

HTTP_EVENT_HEADERS_SENT
After sending all the headers to the server

HTTP_EVENT_HEADER_SENT = HTTP_EVENT_HEADERS_SENT
This header has been kept for backward compatibility and will be deprecated in future versions esp-idf

HTTP_EVENT_ON_HEADER
Occurs when receiving each header sent from the server

HTTP_EVENT_ON_DATA
Occurs when receiving data from the server, possibly multiple portions of the packet

HTTP_EVENT_ON_FINISH
Occurs when finish a HTTP session

HTTP_EVENT_DISCONNECTED
The connection has been disconnected

HTTP_EVENT_REDIRECT
Intercepting HTTP redirects to handle them manually

enum esp_http_client_transport_t

HTTP Client transport.

Values:

HTTP_TRANSPORT_UNKNOWN = 0x0
Unknown

HTTP_TRANSPORT_OVER_TCP
Transport over tcp

HTTP_TRANSPORT_OVER_SSL
Transport over ssl

enum esp_http_client_method_t

HTTP method.

Values:

HTTP_METHOD_GET = 0
HTTP GET Method

HTTP_METHOD_POST
HTTP POST Method

HTTP_METHOD_PUT
HTTP PUT Method
HTTP_METHOD_PATCH
    HTTP PATCH Method

HTTP_METHOD_DELETE
    HTTP DELETE Method

HTTP_METHOD_HEAD
    HTTP HEAD Method

HTTP_METHOD_NOTIFY
    HTTP NOTIFY Method

HTTP_METHOD_SUBSCRIBE
    HTTP SUBSCRIBE Method

HTTP_METHOD_UNSUBSCRIBE
    HTTP UNSUBSCRIBE Method

HTTP_METHOD_OPTIONS
    HTTP OPTIONS Method

HTTP_METHOD_COPY
    HTTP COPY Method

HTTP_METHOD.Move
    HTTP MOVE Method

HTTP_METHOD_LOCK
    HTTP LOCK Method

HTTP_METHOD_UNLOCK
    HTTP UNLOCK Method

HTTP_METHOD_PROPFIND
    HTTP PROPFIND Method

HTTP_METHOD_PROPPATCH
    HTTP PROPPATCH Method

HTTP_METHOD_MKCOL
    HTTP MKCOL Method

HTTP_METHOD_MAX

enum esp_http_client_auth_type_t
    HTTP Authentication type.

    Values:

    HTTP_AUTH_TYPE_NONE = 0
        No authentication

    HTTP_AUTH_TYPE_BASIC
        HTTP Basic authentication

    HTTP_AUTH_TYPE_DIGEST
        HTTP Digest authentication

enum HttpStatus_Code
    Enum for the HTTP status codes.

    Values:

    HttpStatus_Ok = 200
    HttpStatus_MultipleChoices = 300
    HttpStatus_MovedPermanently = 301
    HttpStatus_Found = 302
HttpStatus_TemporaryRedirect = 307
HttpStatus_BadRequest = 400
HttpStatus_Unauthorized = 401
HttpStatus_Forbidden = 403
HttpStatus_NotFound = 404
HttpStatus_InternalError = 500

2.4.6 HTTP Server

Overview

The HTTP Server component provides an ability for running a lightweight web server on ESP32-S3. 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);
}
```
(continues on next page)
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

HTTP server provides a simple websocket support if the feature is enabled in menuconfig, please see CONFIG_HTTPD_WS_SUPPORT. Please check the example under protocols/http_server/ws_echo_server

API Reference

Header File

- components/esp_http_server/include/esp_http_server.h
Functions

```c
esp_err_t httpd_register_uri_handler(httpd_handle_t handle, const httpd_uri_t *uri_handler)
```

Registers a URI handler.

Example usage:

```c
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;
}
```

```c
// URI handler structure
httpd_uri_t my_uri {
    .uri = "/my_uri/path/xyz",
    .method = HTTPD_GET,
    .handler = my_uri_handler,
    .user_ctx = NULL
};
```

```c
// Register handler
if (httpd_register_uri_handler(server_handle, &my_uri) != ESP_OK) {
    // If failed to register handler
    ....
}
```

Note: URI handlers can be registered in real time as long as the server handle is valid.

Return:
- 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

Parameters:
- [in] handle: handle to HTTPD server instance
- [in] uri_handler: pointer to handler that needs to be registered

```c
esp_err_t httpd_unregister_uri_handler(httpd_handle_t handle, const char *uri, httpd_method_t method)
```

Unregister a URI handler.

Return:
- 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

Parameters:
- [in] handle: handle to HTTPD server instance
- [in] uri: URI string
- [in] method: HTTP method

```c
esp_err_t httpd_unregister_uri(httpd_handle_t handle, const char *uri)
```

Unregister all URI handlers with the specified uri string.
Return

• 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

Parameters

• [in] handle: handle to HTTPD server instance
• [in] uri: uri string specifying all handlers that need to be deregistered

\[ \text{esp_err_t } \text{httpd_sess_set_recv_override}(\text{httpd_handle_t } \text{hd}, \text{ int sockfd, httpd_recv_func_t recv_func}) \]

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()

Return

• ESP_OK : On successfully registering override
• ESP_ERR_INVALID_ARG : Null arguments

Parameters

• [in] hd: HTTPD instance handle
• [in] sockfd: Session socket FD
• [in] recv_func: The receive function to be set for this session

\[ \text{esp_err_t } \text{httpd_sess_set_send_override}(\text{httpd_handle_t } \text{hd}, \text{ int sockfd, httpd_send_func_t send_func}) \]

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()

Return

• ESP_OK : On successfully registering override
• ESP_ERR_INVALID_ARG : Null arguments

Parameters

• [in] hd: HTTPD instance handle
• [in] sockfd: Session socket FD
• [in] send_func: The send function to be set for this session

\[ \text{esp_err_t } \text{httpd_sess_set_pending_override}(\text{httpd_handle_t } \text{hd}, \text{ int sockfd, httpd_pending_func_t pending_func}) \]

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()

Return

• ESP_OK : On successfully registering override
• ESP_ERR_INVALID_ARG : Null arguments

Parameters

• [in] hd: HTTPD instance handle
• [in] sockfd: Session socket FD
• [in] pending_func: The receive function to be set for this session

\[ \text{int } \text{httpd_req_to_sockfd}(\text{httpd_req_t } *r) \]

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.

**Return**
- Socket descriptor : The socket descriptor for this request
- -1 : Invalid/NULL request pointer

**Parameters**
- [in] r: The request whose socket descriptor should be found

```c
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

**Return**
- 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()

**Parameters**
- [in] r: The request being responded to
- [in] buf: Pointer to a buffer that the data will be read into
- [in] buf_len: Length of the buffer

```c
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 its 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.

**Return**
- Length : If field is found in the request URL
- Zero : Field not found / Invalid request / Null arguments

**Parameters**
- [in] r: The request being responded to
- [in] field: The header field to be searched in the request

```c
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.
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- 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

**Return**
- 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

**Parameters**
- [in] `r`: The request being responded to
- [in] `field`: The field to be searched in the header
- [out] `val`: Pointer to the buffer into which the value will be copied if the field is found
- [in] `val_size`: Size of the user buffer

```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

**Return**
- `Length`: Query is found in the request URL
- `Zero`: Query not found / Null arguments / Invalid request

**Parameters**
- [in] `r`: The request being responded to

```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

**Return**
- 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

**Parameters**
- [in] `r`: The request being responded to
- [out] `buf`: Pointer to the buffer into which the query string will be copied (if found)
- [in] `buf_len`: Length of output buffer

```c
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 URL decoded. 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.
### Chapter 2. API Reference

#### Return
- **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

#### Parameters
- **[in]** `qry`: Pointer to query string
- **[in]** `key`: The key to be searched in the query string
- **[out]** `val`: Pointer to the buffer into which the value will be copied if the key is found
- **[in]** `val_size`: Size of the user buffer

```c
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.

#### Return
- **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

#### Parameters
- **[in]** `req`: Pointer to the HTTP request
- **[in]** `cookie_name`: The cookie name to be searched in the request
- **[out]** `val`: Pointer to the buffer into which the value of cookie will be copied if the cookie is found
- **[inout]** `val_size`: Pointer to size of the user buffer

```c
bool httpd_uri_matchWildcard(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.

#### Return
true if a match was found

#### Parameters
- **[in]** `uri_template`: URI template (pattern)
- **[in]** `uri_to_match`: URI to be matched
- **[in]** `match_upto`: how many characters of the URI buffer to test (there may be trailing query string etc.)

```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.

Return

- 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

Parameters

- [in] r: The request being responded to
- [in] buf: Buffer from where the content is to be fetched
- [in] buf_len: Length of the buffer, HTTPD_RESP_USE_STRLEN to use strlen()

```
static 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 httpd_resp_send with buffer length set to string length assuming the buffer contains a null terminated string.

Return

- 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

Parameters

- [in] r: The request being responded to
- [in] str: String to be sent as response body
static 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

Return

• 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

Parameters

• [in] r: The request being responded to
• [in] str: String to be sent as response body (NULL to finish response packet)

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.

Return

• ESP_OK : On success
• ESP_ERR_INVALID_ARG : Null arguments
• ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

Parameters

• [in] r: The request being responded to
• [in] status: The HTTP status code of this response

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.

Return

• ESP_OK : On success
• ESP_ERR_INVALID_ARG : Null arguments
• ESP_ERR_HTTPD_INVALID_REQ : Invalid request pointer

Parameters

• [in] r: The request being responded to
• [in] type: The Content Type of the response

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.

Return
• 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

Parameters
• [in] r: The request being responded to
• [in] field: The field name of the HTTP header
• [in] value: The value of this HTTP header

`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.

Return
• 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

Parameters
• [in] req: Pointer to the HTTP request for which the response needs to be sent
• [in] error: Error type to send
• [in] msg: Error message string (pass NULL for default message)

static `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.

Return
• 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

Parameters
• [in] r: The request being responded to

static `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.
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Once this API is called, all request headers are purged, so request headers need be copied into separate buffers if they are required later.

**Return**
- 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

**Parameters**
- [in] r: The request being responded to

---

**static 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.

**Return**
- 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

**Parameters**
- [in] r: The request being responded to

---

**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 delimeters (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()

**Return**
- Bytes : Number of bytes that were 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()

**Parameters**
- [in] r: The request being responded to
- [in] buf: Buffer from where the fully constructed packet is to be read
- [in] buf_len: Length of the buffer

---

**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.

**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()

**Parameters**
- `[in] hd`: server instance
- `[in] sockfd`: session socket file descriptor
- `[in] buf`: buffer with bytes to send
- `[in] buf_len`: data size
- `[in] flags`: flags for the send() function

```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.

**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()

**Parameters**
- `[in] hd`: server instance
- `[in] sockfd`: session socket file descriptor
- `[in] buf`: buffer with bytes to send
- `[in] buf_len`: data size
- `[in] flags`: flags for the send() function

```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.

**Return**
- **ESP_OK**: handler registered successfully
- **ESP_ERR_INVALID_ARG**: invalid error code or server handle

**Parameters**
- `[in] handle`: HTTP server handle
- `[in] error`: Error type
- `[in] handler_fn`: User implemented handler function (Pass NULL to unset any previously set handler)

```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:

```c
// 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
```

(continues on next page)
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;
}

Return
• 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

Parameters
• [in] config: Configuration for new instance of the server
• [out] handle: Handle to newly created instance of the server. NULL on error

esp_err_t httpd_stop(httpd_handle_t handle)

Stop 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);
    }
}

Return
• ESP_OK : Server stopped successfully
• ESP_ERR_INVALID_ARG : Handle argument is Null

Parameters
• [in] handle: Handle to server returned by httpd_start

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.

Return
• ESP_OK : On successfully queueing the work
• ESP_FAIL : Failure in ctrl socket
• ESP_ERR_INVALID_ARG : Null arguments

Parameters
• [in] handle: Handle to server returned by httpd_start
• [in] work: Pointer to the function to be executed in the HTTPD’s context
• [in] arg: Pointer to the arguments that should be passed to this function
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.

Return
• void*: Pointer to the context associated with this session
• NULL: Empty context / Invalid handle / Invalid socket fd

Parameters
• [in] handle: Handle to server returned by httpd_start
• [in] sockfd: The socket descriptor for which the context should be extracted.

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
• [in] handle: Handle to server returned by httpd_start
• [in] sockfd: The socket descriptor for which the context should be extracted.
• [in] ctx: Context object to assign to the session
• [in] free_fn: Function that should be called to free the context

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 httpd_sess_get_ctx()

Return
• void*: Pointer to the transport context associated with this session
• NULL: Empty context / Invalid handle / Invalid socket fd

Parameters
• [in] handle: Handle to server returned by httpd_start
• [in] sockfd: The socket descriptor for which the context should be extracted.

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 httpd_sess_set_ctx()

Parameters
• [in] handle: Handle to server returned by httpd_start
• [in] sockfd: The socket descriptor for which the context should be extracted.
• [in] ctx: Transport context object to assign to the session
• [in] free_fn: Function that should be called to free the transport context

void *httpd_get_global_user_ctx (httpd_handle_t handle)
Get HTTPD global user context (it was set in the server config struct)

Return global user context

Parameters
• [in] handle: Handle to server returned by httpd_start

void *httpd_get_global_transport_ctx (httpd_handle_t handle)
Get HTTPD global transport context (it was set in the server config struct)

Return global transport context

Parameters
• [in] handle: Handle to server returned by httpd_start

esp_err_t httpd_sess_trigger_close (httpd_handle_t handle, int sockfd)
Trigger an httpd session close externally.
Chapter 2. API Reference

**Note** Calling this API is only required in special circumstances wherein some application requires to close an httpd client session asynchronously.

**Return**
- 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

**Parameters**
- **handle** [in]: Handle to server returned by httpd_start
- **sockfd** [in]: The socket descriptor of the session to be closed

```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.

**Return**
- ESP_OK : Socket found and LRU counter updated
- ESP_ERR_NOT_FOUND : Socket not found
- ESP_ERR_INVALID_ARG : Null arguments

**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

```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.

**Note** Size of provided array has to be equal or greater than maximum number of opened sockets, configured upon initialization with max_open_sockets field in httpd_config_t structure.

**Return**
- ESP_OK : Successfully retrieved session list
- ESP_ERR_INVALID_ARG : Wrong arguments or list is longer than provided array

**Parameters**
- **handle** [in]: Handle to server returned by httpd_start
- **fds** [inout]: In: Size of provided client_fds array Out: Number of valid client fds returned in client_fds,
- **client_fds** [out]: Array of client fds

**Structures**

```c
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**

```c
unsigned task_priority
```

Priority of FreeRTOS task which runs the server

```c
size_t stack_size
```

The maximum stack size allowed for the server task
Chapter 2. API Reference

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

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

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 (*handler)(httpd_req_t *r)
   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
HTTPD_DEFAULT_CONFIG()
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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
HTTPRequest 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.

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

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()

Parameters
- [in] hd: server instance
- [in] sockfd: session socket file descriptor
- [in] buf: buffer with bytes to send
- [in] buf_len: data size
- [in] flags: flags for the send() function

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

Return
- Bytes : The number of bytes received successfully
- 0 : Buffer length parameter is zero / connection closed by peer

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• 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()

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor
• [in] buf: buffer with bytes to send
• [in] buf_len: data size
• [in] flags: flags for the send() function

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.

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()

Parameters
• [in] hd: server instance
• [in] sockfd: session socket file descriptor

typedef esp_err_t (*httpd_err_handler_func_t)(httpd_req_t *req, httpd_err_code_t error)
Function prototype for HTTP error handling.

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.

Return
• ESP_OK: error handled successful
• ESP_FAIL: failure indicates that the underlying socket needs to be closed

Parameters
• [in] req: HTTP request for which the error needs to be handled
• [in] error: Error type

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)

Parameters
• [in] ctx: 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.

**Return**
- ESP_OK: On success
- Any value other than ESP_OK will signal the server to close the socket immediately

**Parameters**
- [in] hd: server instance
- [in] sockfd: session socket file descriptor

```c
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.

**Parameters**
- [in] hd: server instance
- [in] sockfd: session socket file descriptor

```c
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.

**Return** true on match

**Parameters**
- [in] reference_uri: URI/template with respect to which the other URI is matched
- [in] uri_to_match: URI/template being matched to the reference URI/template
- [in] match_upto: 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)

```c
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.

```c
typedef void (*httpd_work_fn_t) (void *arg)
```
Prototype of the HTTPD work function Please refer to httpd_queue_work() for more details.

**Parameters**
- [in] arg: The arguments for this work function

**Enumerations**

```c
eenum httpd_err_code_t
```
Error codes sent as HTTP response in case of errors encountered during processing of an HTTP request.

**Values:**
- HTTPD_500_INTERNAL_SERVER_ERROR = 0
- HTTPD_501_METHOD_NOT_IMPLEMENTED
- HTTPD_505_VERSION_NOT_SUPPORTED
- HTTPD_400_BAD_REQUEST
- HTTPD_401_UNAUTHORIZED
- HTTPD_403_FORBIDDEN
- HTTPD_404_NOT_FOUND
- HTTPD_405_METHOD_NOT_ALLOWED
- HTTPD_408_REQ_TIMEOUT
- HTTPD_411_LENGTH_REQUIRED
HTTPD_414_URI_TOO_LONG
HTTPD_431_REQ_HDR_FIELDS_TOO_LARGE
HTTPD_ERR_CODE_MAX

2.4.7 HTTPS server

Overview

This component is built on top of esp_http_server. The HTTPS server takes advantage of hooks and function overrides in the regular HTTP server to provide encryption using OpenSSL.

All documentation for esp_http_server applies also to a server you create this way.

Used APIs

The following API of esp_http_server should not be used with esp_https_server, as they are used internally to handle secure sessions and to maintain internal state:

- “send”, “receive” and “pending” function overrides - 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_t.global_transport_ctx
  - httpd_config_t.global_transport_ctx_free_fn
  - httpd_config_t.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 in the firmware, and provide its pointers and lengths to the start function via 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 speeds 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)

**Return** success

**Parameters**

- [inout] `config`: server config, must not be const. Does not have to stay valid after calling this function.
- [out] `handle`: storage for the server handle, must be a valid pointer

*void* `httpd_ssl_stop (httpd_handle_t handle)`

Stop the server. Blocks until the server is shut down.

**Parameters**

- [in] `handle`:

**Structures**

*struct esp_https_server_user_cb_arg*

Callback data struct, contains the 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

*esp_https_server_user_cb * `user_cb`

User callback for esp_https_server
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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

```c
typedef struct esp_https_server_user_cb_arg esp_https_server_user_cb_arg_t
Callback data struct, contains the ESP-TLS connection handle.
```

```c
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.
```

Parameters

- `user_cb`: Callback data struct

```c
typedef struct httpd_ssl_config httpd_ssl_config_t
```

Enumerations

```c
enum httpd_ssl_transport_mode_t
```

Values:

- HTTPD_SSL_TRANSPORT_SECURE
- HTTPD_SSL_TRANSPORT_INSECURE

### 2.4.8 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 util `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:
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);
}

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 sockaddr_in addr4 = ((struct sockaddr_in *) (res->ai_addr))->sin_addr;
    inet_addr_to_ip4addr(&target_addr.u_addr.ip4, &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
}
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(continued from previous page)

```c
/* 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,
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

```c
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.
```

Return

- `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

Parameters

- `config`: ping configuration
- `cbs`: a bunch of callback functions invoked by internal ping task
- `hdl_out`: handle of ping session

```c
esp_err_t esp_ping_delete_session(esp_ping_handle_t hdl)
Delete a ping session.
```

Return

- `ESP_ERR_INVALID_ARG`: invalid parameters (e.g. ping handle is null, etc)
- `ESP_OK`: delete ping session successfully
**Chapter 2. API Reference**

### Parameters
- **hdl**: handle of ping session

#### esp_err_t esp_ping_start (esp_ping_handle_t hdl)
Start the ping session.

**Return**
- ESP_ERR_INVALID_ARG: invalid parameters (e.g. ping handle is null, etc)
- ESP_OK: start ping session successfully

#### Parameters
- **hdl**: handle of ping session

#### esp_err_t esp_ping_stop (esp_ping_handle_t hdl)
Stop the ping session.

**Return**
- ESP_ERR_INVALID_ARG: invalid parameters (e.g. ping handle is null, etc)
- ESP_OK: stop ping session successfully

#### Parameters
- **hdl**: handle of ping session

#### esp_err_t 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.

**Return**
- 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

**Parameters**
- **hdl**: handle of ping session
- **profile**: type of profile
- **data**: profile data
- **size**: profile data size

### Structures

#### struct esp_ping_callbacks_t
Type of “ping” callback functions.

**Public Members**

- void **cb_args**
  arguments for callback functions

  void (*on_ping_success) (esp_ping_handle_t hdl, void *args)
  Invoked by internal ping thread when received ICMP echo reply packet.

  void (*on_ping_timeout) (esp_ping_handle_t hdl, void *args)
  Invoked by internal ping thread when receive ICMP echo reply packet timeout.

  void (*on_ping_end) (esp_ping_handle_t hdl, void *args)
  Invoked by internal ping thread when a ping session is finished.

#### struct esp_ping_config_t
Type of “ping” configuration.

**Public Members**

- uint32_t **count**
  A “ping” session contains count procedures
## Chapter 2. API Reference

### 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:**

  - **ESP_PING_PROF_SEQNO**
    
    Sequence number of a ping procedure
  
  - **ESP_PING_PROF_TTL**
    
    Time to live of a ping procedure
  
  - **ESP_PING_PROF_REQUEST**
    
    Number of request packets sent out
  
  - **ESP_PING_PROF_REPLY**
    
    Number of reply packets received
  
  - **ESP_PING_PROF_IPADDR**
    
    IP address of replied target
  
  - **ESP_PING_PROF_SIZE**
    
    Size of received packet
  
  - **ESP_PING_PROF_TIMEGAP**
    
    Elapsed time between request and reply packet
  
  - **ESP_PING_PROF_DURATION**
    
    Elapsed time of the whole ping session
2.4.9 ESP Local Control

Overview

ESP Local Control (esp_local_ctrl) component in ESP-IDF provides capability to control an ESP device over Wi-Fi + 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 = & (protocom_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 = PROTOCOM_SEC0,
            .custom_handle = NULL,
            .pop = 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 cacert_pem_start[] asm("_binary_cacert_pem_start");
extern const unsigned char cacert_pem_end[] asm("_binary_cacert_pem_end");
https_conf.cacert_pem = cacert_pem_start;
https_conf.cacert_len = cacert_pem_end - cacert_pem_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;
```

(continues on next page)
esp_local_ctrl_config_t config = {
  .transport = ESP_LOCAL_CTRL_TRANSPORT_HTTPD,
  .transport_config = {
    .httpd = &https_conf
  },
  .proto_sec = {
    .version = PROTOCOM_SEC0,
    .custom_handle = NULL,
    .pop = 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_SEC1: specifies that end to end encryption is used.
2. PROTOCOM_SEC0: specifies that data will be exchanged as a plain text.
3. PROTOCOM_SEC_CUSTOM: you can define your own security requirement. Please note that you will also have to provide custom_handle of type protocomm_security_t * in this context.

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) {
            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);
            /* 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>
<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**

```c
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.

Return
- ESP_OK : Success
- ESP_FAIL : Failure

Parameters
- [in] config: Pointer to configuration structure

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`

Return
- ESP_OK : Success
- ESP_FAIL : Failure

Parameters
```
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- [in] prop: Property description structure

```c
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.

Return
- ESP_OK : Success
- ESP_ERR_NOT_FOUND : Failure

Parameters
- [in] name: Name of the property to remove

```c
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

Return
- Pointer to property
- NULL if not found

Parameters
- [in] name: Name of the property to find

```c
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().

Return
- ESP_OK : Success
- ESP_FAIL : Failure

Parameters
- [in] ep_name: Name of the endpoint
- [in] handler: Endpoint handler function
- [in] user_ctx: User data

Unions

```c
union esp_local_ctrl_transport_config_t
#include <esp_local_ctrl.h> Transport mode (BLE/HTTPD) configuration.
```

Public Members

```c
esp_local_ctrl_transport_config_ble_t *ble
```

This is same as protocomm_ble_config_t. See protocomm_ble.h for available configuration parameters.

```c
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

```c
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[], const 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.

**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

**Parameters**

- **[in] props_count**: Total elements in the props array
- **[in] props**: Array of properties, the current values for which have been requested by the client
- **[out] prop_values**: Array of empty property values, the elements of which need to be populated with the current values of those properties specified by props argument
- **[in] usr_ctx**: This provides value of the usr_ctx field of esp_local_ctrl_handlers_t structure

`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.

**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

**Parameters**

- **[in] props_count**: Total elements in the props array
- **[in] props**: Array of properties, the values for which the client requests to change
- **[in] prop_values**: Array of property values, the elements of which need to be used for updating those properties specified by props argument
- **[in] usr_ctx**: This provides value of the usr_ctx field of esp_local_ctrl_handlers_t structure

`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.

`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.

**struct esp_local_ctrl_proto_sec_cfg**

Protocom security configs

**Public Members**

`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

`void *custom_handle`

Custom security handle if security is set custom via proto_sec above This handle must follow protocomm_security_t signature

`void *pop`

Proof of possession to be used for local control. Could be NULL.

**struct esp_local_ctrl_config**

Configuration structure to pass to esp_local_ctrl_start()
Public Members

```c
const esp_local_ctrl_transport_t *transport
    Transport layer over which service will be provided
```  
```c
esp_local_ctrl_transport_config_t transport_config
    Transport layer over which service will be provided
```  
```c
esp_local_ctrl_proto_sec_cfg_t proto_sec
    Security version and POP
```  
```c
esp_local_ctrl_handlers_t handlers
    Register handlers for responding to get/set requests on properties
```  
```c
size_t max_properties
    This limits the number of properties that are available at a time
```  
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.
```  
```c
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.
```  
```c
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.
```  
```c
typedef struct esp_local_ctrl_transport esp_local_ctrl_transport_t
    Transport mode (BLE/HTTPD) over which the service will be provided.
```

```
    This is forward declaration of a private structure, implemented internally by esp_local_ctrl.
```  
```c
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 CON-
    FIG_BT_BLUEDROID_ENABLED and include protocomm_ble.h.
```  
```c
typedef struct httpd_ssl_config esp_local_ctrl_transport_config_httpd_t
    Configuration for transport mode HTTPD.
```

```
    This is a forward declaration for httpd_ssl_config_t. To use this, application must set CON-
    FIG_ESP_HTTPS_SERVER_ENABLE and include esp_https_server.h
```  
```c
typedef enum esp_local_ctrl_proto_sec esp_local_ctrl_proto_sec_t
    Security types for esp_local_control.
```  
```c
typedef struct esp_local_ctrl_proto_sec_cfg esp_local_ctrl_proto_sec_cfg_t
    Protocom security configs
```  
```c
typedef struct esp_local_ctrl_config esp_local_ctrl_config_t
    Configuration structure to pass to esp_local_ctrl_start()
```
### Enumerations

```c
enum esp_local_ctrl_proto_sec
    Security types for esp_local_control.

Values:

- PROTOCOM_SEC0 = 0
- PROTOCOM_SEC1
- PROTOCOM_SEC_CUSTOM
```

### 2.4.10 mDNS Service

#### Overview

mDNS is a multicast UDP service that is used to provide local network service and host discovery.

mDNS is installed by default on most operating systems or is available as separate package. On Mac OS it is installed by default and is called Bonjour. Apple releases an installer for Windows that can be found on Apple’s support page. On Linux, mDNS is provided by avahi and is usually installed by default.

#### mDNS Properties

- **hostname**: the hostname that the device will respond to. If not set, the hostname will be read from the interface. Example: my-esp32s3 will resolve to my-esp32s3.local
- **default_instance**: friendly name for your device, like Jhon's ESP32-S3 Thing. If not set, hostname will be used.

Example method to start mDNS for the STA interface and set hostname and default_instance:

```c
void start_mdns_service()
{
    //initialize mDNS service
    esp_err_t err = mdns_init();
    if (err) {
        printf("MDNS Init failed: %d\n", err);
        return;
    }

    //set hostname
    mdns_hostname_set("my-esp32s3");
    //set default instance
    mdns_instance_name_set("Jhon's ESP32-S3 Thing");
}
```

#### mDNS Services

mDNS can advertise information about network services that your device offers. Each service is defined by a few properties.

- **instance_name**: friendly name for your service, like Jhon's ESP32-S3 Web Server. If not defined, default_instance will be used.
- **service_type**: (required) service type, prepended with underscore. Some common types can be found here.
- **proto**: (required) protocol that the service runs on, prepended with underscore. Example: _tcp or _udp
- **port**: (required) network port that the service runs on
- **txt**: \{var, val\} array of strings, used to define properties for your service

Example method to add a few services and different properties:
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```c
void add_mdns_services()
{
    // add our services
    mdns_service_add(NULL, "_http", "_tcp", 80, NULL, 0);
    mdns_service_add(NULL, "_arduino", "_tcp", 3232, NULL, 0);
    mdns_service_add(NULL, "_myservice", "_udp", 1234, NULL, 0);

    // NOTE: services must be added before their properties can be set
    // use custom instance for the web server
    mdns_service_instance_name_set("_http", "_tcp", "Jhon's ESP32-S3 Web Server");

    mdns_txt_item_t serviceTxtData[3] = {
        {"board", "esp32s3"},
        {"u", "user"},
        {"p", "password"}
    };
    // set txt data for service (will free and replace current data)
    mdns_service_txt_set("_http", "_tcp", serviceTxtData, 3);

    // change service port
    mdns_service_port_set("_myservice", "_udp", 4321);
}
```

**mDNS Query**

mDNS provides methods for browsing for services and resolving host’s IP/IPv6 addresses.

Results for services are returned as a linked list of `mdns_result_t` objects.

Example method to resolve host IPs:

```c
void resolve_mdns_host(const char * host_name)
{
    printf("Query A: %s.local\n", host_name);

    struct ip4_addr addr;
    addr.addr = 0;

    esp_err_t err = mdns_query_a(host_name, 2000, &addr);
    if(err){
        if(err == ESP_ERR_NOT_FOUND){
            printf("Host was not found!\n");
            return;
        }
        printf("Query Failed\n");
        return;
    }

    printf(IPSTR, IP2STR(&addr));
}
```

Example method to resolve local services:

```c
static const char * if_str[] = {"STA", "AP", "ETH", "MAX"};
static const char * ip_protocol_str[] = {"V4", "V6", "MAX"};

void mdns_print_results(mdns_result_t * results){
    mdns_result_t * r = results;
    mdns_ip_addr_t * a = NULL;
    int i = 1, t;
    while(r){
        printf("%d: Interface: %s, Type: %s\n", i++, if_str[r->tcpip_if], ip_protocol_str[r->ip_protocol]);
    }
}
```

(continues on next page)
```c
if(r->instance_name){
    printf(" PTR : %s\n", r->instance_name);
}
if(r->hostname){
    printf(" SRV : %s.local:%u\n", r->hostname, r->port);
}
if(r->txt_count){
    printf(" TXT : [%u] \n", r->txt_count);
    for(t=0; t<r->txt_count; t++){
        printf("%s=%s; ", r->txt[t].key, r->txt[t].value);
    }
    printf("\n");
}
}
a = r->addr;
while(a){
    if(a->addr.type == IPADDR_TYPE_V6){
        printf(" AAAA: " IPV6STR "\n", IPV62STR(a->addr.u_addr.ip6));
    } else {
        printf(" A : " IPSTR "\n", IP2STR(&a->addr.u_addr.ip4));
    }
    a = a->next;
} r = r->next;

void find_mdns_service(const char * service_name, const char * proto)
{
    ESP_LOGI(TAG, "Query PTR: %s.%s.local\n", service_name, proto);
    mdns_result_t * results = NULL;
    esp_err_t err = mdns_query_ptr(service_name, proto, 3000, 20, &results);
    if(err){
        ESP_LOGE(TAG, "Query Failed");
        return;
    }
    if(!results){
        ESP_LOGW(TAG, "No results found!");
        return;
    }
    mdns_print_results(results);
    mdns_query_results_free(results);
}
```

Example of using the methods above:

```c
void my_app_some_method(){
    //search for esp32s3-mdns.local
    resolve_mdns_host("esp32s3-mdns");

    //search for HTTP servers
    find_mdns_service("_http", "_tcp");
    //or file servers
    find_mdns_service("_smb", "_tcp"); //windows sharing
    find_mdns_service("_afpovertcp", "_tcp"); //apple sharing
    find_mdns_service("_nfs", "_tcp"); //NFS server
    find_mdns_service("_ftp", "_tcp"); //FTP server
    //or networked printer
    find_mdns_service("_printer", "_tcp");
}
```
find_mdns_service("_ipp", "_tcp");
}

Application Example

mDNS server/scanner example: protocols/mdns.

API Reference

Header File

- components/mdns/include/mdns.h

Functions

```c
esp_err_t mdns_init(void)
{
  Initialize mDNS on given interface.

  Return
  • ESP_OK on success
  • ESP_ERR_INVALID_STATE when failed to register event handler
  • ESP_ERR_NO_MEM on memory error
  • ESP_FAIL when failed to start mdns task

void mdns_free(void)
{
  Stop and free mDNS server.
}

esp_err_t mdns_hostname_set(const char* hostname)
{
  Set the hostname for mDNS server required if you want to advertise services.

  Return
  • ESP_OK success
  • ESP_ERR_INVALID_ARG Parameter error
  • ESP_ERR_NO_MEM memory error

Parameters
  • hostname: Hostname to set

esp_err_t mdns_delegate_hostname_add(const char *hostname, const mdns_ip_addr_t *address_list)
{
  Adds a hostname and address to be delegated A/AAAA queries will be replied for the hostname and services can be added to this host.

  Return
  • ESP_OK success
  • ESP_ERR_INVALID_STATE mDNS is not running
  • ESP_ERR_INVALID_ARG Parameter error
  • ESP_ERR_NO_MEM memory error

Parameters
  • hostname: Hostname to add
  • address_list: The IP address list of the host

esp_err_t mdns_delegate_hostname_remove(const char *hostname)
{
  Remove a delegated hostname All the services added to this host will also be removed.

  Return
  • ESP_OK success
  • ESP_ERR_INVALID_STATE mDNS is not running
  • ESP_ERR_INVALID_ARG Parameter error
  • ESP_ERR_NO_MEM memory error

Parameters
```
Chapter 2. API Reference

- hostname: Hostname to remove

bool mdns_hostname_exists(const char *hostname)

Query whether a hostname has been added.

Return
- true The hostname has been added.
- false The hostname has not been added.

Parameters
- hostname: Hostname to query

esp_err_t mdns_instance_name_set(const char *instance_name)

Set the default instance name for mDNS server.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM memory error

Parameters
- instance_name: Instance name to set

esp_err_t mdns_service_add(const char *instance_name, const char *service_type, const char *proto, uint16_t port, mdns_txt_item_t txt[], size_t num_items)

Add service to mDNS server.

Note The value length of txt items will be automatically decided by strlen

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM memory error
- ESP_FAIL failed to add service

Parameters
- instance_name: Instance name to set. If NULL, global instance name or hostname will be used.
  Note that MDNS_MULTIPLEINSTANCE config option needs to be enabled for adding multiple instances with the same instance type.
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- port: service port
- txt: string array of TXT data (eg. {{"var","val"},{"other","2"}})
- num_items: number of items in TXT data

esp_err_t mdns_service_add_for_host(const char *instance_name, const char *service_type, const char *proto, const char *hostname, uint16_t port, mdns_txt_item_t txt[], size_t num_items)

Add service to mDNS server with a delegated hostname.

Note The value length of txt items will be automatically decided by strlen

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NO_MEM memory error
- ESP_FAIL failed to add service

Parameters
- instance_name: instance name to set. If NULL, global instance name or hostname will be used.
  Note that MDNS_MULTIPLEINSTANCE config option needs to be enabled for adding multiple instances with the same instance type.
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- hostname: service hostname. If NULL, localhostname will be used.
- port: service port
- txt: string array of TXT data (eg. {{"var","val"},{"other","2"}})
- num_items: number of items in TXT data
bool mdns_service_exists (const char *service_type, const char *proto, const char *hostname)
Check whether a service has been added.

Return
- true Corresponding service has been added.
- false Service not found.

Parameters
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- hostname: service hostname. If NULL, checks for the local hostname.

bool mdns_service_exists_with_instance (const char *instance, const char *service_type, const char *proto, const char *hostname)
Check whether a service has been added.

Return
- true Corresponding service has been added.
- false Service not found.

Parameters
- instance: instance name
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- hostname: service hostname. If NULL, checks for the local hostname.

esp_err_t mdns_service_remove (const char *service_type, const char *proto)
Remove service from mDNS server.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

Parameters
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)

esp_err_t mdns_service_remove_for_host (const char *instance, const char *service_type, const char *proto, const char *hostname)
Remove service from mDNS server with hostname.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

Parameters
- instance: instance name
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- hostname: service hostname. If NULL, local hostname will be used.

esp_err_t mdns_service_instance_name_set (const char *service_type, const char *proto, const char *instance_name)
Set instance name for service.

Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

Parameters
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
• instance_name: instance name to set

```c
esp_err_t mdns_service_instance_name_set_for_host(const char *instance_old, const char *service_type, const char *proto, const char *hostname, const char *instance_name)
```

Set instance name for service with hostname.

### Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

### Parameters
- instance_old: original instance name
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- hostname: service hostname. If NULL, local hostname will be used.
- instance_name: instance name to set

```c
esp_err_t mdns_service_port_set(const char *service_type, const char *proto, uint16_t port)
```

Set service port.

### Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

### Parameters
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- port: service port

```c
esp_err_t mdns_service_port_set_for_host(const char *instance, const char *service_type, const char *proto, const char *hostname, uint16_t port)
```

Set service port with hostname.

### Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

### Parameters
- instance: instance name
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
- hostname: service hostname. If NULL, local hostname will be used.
- port: service port

```c
esp_err_t mdns_service_txt_set(const char *service_type, const char *proto, mdns_txt_item_t txt[], uint8_t num_items)
```

Replace all TXT items for service.

### Note
The value length of txt items will be automatically decided by strlen

### Return
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

### Parameters
- service_type: service type (_http, _ftp, etc)
- proto: service protocol (_tcp, _udp)
Chapter 2. API Reference

- **txt**: array of TXT data (e.g., `{{ "var","val" },{ "other","2" }}`)
- **num_items**: number of items in TXT data

```c
esp_err_t mdns_service_txt_set_for_host(const char *instance, const char *service_type, const char *proto, const char *hostname, mdns_txt_item_t txt[], uint8_t num_items)
```

Replace all TXT items for service with hostname.

**Note** The value length of txt items will be automatically decided by `strlen`

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

**Parameters**
- **instance**: instance name
- **service_type**: service type (_http, _ftp, etc)
- **proto**: service protocol (_tcp, _udp)
- **hostname**: service hostname. If NULL, local hostname will be used.
- **txt**: array of TXT data (e.g., `{{ "var","val" },{ "other","2" }}`)
- **num_items**: number of items in TXT data

```c
esp_err_t mdns_service_txt_item_set(const char *service_type, const char *proto, const char *key, const char *value)
```

Set/Add TXT item for service TXT record.

**Note** The value length will be automatically decided by `strlen`

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

**Parameters**
- **service_type**: service type (_http, _ftp, etc)
- **proto**: service protocol (_tcp, _udp)
- **key**: the key that you want to add/update
- **value**: the new value of the key

```c
esp_err_t mdns_service_txt_item_set_with_explicit_value_len(const char *service_type, const char *proto, const char *key, const char *value, uint8_t value_len)
```

Set/Add TXT item for service TXT record.

**Parameters**
- **service_type**: service type (_http, _ftp, etc)
- **proto**: service protocol (_tcp, _udp)
- **key**: the key that you want to add/update
- **value**: the new value of the key
- **value_len**: the length of the value

```c
esp_err_t mdns_service_txt_item_set_for_host(const char *instance, const char *service_type, const char *proto, const char *hostname, const char *key, const char *value)
```

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Set/Add TXT item for service TXT record with hostname.

**Note** The value length will be automatically decided by strlen

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

**Parameters**
- `instance`: instance name
- `service_type`: service type (http, ftp, etc)
- `proto`: service protocol (_tcp, _udp)
- `hostname`: service hostname. If NULL, local hostname will be used.
- `key`: the key that you want to add/update
- `value`: the new value of the key

```c
esp_err_t mdns_service_txt_item_set_for_host_with_explicit_value_len(const char *instance, const char *service_type, const char *proto, const char *hostname, const char *key, const char *value, const uint8_t value_len)
```

Set/Add TXT item for service TXT record with hostname and txt value length.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

**Parameters**
- `instance`: instance name
- `service_type`: service type (_http, _ftp, etc)
- `proto`: service protocol (_tcp, _udp)
- `hostname`: service hostname. If NULL, local hostname will be used.
- `key`: the key that you want to add/update
- `value`: the new value of the key
- `value_len`: the length of the value

```c
esp_err_t mdns_service_txt_item_remove(const char *service_type, const char *proto, const char *key)
```

Remove TXT item for service TXT record.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error
Parameters

- **service_type**: service type (http, ftp, etc)
- **proto**: service protocol (tcp, udp)
- **key**: the key that you want to remove

```c
esp_err_t mdns_service_txt_item_remove_for_host(const char *instance, const char *service_type, const char *proto, const char *hostname, const char *key)
```

Remove TXT item for service TXT record with hostname.

Return

- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

Parameters

- **instance**: instance name
- **service_type**: service type (http, ftp, etc)
- **proto**: service protocol (tcp, udp)
- **hostname**: service hostname. If NULL, localhost name will be used.
- **key**: the key that you want to remove

```c
esp_err_t mdns_service_subtype_add_for_host(const char *instance_name, const char *service_type, const char *proto, const char *hostname, const char *subtype)
```

Add subtype for service.

Return

- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error
- ESP_ERR_NOT_FOUND Service not found
- ESP_ERR_NO_MEM memory error

Parameters

- **instance_name**: instance name. If NULL, will find the first service with the same service type and protocol.
- **service_type**: service type (http, ftp, etc)
- **proto**: service protocol (tcp, udp)
- **hostname**: service hostname. If NULL, local hostname will be used.
- **subtype**: The subtype to add.

```c
esp_err_t mdns_service_remove_all(void)
```

Remove and free all services from mDNS server.

Return

- ESP_OK success
- ESP_ERR_INVALID_ARG Parameter error

```c
esp_err_t mdns_query_async_delete(mdns_search_once_t *search)
```

Deletes the finished query. Call this only after the search has ended!

Return

- ESP_OK success
- ESP_ERR_INVALID_STATE search has not finished
- ESP_ERR_INVALID_ARG pointer to search object is NULL

Parameters

- **search**: pointer to search object

```c
bool mdns_query_async_get_results(mdns_search_once_t *search, uint32_t timeout, mdns_result_t **results, uint8_t *num_results)
```

Get results from search pointer. Results available as a pointer to the output parameter. Pointer to search object has to be deleted via `mdns_query_async_delete` once the query has finished. The results although have to be freed manually.
Return True if search has finished before or at timeout False if search timeout is over

Parameters
• search: pointer to search object
• timeout: time in milliseconds to wait for answers
• results: pointer to the results of the query
• num_results: pointer to the number of the actual result items (set to NULL to ignore this return value)

`mdns_search_once_t *mdns_query_async_new(const char *name, const char *service_type, const char *proto, uint16_t type, uint32_t timeout, size_t max_results, mdns_query_notify_t notifier)`

Query mDNS for host or service asynchronously. Search has to be tested for progress and deleted manually!

Return `mdns_search_once_s` pointer to new search object if query initiated successfully. NULL otherwise.

Parameters
• name: service instance or host name (NULL for PTR queries)
• service_type: service type (http, _arduino, _ftp etc.) (NULL for host queries)
• proto: service protocol (_tcp, _udp, etc.) (NULL for host queries)
• type: type of query (MDNS_TYPE_*)
• timeout: time in milliseconds during which mDNS query is active
• max_results: maximum results to be collected
• notifier: Notification function to be called when the result is ready, can be NULL

`esp_err_t mdns_query_generic(const char *name, const char *service_type, const char *proto, uint16_t type, mdns_query_transmission_type_t transmission_type, uint32_t timeout, size_t max_results, mdns_result_t **results)`

Generic mDNS query. All following query methods are derived from this one.

Return
• ESP_OK success
• ESP_ERR_INVALID_STATE mDNS is not running
• ESP_ERR_NO_MEM memory error
• ESP_ERR_INVALID_ARG timeout was not given

Parameters
• name: service instance or host name (NULL for PTR queries)
• service_type: service type (http, _arduino, _ftp etc.) (NULL for host queries)
• proto: service protocol (_tcp, _udp, etc.) (NULL for host queries)
• type: type of query (MDNS_TYPE_*)
• transmission_type: either Unicast query, or Multicast query
• timeout: time in milliseconds to wait for answers.
• max_results: maximum results to be collected
• results: pointer to the results of the query results must be freed using `mdns_query_results_free` below

`esp_err_t mdns_query(const char *name, const char *service_type, const char *proto, uint16_t type, uint32_t timeout, size_t max_results, mdns_result_t **results)`

Query mDNS for host or service.

Note that querying PTR types sends Multicast query, all other types send Unicast queries

Return
• ESP_OK success
• ESP_ERR_INVALID_STATE mDNS is not running
• ESP_ERR_NO_MEM memory error
• ESP_ERR_INVALID_ARG timeout was not given

Parameters
• name: service instance or host name (NULL for PTR queries)
• service_type: service type (http, _arduino, _ftp etc.) (NULL for host queries)
• proto: service protocol (_tcp, _udp, etc.) (NULL for host queries)
• type: type of query (MDNS_TYPE_*)
• timeout: time in milliseconds to wait for answers.
• max_results: maximum results to be collected
- **results**: pointer to the results of the query results must be freed using `mdns_query_results_free` below

```c
void mdns_query_results_free (mdns_result_t *results)
```

Free query results.

**Parameters**
- **results**: linked list of results to be freed

```c
esp_err_t mdns_query_ptr (const char *service_type, const char *proto, uint32_t timeout, size_t max_results, mdns_result_t **results)
```

Query mDNS for service.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_STATE mDNS is not running
- ESP_ERR_NO_MEM memory error
- ESP_ERR_INVALID_ARG parameter error

**Parameters**
- **service_type**: service type (HTTP, _arduino, _ftp etc.)
- **proto**: service protocol (TCP, UDP, etc.)
- **timeout**: time in milliseconds to wait for answer.
- **max_results**: maximum results to be collected
- **results**: pointer to the results of the query

```c
esp_err_t mdns_query_srv (const char *instance_name, const char *service_type, const char *proto, uint32_t timeout, mdns_result_t **result)
```

Query mDNS for SRV record.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_STATE mDNS is not running
- ESP_ERR_NO_MEM memory error
- ESP_ERR_INVALID_ARG parameter error

**Parameters**
- **instance_name**: service instance name
- **service_type**: service type (HTTP, _arduino, _ftp etc.)
- **proto**: service protocol (TCP, UDP, etc.)
- **timeout**: time in milliseconds to wait for answer.
- **result**: pointer to the result of the query

```c
esp_err_t mdns_query_txt (const char *instance_name, const char *service_type, const char *proto, uint32_t timeout, mdns_result_t **result)
```

Query mDNS for TXT record.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_STATE mDNS is not running
- ESP_ERR_NO_MEM memory error
- ESP_ERR_INVALID_ARG parameter error

**Parameters**
- **instance_name**: service instance name
- **service_type**: service type (HTTP, _arduino, _ftp etc.)
- **proto**: service protocol (TCP, UDP, etc.)
- **timeout**: time in milliseconds to wait for answer.
- **result**: pointer to the result of the query

```c
esp_err_t mdns_query_a (const char *host_name, uint32_t timeout, esp_ip4_addr_t *addr)
```

Query mDNS for A record.

**Return**
- ESP_OK success
- ESP_ERR_INVALID_STATE mDNS is not running
- ESP_ERR_NO_MEM memory error
• ESP_ERR_INVALID_ARG parameter error

Parameters
• host_name: host name to look for
• timeout: time in milliseconds to wait for answer.
• addr: pointer to the resulting IP4 address

```c
esp_err_t mdns_query_aaaa(const char *host_name, uint32_t timeout, esp_ip6_addr_t *addr)
```

Query mDNS for A record.

Please note that hostname must not contain domain name, as mDNS uses ‘.local’ domain.

Return
• ESP_OK success
• ESP_ERR_INVALID_STATE mDNS is not running
• ESP_ERR_NO_MEM memory error
• ESP_ERR_INVALID_ARG parameter error

Parameters
• host_name: host name to look for
• timeout: time in milliseconds to wait for answer. If 0, max_results needs to be defined
• addr: pointer to the resulting IP6 address

```c
esp_err_t mdns_handle_system_event (void *ctx, system_event_t *event)
```

System event handler This method controls the service state on all active interfaces and applications are required to call it from the system event handler for normal operation of mDNS service.

Please note that hostname must not contain domain name, as mDNS uses ‘.local’ domain.

Parameters
• ctx: The system event context
• event: The system event

Structures
```c
struct mdns_txt_item_t
```

mDNS basic text item structure Used in mdns_service_add()

Public Members
```c
const char *key
```
item key name

```c
const char *value
```
item value string

```c
struct mdns_ip_addr_s
```

mDNS query linked list IP item

Public Members
```c
esp_ip_addr_t addr
```
IP address

```c
struct mdns_ip_addr_s *next
```
next IP, or NULL for the last IP in the list

```c
struct mdns_result_s
```

mDNS query result structure

Public Members
```c
struct mdns_result_s *next
```
next result, or NULL for the last result in the list
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```c
mdns_if_t tcpip_if
    interface index

uint32_t ttl
time to live

mdns_ip_protocol_t ip_protocol
    ip_protocol type of the interface (v4/v6)

char *instance_name
    instance name

char *service_type
    service type

char *proto
    service protocol

char *hostname
    hostname

uint16_t port
    service port

mdns_txt_item_t *txt
    txt record

uint8_t *txt_value_len
    array of txt value len of each record

size_t txt_count
    number of txt items

mdns_ip_addr_t *addr
    linked list of IP addresses found
```

**Macros**

- `MDNS_TYPE_A`
- `MDNS_TYPE_PTR`
- `MDNS_TYPE_TXT`
- `MDNS_TYPE_AAAA`
- `MDNS_TYPE_SRV`
- `MDNS_TYPE_OPT`
- `MDNS_TYPE_NSEC`
- `MDNS_TYPE_ANY`

**Type Definitions**

```c
typedef struct mdns_search_once_s mdns_search_once_t
    Asynchronous query handle.

typedef struct mdns_ip_addr_s mdns_ip_addr_t
    mDNS query linked list IP item

typedef enum mdns_if_internal mdns_if_t

typedef struct mdns_result_s mdns_result_t
    mDNS query result structure

typedef void (*mdns_query_notify_t)(mdns_search_once_t *search)
```
Chapter 2. API Reference

Enumerations

`enum mdns_ip_protocol_t`

mDNS enum to specify the ip_protocol type

Values:

- **MDNS_IP_PROTOCOL_V4**
- **MDNS_IP_PROTOCOL_V6**
- **MDNS_IP_PROTOCOL_MAX**

`enum mdns_if_internal`

Values:

- **MDNS_IF_STA** = 0
- **MDNS_IF_AP** = 1
- **MDNS_IF_ETH** = 2
- **MDNS_IF_MAX**

`enum mdns_query_transmission_type_t`

mDNS query type to be explicitly set to either Unicast or Multicast

Values:

- **MDNS_QUERY_UNICAST**
- **MDNS_QUERY_MULTICAST**

2.4.11 ESP-Modbus

Overview

The Modbus serial communication protocol is de facto standard protocol widely used to connect industrial electronic devices. Modbus allows communication among many devices connected to the same network, for example, a system that measures temperature and humidity and communicates the results to a computer. The Modbus protocol uses several types of data: Holding Registers, Input Registers, Coils (single bit output), Discrete Inputs. Versions of the Modbus protocol exist for serial port and for Ethernet and other protocols that support the Internet protocol suite. There are many variants of Modbus protocols, some of them are:

- **Modbus RTU** — This is used in serial communication and makes use of a compact, binary representation of the data for protocol communication. The RTU format follows the commands/data with a cyclic redundancy check checksum as an error check mechanism to ensure the reliability of data. Modbus RTU is the most common implementation available for Modbus. A Modbus RTU message must be transmitted continuously without inter-character hesitations. Modbus messages are framed (separated) by idle (silent) periods. The RS-485 interface communication is usually used for this type.

- **Modbus ASCII** — This is used in serial communication and makes use of ASCII characters for protocol communication. The ASCII format uses a longitudinal redundancy check checksum. Modbus ASCII messages are framed by leading colon (":" ) and trailing newline (CR/LF).

- **Modbus TCP/IP or Modbus TCP** — This is a Modbus variant used for communications over TCP/IP networks, connecting over port 502. It does not require a checksum calculation, as lower layers already provide checksum protection.

The following document (and included code snippets) requires some familiarity with the Modbus protocol. Refer to the Modbus Organization’s with protocol specifications for specifics.

Messaging Model And Data Mapping

Modbus is an application protocol that defines rules for messaging structure and data organization that are independent of the data transmission medium. Traditional serial Modbus is a register-based protocol that defines message transactions that occur between master(s) and slave devices (multiple masters are allowed on using Modbus TCP/IP).
The slave devices listen for communication from the master and simply respond as instructed. The master(s) always controls communication and may communicate directly to one slave, or all connected slaves, but the slaves cannot communicate directly with each other.

The register map of each slave device is usually part of its device manual. A Slave device usually permits configuration of its short slave address and communication options that are used within the device’s network segment.

The Modbus protocol allows devices to map data to four types of registers (Holding, Input, Discrete, Coil). The figure below illustrates an example mapping of a device’s data to the four types of registers.

The following sections give an overview of how to use the ESP_Modbus component found under components/freemodbus. The sections cover initialization of a Modbus port, and the setup a master or slave device accordingly:

- Modbus Port Initialization
- Modbus Slave API Overview
- Modbus Master API Overview
**Modbus Port Initialization**  
The ESP_Modbus supports Modbus SERIAL and TCP ports and a port must be initialized before calling any other Modbus API. The functions below are used to create and then initialize Modbus controller interface (either master or slave) over a particular transmission medium (either Serial or TCP/IP):

- `mbc_slave_init()`
- `mbc_master_init()`
- `mbc_slave_init_tcp()`
- `mbc_master_init_tcp()`

The API call uses the first parameter to recognize the type of port being initialized. Supported enumeration for different ports: `MB_PORT_SERIAL_MASTER`, `MB_PORT_SERIAL_SLAVE` accordingly. The parameters `MB_PORT_TCP_MASTER`, `MB_PORT_TCP_SLAVE` are reserved for internal usage.

```c
void* master_handler = NULL; // Pointer to allocate interface structure
// Initialization of Modbus master for serial port
esp_err_t err = mbc_master_init(MB_PORT_SERIAL_MASTER, &master_handler);
if (master_handler == NULL || err != ESP_OK) {
    ESP_LOGE(TAG, "mb controller initialization fail.");
}
```

This example code to initialize slave port:

```c
void* slave_handler = NULL; // Pointer to allocate interface structure
// Initialization of Modbus slave for TCP
esp_err_t err = mbc_slave_init_tcp(&slave_handler);
if (slave_handler == NULL || err != ESP_OK) {
    // Error handling is performed here
    ESP_LOGE(TAG, "mb controller initialization fail.");
}
```

**Modbus Master API Overview**

The following overview describes how to setup Modbus master communication. The overview reflects a typical programming workflow and is broken down into the sections provided below:

1. **Modbus Port Initialization** - Initialization of Modbus controller interface for the selected port.
2. **Configuring Master Data Access** - Configure data descriptors to access slave parameters.
3. **Master Communication Options** - Allows to setup communication options for selected port.
4. **Master Communication** - Start stack and sending / receiving data.
5. **Modbus Master Teardown** - Destroy Modbus controller and its resources.

**Configuring Master Data Access**   The architectural approach of ESP_Modbus includes one level above standard Modbus IO driver. The additional layer is called Modbus controller and its goal is to add an abstraction such as CID - characteristic identifier. The CID is linked to a corresponding Modbus registers through the table called Data Dictionary and represents device physical parameter (such as temperature, humidity, etc.) in specific Modbus slave device. This approach allows the upper layer (e.g., MESH or MQTT) to be isolated from Modbus specifics thus simplify Modbus integration with other protocols/networks.

The Data Dictionary is the list in the Modbus master which shall be defined by user to link each CID to its corresponding Modbus registers representation using Register Mapping table of the Modbus slave being used. Each element in this data dictionary is of type `mb_parameter_descriptor_t` and represents the description of one physical characteristic:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
<th>Detailed Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>cid</td>
<td>Character ID</td>
<td>The identifier of characteristic (must be unique).</td>
</tr>
<tr>
<td>param_key</td>
<td>Character Name</td>
<td>String description of the characteristic.</td>
</tr>
<tr>
<td>param_units</td>
<td>_characteristic Units</td>
<td>Physical Units of the characteristic.</td>
</tr>
<tr>
<td>mb_slave_addr</td>
<td>Slave Address</td>
<td>The short address of the device with correspond parameter UID.</td>
</tr>
<tr>
<td>mb_param_type</td>
<td>Register Type</td>
<td>Type of Modbus register area. MB_PARAM_INPUT, MB_PARAM_HOLDING, MB_PARAM_COIL, MB_PARAM_DISCRETE - represents Input, Holding, Coil and Discrete input register area accordingly;</td>
</tr>
<tr>
<td>mb_reg_start</td>
<td>Register Start</td>
<td>Relative register address of the characteristic in the register area.</td>
</tr>
<tr>
<td>mb_size</td>
<td>Register Size</td>
<td>Length of characteristic in registers.</td>
</tr>
<tr>
<td>param_instance_offset</td>
<td>Offset</td>
<td>Offset to instance of the characteristic in bytes. It is used to calculate the absolute address to the characteristic in the storage structure. It is optional field and can be set to zero if the parameter is not used in the application.</td>
</tr>
<tr>
<td>param_type</td>
<td>Data Type</td>
<td>Specifies type of the characteristic. PARAM_TYPE_U8, PARAM_TYPE_U16, PARAM_TYPE_U32 - Unsigned integer 8/16/32 bit type; PARAM_TYPE_FLOAT - IEEE754 floating point format; PARAM_TYPE_ASCII - ASCII string or binary data;</td>
</tr>
<tr>
<td>param_size</td>
<td>Data Size</td>
<td>The storage size of the characteristic (bytes).</td>
</tr>
<tr>
<td>param_opts</td>
<td>Parameter Options</td>
<td>Limits, options of characteristic used during processing of alarm in user application (optional)</td>
</tr>
<tr>
<td>access_type</td>
<td>Can be used in user application to define the behavior of the characteristic during processing of data in user application; PAR_PERMS_READ_WRITE_TRIGGER, PAR_PERMS_READ, PAR_PERMS_READ_WRITE_TRIGGER;</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The `cid` and `param_key` have to be unique. Please use the prefix to the parameter key if you have several similar parameters in your register map table.

---

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Table 9: Table 2 Example Register mapping table of Modbus slave

<table>
<thead>
<tr>
<th>CID</th>
<th>Register</th>
<th>Length</th>
<th>Type</th>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30000</td>
<td>4</td>
<td>MAX_UINT</td>
<td>U32</td>
<td>Serial number of device (4 bytes) read-only</td>
</tr>
<tr>
<td>1</td>
<td>30002</td>
<td>2</td>
<td>MAX_UINT</td>
<td>U16</td>
<td>Software version (4 bytes) read-only</td>
</tr>
<tr>
<td>2</td>
<td>40000</td>
<td>4</td>
<td>-20..40</td>
<td>FLOAT</td>
<td>Room temperature in DegC. Writing a temperature value to this register for single point calibration.</td>
</tr>
</tbody>
</table>

// Enumeration of modbus slave addresses accessed by master device
enum {
    MB_DEVICE_ADDR1 = 1,
    MB_DEVICE_ADDR2,
    MB_SLAVE_COUNT
};

// Enumeration of all supported CIDs for device
enum {
    CID_SER_NUM1 = 0,
    CID_SW_VER1,
    CID_TEMP_DATA_1,
    CID_SER_NUM2,
    CID_SW_VER2,
    CID_TEMP_DATA_2
};

// Example Data Dictionary for Modbus parameters in 2 slaves in the segment
mb_parameter_descriptor_t device_parameters[] = {
    // CID, Name, Units, Modbus addr, register type, Modbus Reg Start Addr, Modbus Reg read length, 
    // Instance offset (NA), Instance type, Instance length (bytes), Options (NA), Permissions
    { CID_SER_NUM1, STR("Serial_number_1"), STR("--"), MB_DEVICE_ADDR1, MB_PARAM_INPUT, 0, 2, 0, PARAM_TYPE_U32, 4, OPTS( 0, 0, 0 ), PAR_PERMS_READ_WRITE_INPUT_TRIGGER },
    { CID_SW_VER1, STR("Software_version_1"), STR("--"), MB_DEVICE_ADDR1, MB_PARAM_INPUT, 2, 1, 0, PARAM_TYPE_U16, 2, OPTS( 0, 0, 0 ), PAR_PERMS_READ_WRITE_INPUT_TRIGGER },
    { CID_TEMP_DATA_1, STR("Temperature_1"), STR("C"), MB_DEVICE_ADDR1, MB_PARAM_HOLDING, 0, 2, 0, PARAM_TYPE_FLOAT, 4, OPTS( 16, 30, 1 ), PAR_PERMS_READ_WRITE_TRIGGER },
    { CID_SER_NUM2, STR("Serial_number_2"), STR("--"), MBDEVICE_ADDR2, MB_PARAM_INPUT, 0, 2, 0, PARAM_TYPE_U32, 4, OPTS( 0, 0, 0 ), PAR_PERMS_READ_WRITE_INPUT_TRIGGER },
    { CID_SW_VER2, STR("Software_version_2"), STR("--"), MBDEVICE_ADDR2, MB_PARAM_INPUT, 2, 1, 0, PARAM_TYPE_U16, 2, OPTS( 0, 0, 0 ), PAR_PERMS_READ_WRITE_INPUT_TRIGGER },
    { CID_TEMP_DATA_2, STR("Temperature_2"), STR("C"), MBDEVICE_ADDR2, MB_PARAM_HOLDING, 0, 2, 0, PARAM_TYPE_FLOAT, 4, OPTS( 20, 30, 1 ), PAR_PERMS_READ_WRITE_TRIGGER },
};

// Calculate number of parameters in the table
(continues on next page)
During initialization of the Modbus stack, a pointer to the Data Dictionary (called descriptor) must be provided as the parameter of the function below.

\textit{mbc\_master\_set\_descriptor()}: Initialization of master descriptor.

```c
void *
mbc_master_set_descriptor(void *device_parameters[0], num_device_parameters);
```

The Data Dictionary can be initialized from SD card, MQTT or other source before start of stack. Once the initialization and setup is done, the Modbus controller allows the reading of complex parameters from any slave included in descriptor table using its CID.

**Master Communication Options** Calling the setup function allows for specific communication options to be defined for port.

\textit{mbc\_master\_setup()}

The communication structure provided as a parameter is different for serial and TCP communication mode.

Example setup for serial port:

```c
mb_communication_info_t comm_info = {
    .port = MB_PORT_NUM,  // Serial port number
    .mode = MB_MODE_RTU,   // Modbus mode of communication (MB\_MODE\_RTU or MB\_MODE\_ASCII)
    .baudrate = 9600,      // Modbus communication baud rate
    .parity = MB_PARITY_NONE // parity option for serial port
};
ESP_ERROR_CHECK(mbc_master_setup((void*) &comm_info));
```

Modbus master TCP port requires additional definition of IP address table where number of addresses should be equal to number of unique slave addresses in master Modbus Data Dictionary:

The order of IP address string corresponds to short slave address in the Data Dictionary.

```c
#define MB_SLAVE_COUNT 2  // Number of slaves in the segment being accessed (as defined in Data Dictionary)
char *slave_ip_address_table[MB_SLAVE_COUNT] = {
    "192.168.1.2",  // Address corresponds to UID1 and set to predefined value by user
    "192.168.1.3",  // corresponds to UID2 in the segment
    NULL};  // end of table

mb_communication_info_t comm_info = {
    .ip_port = MB_TCP_PORT,  // Modbus TCP port number (default = 502)
    .ip_addr_type = MB_IPV4,  // version of IP protocol
    .ip_mode = MB_MODE_TCP,   // Port communication mode
    .ip_addr = (void*)slave_ip_address_table,  // assign table of IP addresses
    .ip_netif_ptr = esp_netif_ptr // esp_netif_ptr pointer to the corresponding network interface
};
ESP_ERROR_CHECK(mbc_master_setup((void*) &comm_info));
```
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Note: Refer to esp_netif component for more information about network interface initialization.

The slave IP addresses in the table can be assigned automatically using mDNS service as described in the example. Refer to protocols/modbus/tcp/mb_tcp_master for more information.

Note: RS485 communication requires call to UART specific APIs to setup communication mode and pins. Refer to Running UART Communication section of UART documentation.

Master Communication

The starting of the Modbus controller is the final step in enabling communication. This is performed using function below:

```c
mbc_master_start()
```

```c
esp_err_t err = mbc_master_start();
if (err != ESP_OK) {
    ESP_LOGE(TAG, "mb controller start fail, err=%x.", err);
}
```

The list of functions below are used by the Modbus master stack from a user’s application:

- `mbc_master_send_request()`: This function executes a blocking Modbus request. The master sends a data request (as defined in parameter request structure `mb_param_request_t`) and then blocks until a response from the corresponding slave and returns the status of command execution. This function provides a standard way for read/write access to Modbus devices in the network.

- `mbc_master_get_cid_info()`: The function gets information about each characteristic supported in the data dictionary and returns the characteristic’s description in the form of the `mb_parameter_descriptor_t` structure. Each characteristic is accessed using its CID.

- `mbc_master_get_parameter()`: The function reads the data of a characteristic defined in the parameters of a Modbus slave device. The additional data for request is taken from parameter description table.

Example:

```c
const mb_parameter_descriptor_t* param_descriptor = NULL;
uint8_t temp_data[4] = {0}; // temporary buffer to hold maximum CID size
uint8_t type = 0;
....

// Get the information for characteristic cid from data dictionary
esp_err_t err = mbc_master_get_cid_info(cid, &param_descriptor);
if ((err != ESP_ERR_NOT_FOUND) && (param_descriptor != NULL)) {
    err = mbc_master_get_parameter(param_descriptor->cid, (char*)param_descriptor->param_key, (uint8_t*)temp_data, &type);
    if (err == ESP_OK) {
        ESP_LOGI(TAG, "Characteristic #%d %s (%s) value = (0x%08x) read successful.
        " param_descriptor->cid,
               (char*)param_descriptor->param_key,
               (char*)param_descriptor->param_units,
               *(uint32_t*)temp_data);
    } else {
        ESP_LOGE(TAG, "Characteristic #%d (%s) read fail, err = 0x%x (%s).",
               param_descriptor->cid,
               (char*)param_descriptor->param_key,
               (int)err,
               (char*)esp_err_to_name(err));
    }
} else {
```

(continues on next page)
mbc_master_set_parameter()

The function writes characteristic's value defined as a name and cid parameter in corresponded slave device. The additional data for parameter request is taken from master parameter description table.

```c
uint8_t type = 0; // Type of parameter
temp_data[4] = {0}; // temporary buffer

esp_err_t err = mbc_master_set_parameter(CID_TEMP_DATA_2, "Temperature_2", (uint8_t*)temp_data, &type);
if (err == ESP_OK) {
    ESP_LOGI(TAG, "Set parameter data successfully.");
} else {
    ESP_LOGE(TAG, "Set data fail, err = 0x%x (%s).", (int)err, esp_err_to_name(err));
}
```

Modbus Master Teardown  This function stops Modbus communication stack and destroys controller interface and free all used active objects.

```c
mbc_master_destroy();
```

Modbus Slave API Overview

The sections below represent typical programming workflow for the slave API which should be called in following order:

1. **Modbus Port Initialization** - Initialization of Modbus controller interface for the selected port.
2. **Configuring Slave Data Access** - Configure data descriptors to access slave parameters.
3. **Slave Communication Options** - Allows to setup communication options for selected port.
4. **Slave Communication** - Start stack and sending / receiving data. Filter events when master accesses the register areas.
5. **Modbus Slave Teardown** - Destroy Modbus controller and its resources.

**Configuring Slave Data Access**  The following functions must be called when the Modbus controller slave port is already initialized. Refer to **Modbus Port Initialization**.

The slave stack requires the user to define structures (memory storage areas) that store the Modbus parameters accessed by stack. These structures should be prepared by the user and be assigned to the Modbus controller interface using `mbc_slave_set_descriptor()` API call before the start of communication. The slave task can call the `mbc_slave_check_event()` function which will block until the Modbus master access the slave. The slave task can then get information about the data being accessed.

**Note:** One slave can define several area descriptors per each type of Modbus register area with different start_offset.

Register area is defined by using the `mb_register_area_descriptor_t` structure.
### Table 10: Table 3 Modbus register area descriptor

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>start_offset</td>
<td>Zero based register relative offset for defined register area. Example: register address = 40002 ( 4x register area - Function 3 - holding register ), start_offset = 2</td>
</tr>
<tr>
<td>type</td>
<td>Type of the Modbus register area. Refer to <code>mb_param_type_t</code> for more information.</td>
</tr>
<tr>
<td>address</td>
<td>A pointer to the memory area which is used to store the register data for this area descriptor.</td>
</tr>
<tr>
<td>size</td>
<td>The size of the memory area in bytes which is used to store register data.</td>
</tr>
</tbody>
</table>

#### `mbc_slave_set_descriptor()`

The function initializes Modbus communication descriptors for each type of Modbus register area (Holding Registers, Input Registers, Coils (single bit output), Discrete Inputs). Once areas are initialized and the `mbc_slave_start()` API is called the Modbus stack can access the data in user data structures by request from master.

```c
#define MB_REG_INPUT_START_AREA0 (0)
#define MB_REG_HOLDING_START_AREA0 (0)
#define MB_REG_HOLD_CNT (100)
#define MB_REG_INPUT_CNT (100)

mb_register_area_descriptor_t reg_area; // Modbus register area descriptor

~structure

unit16_t * holding_reg_area[MB_REG_HOLD_CNT] = {0}; // storage area for holding
~registers

unit16_t * input_reg_area[MB_REG_INPUT_CNT] = {0}; // storage area for input
~registers

reg_area.type = MB_PARAM_HOLDING; // Set type of
~register area
reg_area.start_offset = MB_REG_HOLDING_START_AREA0; // Offset of
~register area in Modbus protocol
reg_area.address = (void *)&holding_reg_area[0]; // Set pointer to
~storage instance
reg_area.size = sizeof(holding_reg_area) << 1; // Set the size of
~register storage area in bytes
ESP_ERROR_CHECK(mbc_slave_set_descriptor(reg_area));

reg_area.type = MB_PARAM_INPUT;
reg_area.start_offset = MB_REG_INPUT_START_AREA0;
reg_area.address = (void *)&input_reg_area[0];
reg_area.size = sizeof(input_reg_area) << 1;
ESP_ERROR_CHECK(mbc_slave_set_descriptor(reg_area));
```

At least one area descriptor per each Modbus register type must be set in order to provide register access to its area. If the master tries to access an undefined area, the stack will generate a Modbus exception.

Direct access to register area from user application must be protected by critical section:

```c
portENTER_CRITICAL(&param_lock);
holding_reg_area[2] += 10;
portEXIT_CRITICAL(&param_lock);
```

#### Slave Communication Options

The function initializes the Modbus controller interface and its active context (tasks, RTOS objects and other resources).

#### `mbc_slave_setup()`

The function is used to setup communication parameters of the Modbus stack.

Example initialization of Modbus TCP communication:
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```
esp_netif_init();
...

mb_communication_info_t comm_info = {
    .ip_port = MB_TCP_PORT,  // Modbus TCP port number (default = 502)
    .ip_addr_type = MB_IPV4,  // version of IP protocol
    .ip_mode = MB_MODE_TCP,  // Port communication mode
    .ip_addr = NULL,         // This field keeps the client IP
    .ip_netif_ptr = esp_netif_ptr,  // esp_netif_ptr - pointer to the corresponding network interface
};

// Setup communication parameters and start stack
ESP_ERROR_CHECK(mbc_slave_setup((void*)comm_info));
```

Example initialization of Modbus serial communication:

```
#define MB_SLAVE_DEV_SPEED 9600
#define MB_SLAVE_ADDR 1
#define MB_SLAVE_PORT_NUM 2
...

// Setup communication parameters and start stack
mb_communication_info_t comm_info = {
    .mode = MB_MODE_RTU,    // Communication type
    .slave_addr = MB_SLAVE_ADDR,  // Short address of the slave
    .port = MB_SLAVE_PORT_NUM,  // UART physical port number
    .baudrate = MB_SLAVE_DEV_SPEED,  // Baud rate for communication
    .parity = MB_PARITY_NONE  // Parity option
};
ESP_ERROR_CHECK(mbc_slave_setup((void*)comm_info));
```

**Slave Communication**  The function below is used to start Modbus controller interface and allows communication.

```
mbc_slave_start()
ESP_ERROR_CHECK(mbc_slave_start());
```

```
mbc_slave_check_event()
The blocking call to function waits for a event specified (represented as an event mask parameter). Once the master accesses the parameter and the event mask matches the parameter type, the application task will be unblocked and function will return the corresponding event mb_event_group_t which describes the type of register access being done.

mbc_slave_get_param_info()
The function gets information about accessed parameters from the Modbus controller event queue. The KConfig CONFIG_FMB_CONTROLLER_NOTIFY_QUEUE_SIZE key can be used to configure the notification queue size. The timeout parameter allows a timeout to be specified when waiting for a notification. The mb_param_info_t structure contains information about accessed parameter.
```
Table 11: Description of the register info structure:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>time_stamp</td>
<td>the timestamp of the event when defined parameter is accessed</td>
</tr>
<tr>
<td>mb_offset</td>
<td>start Modbus register accessed by master</td>
</tr>
<tr>
<td>type</td>
<td>type of the Modbus register area being accessed (See the mb_event_group_t for more information)</td>
</tr>
<tr>
<td>address</td>
<td>memory address that corresponds to accessed register in defined area descriptor</td>
</tr>
<tr>
<td>size</td>
<td>number of registers being accessed by master</td>
</tr>
</tbody>
</table>

Example to get event when holding or input registers accessed in the slave:

```c
#define MB_READ_MASK    (MB_EVENT_INPUT_REG_RD | MB_EVENT_HOLDING_REG_RD)
#define MB_WRITE_MASK    (MB_EVENT_HOLDING_REG_WR)
#define MB_READ_WRITE_MASK (MB_READ_MASK | MB_WRITE_MASK)
#define MB_PAR_INFO_GET_TOUT (10 / portTICK_PERIOD_MS)

// The function blocks while waiting for register access
mb_event_group_t event = mbc_slave_check_event(MB_READ_WRITE_MASK);

// Get information about data accessed from master
ESP_ERROR_CHECK(mbc_slave_get_param_info(reg_info, MB_PAR_INFO_GET_TOUT));
const char* rw_str = (event & MB_READ_MASK) ? "READ" : "WRITE";

// Filter events and process them accordingly
if (event & (MB_EVENT_HOLDING_REG_WR | MB_EVENT_HOLDING_REG_RD)) {
    ESP_LOGI(TAG, "HOLDING %s (%u us), ADDR:%u, TYPE:%u, INST_ADDR:0x%.4x, SIZE:%u",
             rw_str,
             (uint32_t)reg_info.time_stamp,
             (uint32_t)reg_info.mb_offset,
             (uint32_t)reg_info.type,
             (uint32_t)reg_info.address,
             (uint32_t)reg_info.size);
} else if (event & (MB_EVENT_INPUT_REG_RD)) {
    ESP_LOGI(TAG, "INPUT %s (%u us), ADDR:%u, TYPE:%u, INST_ADDR:0x%.4x, SIZE:%u",
             rw_str,
             (uint32_t)reg_info.time_stamp,
             (uint32_t)reg_info.mb_offset,
             (uint32_t)reg_info.type,
             (uint32_t)reg_info.address,
             (uint32_t)reg_info.size);
}
```

Modbus Slave Teardown  This function stops the Modbus communication stack, destroys the controller interface, and frees all used active objects allocated for the slave.

`mbc_slave_destroy()`

ESP_ERROR_CHECK(mbc_slave_destroy());

Possible Communication Issues And Solutions

If the examples do not work as expected and slave and master boards are not able to communicate correctly, it is possible to find the reason for errors. The most important errors are described in master example output and formatted as below:
Table 12: Table 5 Modbus error codes and troubleshooting

<table>
<thead>
<tr>
<th>Error Code</th>
<th>Description</th>
<th>Possible solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x106</td>
<td>ESP_ERR_NOT_SUPPORTED</td>
<td>- Invalid register request - slave returned an exception because the requested register is not supported. Refer to slave register map. Check the master data dictionary for correctness.</td>
</tr>
<tr>
<td>0x107</td>
<td>ESP_ERR_TIMEOUT</td>
<td>- Slave response timeout - Modbus slave did not send response during configured slave response timeout. Measure and increase the maximum slave response timeout idf.py menu-config, option CONFIG_FMB_MASTER_TIMEOUT_MS_RESPOND. Check physical connection or network configuration and make sure that the slave response can reach the master side. If the application has some high performance tasks with higher priority than CONFIG_FMB_PORT_TASK_PRIO it is recommended to place Modbus tasks on the other core using an option CONFIG_FMB_PORT_TASK_AFFINITY. Configure the Modbus task’s priority CONFIG_FMB_PORT_TASK_PRIO to ensure that the task gets sufficient processing time to handle Modbus stack events.</td>
</tr>
<tr>
<td>0x108</td>
<td>ESP_ERR_INVALID_RESPONSE</td>
<td>- Received unsupported response from slave or frame check failure. Master can not execute command handler because the command is either not supported or is incorrect. Check the physical connection then refer to register map of your slave to configure the master data dictionary properly.</td>
</tr>
<tr>
<td>0x109</td>
<td>ESP_ERR_INVALID_STATE</td>
<td>- Critical failure or FSM sequence failure or master FSM is busy processing previous request. Make sure your physical connection is working properly. Increase task stack size and check Modbus initialization sequence.</td>
</tr>
</tbody>
</table>

Application Example

The examples below use the FreeModbus library port for serial TCP slave and master implementations accordingly. The selection of stack is performed through KConfig menu option “Enable Modbus stack support…” for appropriate communication mode and related configuration keys.

- 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


API Reference

Header File

- components/freemodbus/common/include/esp_modbus_common.h
Unions

union mb_communication_info_t
#include <esp_modbus_common.h> Device communication structure to setup Modbus controller.

Public Members

mb_mode_type_t mode
Modbus communication mode

uint8_t slave_addr
Modbus slave address field (dummy for master)

uart_port_t port
Modbus communication port (UART) number

uint32_t baudrate
Modbus baudrate

uart_parity_t parity
Modbus UART parity settings

uint16_t dummy_port
Dummy field, unused

struct mb_communication_info_t::[anonymous] [anonymous]

mb_mode_type_t ip_mode
Modbus communication mode

uint16_t ip_port
Modbus port

mb_tcp_addr_type_t ip_addr_type
Modbus address type

void *ip_addr
Modbus address table for connection

void *ip_netif_ptr
Modbus network interface

struct mb_communication_info_t::[anonymous] [anonymous]

Macros

MB_RETURN_ON_FALSE (a, err_code, tag, format, ...)

MB_CONTROLLER_STACK_SIZE

MB_CONTROLLER_PRIORITY

MB_DEVICE_ADDRESS

MB_DEVICE_SPEED

MB_UART_PORT

MB_PAR_INFO_TOUT

MB_PARITY_NONE

_XFER_4_RD (dst, src)

_XFER_2_RD (dst, src)

_XFER_4_WR (dst, src)

_XFER_2_WR (dst, src)
Type Definitions

typedef esp_err_t (*iface_init)(void **)
  common interface method types Interface method init

typedef esp_err_t (*iface_destroy)(void)
  Interface method destroy

typedef esp_err_t (*iface_setup)(void *)
  Interface method setup

typedef esp_err_t (*iface_start)(void)
  Interface method start

Enumerations

enum mb_port_type_t
  Types of actual Modbus implementation.
  
  Values:

  MB_PORT_SERIAL_MASTER = 0x00
    Modbus port type serial master.

  MB_PORT_SERIAL_SLAVE
    Modbus port type serial slave.

  MB_PORT_TCP_MASTER
    Modbus port type TCP master.

  MB_PORT_TCP_SLAVE
    Modbus port type TCP slave.

  MB_PORT_COUNT
    Modbus port count.

  MB_PORT_INACTIVE = 0xFF

enum mb_event_group_t
  Event group for parameters notification.
  
  Values:

  MB_EVENT_NO_EVENTS = 0x00

  MB_EVENT_HOLDING_REG_WR = BIT0
    Modbus Event Write Holding registers.

  MB_EVENT_HOLDING_REG_RD = BIT1
    Modbus Event Read Holding registers.

  MB_EVENT_INPUT_REG_RD = BIT3
    Modbus Event Read Input registers.

  MB_EVENT_COILS_WR = BIT4
    Modbus Event Write Coils.

  MB_EVENT_COILS_RD = BIT5
    Modbus Event Read Coils.

  MB_EVENT_DISCRETE_RD = BIT6
    Modbus Event Read Discrete bits.

  MB_EVENT_STACK_STARTED = BIT7
    Modbus Event Stack started

enum mb_param_type_t
  Type of Modbus parameter.
  
  Values:
Chapter 2. API Reference

\textbf{MB_PARAM_HOLDING} = 0x00
Modbus Holding register.

\textbf{MB_PARAM_INPUT}
Modbus Input register.

\textbf{MB_PARAM_COIL}
Modbus Coils.

\textbf{MB_PARAM_DISCRETE}
Modbus Discrete bits.

\textbf{MB_PARAM_COUNT}
\textbf{MB_PARAM_UNKNOWN} = 0xFF

\textbf{enum mb_mode_type_t}
Modbus serial transmission modes (RTU/ASCII).

\textbf{Values:}

\textbf{MB_MODE_RTU}
RTU transmission mode.

\textbf{MB_MODE_ASCII}
ASCII transmission mode.

\textbf{MB_MODE_TCP}
TCP communication mode.

\textbf{MB_MODE_UDP}
UDP communication mode.

\textbf{enum mb_tcp_addr_type_t}
Modbus TCP type of address.

\textbf{Values:}

\textbf{MB_IPV4} = 0
TCP IPV4 addressing

\textbf{MB_IPV6} = 1
TCP IPV6 addressing

\textbf{Header File}

- components/freemodbus/common/include/esp_modbus_master.h

\textbf{Functions}

\textbf{esp_err_t mbc_master_init_tcp} (void **\textit{handler})
Initialize Modbus controller and stack for TCP port.

\textbf{Return}

- ESP_OK Success
- ESP_ERR_NO_MEM Parameter error
- ESP_ERR_NOT_SUPPORTED Port type not supported
- ESP_ERR_INVALID_STATE Initialization failure

\textbf{Parameters}

- [out] \textit{handler}: handler(pointer) to master data structure

\textbf{esp_err_t mbc_master_init} (mb_port_type_t \textit{port_type}, void **\textit{handler})
Initialize Modbus Master controller and stack for Serial port.

\textbf{Return}

- ESP_OK Success
- ESP_ERR_NO_MEM Parameter error
- ESP_ERR_NOT_SUPPORTED Port type not supported
• ESP_ERR_INVALID_STATE Initialization failure

**Parameters**
- [out] handler: handler(pointer) to master data structure
- [in] port_type: type of stack

void **mbc_master_init_iface** (void *handler)
Initialize Modbus Master controller interface handle.

**Parameters**
- [in] handler: - pointer to master data structure

**esp_err_t** **mbc_master_destroy** (void)
Destroy Modbus controller and stack.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_STATE Parameter error

**esp_err_t** **mbc_master_start** (void)
Start Modbus communication stack.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Modbus stack start error

**esp_err_t** **mbc_master_setup** (void *comm_info)
Set Modbus communication parameters for the controller.

**Return**
- ESP_OK Success
- ESP_ERR_INVALID_ARG Incorrect parameter data

**Parameters**
- comm_info: Communication parameters structure.

**esp_err_t** **mbc_master_set_descriptor** (const mb_parameter_descriptor_t *descriptor, const uint16_t num_elements)
Assign parameter description table for Modbus controller interface.

**Return**
- esp_err_t ESP_OK - set descriptor successfully
- esp_err_t ESP_ERR_INVALID_ARG - invalid argument in function call

**Parameters**
- [in] descriptor: pointer to parameter description table
- num_elements: number of elements in the table

**esp_err_t** **mbc_master_send_request** (mb_param_request_t *request, void *data_ptr)
Send data request as defined in parameter request, waits response from slave and returns status of command execution. This function provides standard way for read/write access to Modbus devices in the network.

**Return**
- esp_err_t ESP_OK - request was successful
- esp_err_t ESP_ERR_INVALID_ARG - invalid argument of function
- esp_err_t ESP_ERR_INVALID_RESPONSE - an invalid response from slave
- esp_err_t ESP_ERR_TIMEOUT - operation timeout or no response from slave
- esp_err_t ESP_ERR_NOT_SUPPORTED - the request command is not supported by slave
- esp_err_t ESP_FAIL - slave returned an exception or other failure

**Parameters**
- [in] request: pointer to request structure of type mb_param_request_t
- [in] data_ptr: pointer to data buffer to send or received data (dependent of command field in request)

**esp_err_t** **mbc_master_get_cid_info** (uint16_t cid, const mb_parameter_descriptor_t **param_info)
Get information about supported characteristic defined as cid. Uses parameter description table to get this
information. The function will check if characteristic defined as a cid parameter is supported and returns its description in param_info. Returns ESP_ERR_NOT_FOUND if characteristic is not supported.

Return
- esp_err_t ESP_OK - request was successful and buffer contains the supported characteristic name
- esp_err_t ESP_ERR_INVALID_ARG - invalid argument of function
- esp_err_t ESP_ERR_NOT_FOUND - the characteristic (cid) not found
- esp_err_t ESP_FAIL - unknown error during lookup table processing

Parameters
- [in] cid: characteristic id
- param_info: pointer to pointer of characteristic data.

`esp_err_t mbc_master_get_parameter (uint16_t cid, char *name, uint8_t *value, uint8_t *type)`
Read parameter from modbus slave device whose name is defined by name and has cid. The additional data for request is taken from parameter description (lookup) table.

Return
- esp_err_t ESP_OK - request was successful and value buffer contains representation of actual parameter data from slave
- esp_err_t ESP_ERR_INVALID_ARG - invalid argument of function or parameter descriptor
- esp_err_t ESP_ERR_INVALID_RESPONSE - an invalid response from slave
- esp_err_t ESP_ERR_INVALID_STATE - invalid state during data processing or allocation failure
- esp_err_t ESP_ERR_TIMEOUT - operation timed out and no response from slave
- esp_err_t ESP_ERR_NOT_SUPPORTED - the request command is not supported by slave
- esp_err_t ESP_ERR_NOT_FOUND - the parameter is not found in the parameter description table
- esp_err_t ESP_FAIL - slave returned an exception or other failure

Parameters
- [in] cid: id of the characteristic for parameter
- [in] name: pointer into string name (key) of parameter (null terminated)
- [out] value: pointer to data buffer of parameter
- [out] type: parameter type associated with the name returned from parameter description table.

`esp_err_t mbc_master_set_parameter (uint16_t cid, char *name, uint8_t *value, uint8_t *type)`
Set characteristic’s value defined as a name and cid parameter. The additional data for cid parameter request is taken from master parameter lookup table.

Return
- esp_err_t ESP_OK - request was successful and value was saved in the slave device registers
- esp_err_t ESP_ERR_INVALID_ARG - invalid argument of function or parameter descriptor
- esp_err_t ESP_ERR_INVALID_RESPONSE - an invalid response from slave during processing of parameter
- esp_err_t ESP_ERR_INVALID_STATE - invalid state during data processing or allocation failure
- esp_err_t ESP_ERR_TIMEOUT - operation timed out and no response from slave
- esp_err_t ESP_ERR_NOT_SUPPORTED - the request command is not supported by slave
- esp_err_t ESP_FAIL - slave returned an exception or other failure

Parameters
- [in] cid: id of the characteristic for parameter
- [in] name: pointer into string name (key) of parameter (null terminated)
- [out] value: pointer to data buffer of parameter (actual representation of json value field in binary form)
- [out] type: pointer to parameter type associated with the name returned from parameter lookup table.

Unions

```c
union mb_parameter_opt_t
    #include <esp_modbus_master.h> Modbus parameter options for description table.
```
### Public Members

```c
int opt1
   Parameter option1

int opt2
   Parameter option2

int opt3
   Parameter option3

struct mb_parameter_opt_t::[anonymous] [anonymous]

int min
   Parameter minimum value

int max
   Parameter maximum value

int step
   Step of parameter change tracking

struct mb_parameter_opt_t::[anonymous] [anonymous]
```

### Structures

```c
struct mb_parameter_descriptor_t
   Characteristics descriptor type is used to describe characteristic and link it with Modbus parameters that reflect its data.

Public Members

```c
uint16_t cid
   Characteristic cid

const char *param_key
   The key (name) of the parameter

const char *param_units
   The physical units of the parameter

uint8_t mb_slave_addr
   Slave address of device in the Modbus segment

mb_param_type_t mb_param_type
   Type of modbus parameter

uint16_t mb_reg_start
   This is the Modbus register address. This is the 0 based value.

uint16_t mb_size
   Size of mb parameter in registers

uint16_t param_offset
   Parameter name (OFFSET in the parameter structure)

mb_descr_type_t param_type
   Float, U8, U16, U32, ASCII, etc.

mb_descr_size_t param_size
   Number of bytes in the parameter.

mb_parameter_opt_t::param_opts
   Parameter options used to check limits and etc.

mb_param_perms_t access
   Access permissions based on mode
```
**struct mb_param_request_t**
Modbus register request type structure.

**Public Members**

- `uint8_t slave_addr`: Modbus slave address
- `uint8_t command`: Modbus command to send
- `uint16_t reg_start`: Modbus start register
- `uint16_t reg_size`: Modbus number of registers

**Macros**

- `MB_MASTER_CHECK(a, err_code, format, ...)`
- `MB_MASTER_ASSERT(con)`

**Enumerations**

**enum mb_descr_type_t**
Modbus descriptor table parameter type defines.

**Values:**

- `PARAM_TYPE_U8 = 0x00`: Unsigned 8
- `PARAM_TYPE_U16 = 0x01`: Unsigned 16
- `PARAM_TYPE_U32 = 0x02`: Unsigned 32
- `PARAM_TYPE_FLOAT = 0x03`: Float type
- `PARAM_TYPE_ASCII = 0x04`: ASCII type

**enum mb_descr_size_t**
Modbus descriptor table parameter size in bytes.

**Values:**

- `PARAM_SIZE_U8 = 0x01`: Unsigned 8
- `PARAM_SIZE_U16 = 0x02`: Unsigned 16
- `PARAM_SIZE_U32 = 0x04`: Unsigned 32
- `PARAM_SIZE_FLOAT = 0x04`: Float size
- `PARAM_SIZE_ASCII = 0x08`: ASCII size
- `PARAM_SIZE_ASCII24 = 0x18`: ASCII24 size
enum mb_param_perms_t
Permissions for the characteristics.

Values:

PAR_PERMS_READ = 1 << BIT0
the characteristic of the device are readable

PAR_PERMS_WRITE = 1 << BIT1
the characteristic of the device are writable

PAR_PERMS_TRIGGER = 1 << BIT2
the characteristic of the device are triggerable

PAR_PERMS_READ_WRITE = PAR_PERMS_READ | PAR_PERMS_WRITE
the characteristic of the device are readable & writable

PAR_PERMS_READ_TRIGGER = PAR_PERMS_READ | PAR_PERMS_TRIGGER
the characteristic of the device are readable & triggerable

PAR_PERMS_WRITE_TRIGGER = PAR_PERMS_WRITE | PAR_PERMS_TRIGGER
the characteristic of the device are writable & triggerable

PAR_PERMS_READ_WRITE_TRIGGER = PAR_PERMS_READ_WRITE | PAR_PERMS_TRIGGER
the characteristic of the device are readable & writable & triggerable

Header File

- components/freemodbus/common/include/esp_modbus_slave.h

Functions

esp_err_t mbc_slave_init_tcp (void **handler)
Initialize Modbus Slave controller and stack for TCP port.

Return
- ESP_OK Success
- ESP_ERR_NO_MEM Parameter error
- ESP_ERR_NOT_SUPPORTED Port type not supported
- ESP_ERR_INVALID_STATE Initialization failure

Parameters
- [out] handler: handler(pointer) to master data structure

esp_err_t mbc_slave_init (mb_port_type_t port_type, void **handler)
Initialize Modbus Slave controller and stack for Serial port.

Return
- ESP_OK Success
- ESP_ERR_NO_MEM Parameter error
- ESP_ERR_NOT_SUPPORTED Port type not supported
- ESP_ERR_INVALID_STATE Initialization failure

Parameters
- [out] handler: handler(pointer) to master data structure
- [in] port_type: the type of port

void mbc_slave_init_iface (void *handler)
Initialize Modbus Slave controller interface handle.

Parameters
- [in] handler: pointer to slave interface data structure

esp_err_t mbc_slave_destroy (void)
Destroy Modbus controller and stack.

Return
• ESP_OK Success
• ESP_ERR_INVALID_STATE Parameter error

`esp_err_t mbc_slave_start (void)`
Start Modbus communication stack.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Modbus stack start error

`esp_err_t mbc_slave_setup (void *comm_info)`
Set Modbus communication parameters for the controller.

Return
• ESP_OK Success
• ESP_ERR_INVALID_ARG Incorrect parameter data

Parameters
*comm_info: Communication parameters structure.

`mb_event_group_t mbc_slave_check_event (mb_event_group_t group)`
Wait for specific event on parameter change.

Return
• mb_event_group_t event bits triggered

Parameters
*group: Group event bit mask to wait for change

`esp_err_t mbc_slave_get_param_info (mb_param_info_t *reg_info, uint32_t timeout)`
Get parameter information.

Return
• ESP_OK Success
• ESP_ERR_TIMEOUT Cannot get data from parameter queue or queue overflow

Parameters
*[out] reg_info: parameter info structure
*timeout: Timeout in milliseconds to read information from parameter queue

`esp_err_t mbc_slave_set_descriptor (mb_register_area_descriptor_t descr_data)`
Set Modbus area descriptor.

Return
• ESP_OK: The appropriate descriptor is set
• ESP_ERR_INVALID_ARG: The argument is incorrect

Parameters
*descr_data: Modbus registers area descriptor structure

Structures

`struct mb_param_info_t`
Parameter access event information type.

Public Members

`uint32_t time_stamp`
Timestamp of Modbus Event (uS)

`uint16_t mb_offset`
Modbus register offset

`mb_event_group_t type`
Modbus event type

`uint8_t *address`
Modbus data storage address
Chapter 2. API Reference

```c
size_t size
    Modbus event register size (number of registers)

struct mb_register_area_descriptor_t
    Parameter storage area descriptor.
```

### Public Members

```c
uint16_t start_offset
    Modbus start address for area descriptor

mb_param_type_t type
    Type of storage area descriptor

void *address
    Instance address for storage area descriptor

size_t size
    Instance size for area descriptor (bytes)
```

### Macros

- `MB_SLAVE_CHECK(a, err_code, format, ...)`
- `MB_SLAVE_ASSERT(con)`

## 2.4.12 ESP WebSocket Client

### Overview

The ESP WebSocket client is an implementation of WebSockets for ESP32-S3.

### Features

- Supports WebSocket over TCP, TLS with mbedtls
- Easy to setup with URI
- Multiple instances (Multiple clients in one application)

### Configuration

#### URI

- Supports ws, wss schemes
- WebSocket samples:
  - `ws://echo.websocket.org`: WebSocket over TCP, default port 80
  - `wss://echo.websocket.org`: WebSocket over SSL, default port 443

Minimal configurations:

```c
const esp_websocket_client_config_t ws_cfg = {
    .uri = "ws://echo.websocket.org",
};
```

The WebSocket client supports the use of both path and query in the URI. Sample:

```c
const esp_websocket_client_config_t ws_cfg = {
    .uri = "ws://echo.websocket.org/connectionhandler?id=104",
};
```

If there are any options related to the URI in `esp_websocket_client_config_t`, the option defined by the URI will be overridden. Sample:
const esp_websocket_client_config_t ws_cfg = {
    .uri = "ws://echo.websocket.org:123",
    .port = 4567,
};
//WebSocket client will connect to websocket.org using port 4567

**TLS Configuration:**

const esp_websocket_client_config_t ws_cfg = {
    .uri = "wss://echo.websocket.org",
    .cert_pem = (const char *)websocket_org_pem_start,
};

**Note:** If you want to verify the server, then you need to provide a certificate in PEM format, and provide to cert_pem in websocket_client_config_t. If no certificate is provided then the TLS connection will default to not requiring verification.

PEM certificate for this example could be extracted from an openssl s_client command connecting to websocket.org. In case a host operating system has openssl and sed packages installed, one could execute the following command to download and save the root or intermediate root certificate to a file (Note for Windows users: Both Linux like environment or Windows native packages may be used).

```
  ` echo "" | openssl s_client -showcerts -connect websocket.org:443 | sed -n "1,/Root/d; /BEGIN/,/END/p" | openssl x509 -outform PEM >websocket_org.pem`
```

This command will extract the second certificate in the chain and save it as a pem-file.

**Subprotocol** The subprotocol field in the config struct can be used to request a subprotocol

const esp_websocket_client_config_t ws_cfg = {
    .uri = "ws://websocket.org",
    .subprotocol = "soap",
};

**Note:** The client is indifferent to the subprotocol field in the server response and will accept the connection no matter what the server replies.

For more options on esp_websocket_client_config_t, please refer to API reference below

**Events**

- **WEBSOCKET_EVENT_CONNECTED:** The client has successfully established a connection to the server. The client is now ready to send and receive data. Contains no event data.
- **WEBSOCKET_EVENT_DISCONNECTED:** The client has aborted the connection due to the transport layer failing to read data, e.g. because the server is unavailable. Contains no event data.
- **WEBSOCKET_EVENT_DATA:** The client has successfully received and parsed a WebSocket frame. The event data contains a pointer to the payload data, the length of the payload data as well as the opcode of the received frame. A message may be fragmented into multiple events if the length exceeds the buffer size. This event will also be posted for non-payload frames, e.g. pong or connection close frames.
- **WEBSOCKET_EVENT_ERROR:** Not used in the current implementation of the client.

If the client handle is needed in the event handler it can be accessed through the pointer passed to the event handler:

```c
esp_websocket_client_handle_t client = (esp_websocket_client_handle_t)handler_args;
```
Limitations and Known Issues

- The client is able to request the use of a subprotocol from the server during the handshake, but does not do any subprotocol related checks on the response from the server.

Application Example

A simple WebSocket example that uses esp_websocket_client to establish a websocket connection and send/receive data with the websocket.org server can be found here: protocols/websocket.

Sending Text Data

The WebSocket client supports sending data as a text data frame, which informs the application layer that the payload data is text data encoded as UTF-8. Example:

```c
esp_websocket_client_send_text(client, data, len, portMAX_DELAY);
```

API Reference

Header File

- components/esp_websocket_client/include/esp_websocket_client.h

Functions

```c
esp_websocket_client_handle_t esp_websocket_client_init(const esp_websocket_client_config_t *config)
```

Start a Websocket session. This function must be the first function to call, and it returns a esp_websocket_client_handle_t that you must use as input to other functions in the interface. This call MUST have a corresponding call to esp_websocket_client_destroy when the operation is complete.

Return

- esp_websocket_client_handle_t
- NULL if any errors

Parameters

- [in] config: The configuration

```c
esp_err_t esp_websocket_client_set_uri(esp_websocket_client_handle_t client, const char *uri)
```

Set URL for client, when performing this behavior, the options in the URL will replace the old ones. Must stop the WebSocket client before set URI if the client has been connected.

Return

esp_err_t

Parameters

- [in] client: The client
- [in] uri: The uri

```c
esp_err_t esp_websocket_client_start(esp_websocket_client_handle_t client)
```

Open the WebSocket connection.

Return

esp_err_t

Parameters

- [in] client: The client

```c
esp_err_t esp_websocket_client_stop(esp_websocket_client_handle_t client)
```

Stopping the WebSocket connection without websocket closing handshake.

This API stops ws client and closes TCP connection directly without sending close frames. It is a good practice to close the connection in a clean way using esp_websocket_client_close().

Notes

- Cannot be called from the websocket event handler
Return `esp_err_t`
Parameters
- `[in] client`: The client

`esp_err_t esp_websocket_client_destroy (esp_websocket_client_handle_t client)`
Destroy the WebSocket connection and free all resources. This function must be the last function to call for an session. It is the opposite of the `esp_websocket_client_init` function and must be called with the same handle as input that a `esp_websocket_client_init` call returned. This might close all connections this handle has used.

Notes:
- Cannot be called from the websocket event handler

Return `esp_err_t`
Parameters
- `[in] client`: The client

`int esp_websocket_client_send_bin (esp_websocket_client_handle_t client, const char *data, int len, TickType_t timeout)`
Write binary data to the WebSocket connection (data send with WS OPCODE=02, i.e. binary)

Return
- Number of data was sent
- (-1) if any errors
Parameters
- `[in] client`: The client
- `[in] data`: The data
- `[in] len`: The length
- `[in] timeout`: Write data timeout in RTOS ticks

`int esp_websocket_client_send_text (esp_websocket_client_handle_t client, const char *data, int len, TickType_t timeout)`
Write textual data to the WebSocket connection (data send with WS OPCODE=01, i.e. text)

Return
- Number of data was sent
- (-1) if any errors
Parameters
- `[in] client`: The client
- `[in] data`: The data
- `[in] len`: The length
- `[in] timeout`: Write data timeout in RTOS ticks

`esp_err_t esp_websocket_client_close (esp_websocket_client_handle_t client, TickType_t timeout)`
Close the WebSocket connection in a clean way.

Sequence of clean close initiated by client:
- Client sends CLOSE frame
- Client waits until server echoes the CLOSE frame
- Client waits until server closes the connection
- Client is stopped the same way as by the `esp_websocket_client_stop()`

Notes:
- Cannot be called from the websocket event handler

Return `esp_err_t`
Parameters
- `[in] client`: The client
- `[in] timeout`: Timeout in RTOS ticks for waiting

`esp_err_t esp_websocket_client_close_with_code (esp_websocket_client_handle_t client, int code, const char *data, int len, TickType_t timeout)`
Close the WebSocket connection in a clean way with custom code/data Closing sequence is the same as for
Chapter 2. API Reference

esp_websocket_client_close()

Notes:
• Cannot be called from the websocket event handler

Return esp_err_t
Parameters
• [in] client: The client
• [in] code: Close status code as defined in RFC6455 section-7.4
• [in] data: Additional data to closing message
• [in] len: The length of the additional data
• [in] timeout: Timeout in RTOS ticks for waiting

bool esp_websocket_client_is_connected(esp_websocket_client_handle_t client)
Check the WebSocket client connection state.

Return
• true
• false
Parameters
• [in] client: The client handle

esp_err_t esp_websocket_register_events(esp_websocket_client_handle_t client,
esp_websocket_event_id_t event, esp_event_handler_t event_handler,
void *event_handler_arg)

Register the Websocket Events.

Return esp_err_t
Parameters
• client: The client handle
• event: The event id
• event_handler: The callback function
• event_handler_arg: User context

Structures
struct esp_websocket_event_data_t
Websocket event data.

Public Members

const char *data_ptr
Data pointer

int data_len
Data length

uint8_t op_code
Received opcode

esp_websocket_client_handle_t client
esp_websocket_client_handle_t context

void *user_context
user_data context, from esp_websocket_client_config_t user_data

int payload_len
Total payload length, payloads exceeding buffer will be posted through multiple events

int payload_offset
Actual offset for the data associated with this event

struct esp_websocket_client_config_t
Websocket client setup configuration.
Public Members

**const char* `uri`**  
Websocket URI, the information on the URI can be overrides the other fields below, if any

**const char* `host`**  
Domain or IP as string

**int `port`**  
Port to connect, default depend on esp_websocket_transport_t (80 or 443)

**const char* `username`**  
Using for Http authentication - Not supported for now

**const char* `password`**  
Using for Http authentication - Not supported for now

**const char* `path`**  
HTTP Path, if not set, default is /

**bool `disable_auto_reconnect`**  
Disable the automatic reconnect function when disconnected

**void* `user_context`**  
HTTP user data context

**int `task_prio`**  
Websocket task priority

**int `task_stack`**  
Websocket task stack

**int `buffer_size`**  
Websocket buffer size

**const char* `cert_pem`**  
Pointer to certificate data in PEM or DER format for server verify (with SSL), default is NULL, not required to verify the server. PEM-format must have a terminating NULL-character. DER-format requires the length to be passed in `cert_len`.

**size_t `cert_len`**  
Length of the buffer pointed to by `cert_pem`. May be 0 for null-terminated pem

**const char* `client_cert`**  
Pointer to certificate data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed. If it is not NULL, also `client_key` has to be provided. PEM-format must have a terminating NULL-character. DER-format requires the length to be passed in `client_cert_len`.

**size_t `client_cert_len`**  
Length of the buffer pointed to by `client_cert`. May be 0 for null-terminated pem

**const char* `client_key`**  
Pointer to private key data in PEM or DER format for SSL mutual authentication, default is NULL, not required if mutual authentication is not needed. If it is not NULL, also `client_cert` has to be provided. PEM-format must have a terminating NULL-character. DER-format requires the length to be passed in `client_key_len`.

**size_t `client_key_len`**  
Length of the buffer pointed to by `client_key_pem`. May be 0 for null-terminated pem

**esp_websocket_transport_t `transport`**  
Websocket transport type, see `esp_websocket_transport_t`

**const char* `subprotocol`**  
Websocket subprotocol
**const** char *user_agent
Websocket user-agent

**const** char *headers
Websocket additional headers

**int** pong_timeout_sec
Period before connection is aborted due to no PONGs received

**bool** disable_pingpong_discon
Disable auto-disconnect due to no PONG received within pong_timeout_sec

**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

**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

**int** reconnect_timeout_ms
Reconnect after this value in milliseconds if disable_auto_reconnect is not enabled (defaults to 10s)

**int** network_timeout_ms
Abort network operation if it is not completed after this value, in milliseconds (defaults to 10s)

**size_t** ping_interval_sec
Websocket ping interval, defaults to 10 seconds if not set

**struct** ifreq *if_name
The name of interface for data to go through. Use the default interface without setting

**Type Definitions**

typedef **struct** esp_websocket_client *esp_websocket_client_handle_t

**Enumerations**

defined in esp_websocket.h

enum esp_websocket_event_id_t
Websocket Client events id.

*Values:*

**WEBSOCKET_EVENT_ANY** = -1

**WEBSOCKET_EVENT_ERROR** = 0
This event occurs when there are any errors during execution

**WEBSOCKET_EVENT_CONNECTED**
Once the Websocket has been connected to the server, no data exchange has been performed

**WEBSOCKET_EVENT_DISCONNECTED**
The connection has been disconnected

**WEBSOCKET_EVENT_DATA**
When receiving data from the server, possibly multiple portions of the packet

**WEBSOCKET_EVENT_CLOSED**
The connection has been closed cleanly
WEBSOCKET_EVENT_MAX
enum esp_websocket_transport_t
Websocket Client transport.
Values:
WEB_SOCKET_TRANSPORT_UNKNOWN = 0x0
Transport unknown
WEB_SOCKET_TRANSPORT_OVER_TCP
Transport over tcp
WEB_SOCKET_TRANSPORT_OVER_SSL
Transport over ssl

2.4.13 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.

ESP SPI Slave HD (Half Duplex) Mode Protocol

<table>
<thead>
<tr>
<th>SPI Slave Capabilities of Espressif chips</th>
<th>ESP32</th>
<th>ESP32-S2</th>
<th>ESP32-C3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI Slave HD</td>
<td>N</td>
<td>Y (v2)</td>
<td>Y (v2)</td>
</tr>
<tr>
<td>Tohost intr</td>
<td>N</td>
<td>N</td>
<td></td>
</tr>
<tr>
<td>Fhost intr</td>
<td>2 *</td>
<td>2 *</td>
<td></td>
</tr>
<tr>
<td>TX DMA</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>RX DMA</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Shared registers</td>
<td>72</td>
<td>64</td>
<td></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.

<table>
<thead>
<tr>
<th>Mode</th>
<th>command WN</th>
<th>address WN</th>
<th>dummy cycles</th>
<th>data WN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-bit</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DOUT</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>DIO</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>QOUT</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>QIO</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>QPI</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

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.
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.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mask</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-bit</td>
<td>0x00</td>
</tr>
<tr>
<td>DOUT</td>
<td>0x10</td>
</tr>
<tr>
<td>DIO</td>
<td>0x50</td>
</tr>
<tr>
<td>QOUT</td>
<td>0x20</td>
</tr>
<tr>
<td>QIO</td>
<td>0xA0</td>
</tr>
<tr>
<td>QPI</td>
<td>0xA0</td>
</tr>
</tbody>
</table>

**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 load 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.
   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 *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` in `Storage` section) 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 `essi_init()` to do initialization of the SDIO part.
5. Call `essi_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:

**Tohost 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.

**Frhost 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_data` 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-S3 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/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.

**Return**

- ESP_OK: If success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- Other value returned from lower layer init.

**Parameters**

- handle: Handle of an ESSL device.
- wait_ms: Millisecond to wait before timeout, will not wait at all if set to 0-9.

```c
esp_err_t essl_wait_for_ready (essl_handle_t handle, uint32_t wait_ms)
```

Wait for interrupt of an ESSL slave device.

**Return**

- ESP_OK: If success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

**Parameters**

- handle: Handle of an ESSL device.
- wait_ms: Millisecond to wait before timeout, will not wait at all if set to 0-9.

```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`.

**Return**
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- 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

Parameters
- handle: Handle of an 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.

```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

Return
- 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

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.

```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.

Return
- 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.

Parameters
- handle: Handle of an ESSL device.

```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).

Return
- 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.

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.

```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.

Return
- 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.

Parameters
- handle: Handle of an ESSL device.
• [out] 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] 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.

```
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.

**Return**
- ESP_OK Success
- One of the error codes from SDMMC/SPI host controller

**Parameters**
- handle: Handle of an ESSL device.
- addr: Address of register to write. For SDIO, valid address: 0-59. For SPI, see `essl_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.

```
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.

**Return**
- ESP_OK Success
- One of the error codes from SDMMC/SPI host controller

**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 `essl_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.

```
esp_err_t essl_wait_int (essl_handle_t handle, uint32_t wait_ms)
```
wait for an interrupt of the slave

**Return**
- ESP_OK: If interrupt is triggered.
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- ESP_ERR_TIMEOUT: No interrupts before timeout.

**Parameters**
- handle: Handle of an ESSL device.
- wait_ms: Millisecond to wait before timeout, will not wait at all if set to 0-9.

```
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.

**Return**
- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

**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.

```
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.

**Return**
- ESP_OK: Success
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- 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

**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.

```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.

**Return**

- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

**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.

```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.

**Return**

- ESP_OK: Success
- One of the error codes from SDMMC host controller

**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.

```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.

**Return**

- ESP_OK: Success
- ESP_ERR_NOT_SUPPORTED: Current device does not support this function.
- One of the error codes from SDMMC host controller

**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.

**Type Definitions**

```c
typedef struct essl_dev_t *essl_handle_t
```

Handle of an ESSL device.

**Header File**

- 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.

**Return**

- ESP_OK: on success
- ESP_ERR_NO_MEM: memory exhausted.
Parameters
• out_handle: Output of the handle.
• config: Configuration for the ESSL SDIO device.

`esp_err_t essl_sdio_deinit_dev (essl_handle_t handle)`
Deinitialize and free the space used by the ESSL SDIO device.

Return
• ESP_OK: on success
• ESP_ERR_INVALID_ARG: wrong handle passed

Parameters
• handle: Handle of the ESSL SDIO device to deinit.

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/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.

Return
• 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

Parameters
• [out] out_handle: Output of the handle
• init_config: Configuration for the ESSL SPI device

`esp_err_t essl_spi_deinit_dev (essl_handle_t handle)`
Deinitialize the ESSL SPI device and free the memory used by the device.

Return
• ESP_OK: On success
• ESP_ERR_INVALID_STATE: ESSL SPI is not in use

Parameters
• handle: Handle of the ESSL SPI device

`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`)

Return
• 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.
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] out_value`: Read buffer for the shared registers.
- `wait_ms`: Time to wait before timeout (reserved for future use, user should set this to 0).

`esp_err_t` `essl_spi_get_packet` (void *`arg`, void *`out_data`, size_t `size`, uint32_t `wait_ms`)
Get a packet from Slave.

Return
- 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.

Parameters
- `arg`: Context of the component. (Member `arg` from `essl_handle_t`)
- `[out] out_data`: 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).

`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.

Return
- 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`.

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] out_value`: Not supported, should be set to NULL.
- `wait_ms`: Time to wait before timeout (reserved for future use, user should set this to 0).

`esp_err_t` `essl_spi_send_packet` (void *`arg`, const void *`data`, size_t `size`, uint32_t `wait_ms`)
Send a packet to Slave.

Return
- 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

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).

`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)

```c
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.

**Return**
- ESP_OK: on success
- or other return value from :cpp:func:spi_device_transmit.

**Parameters**
- **spi**: SPI device handle representing the slave
- [out] **out_data**: 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.

```c
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.

**Return**
- ESP_OK: on success
- or other return value from :cpp:func:spi_device_transmit.

**Parameters**
- **spi**: SPI device handle representing the slave
- [out] **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.

```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.

**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.

**Return**
- ESP_OK: success
- or other return value from :cpp:func:spi_device_transmit.

**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.

```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.

**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.
Return
- ESP_OK: success
- or other return value from `cpp:func:spx_device_polling_transmit`.

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.

```c
void 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.

**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.

Return
- ESP_OK: success
- or other return value from `cpp:func:spx_device_transmit`.

Parameters
- `spi`: SPI device handle representing the slave
- `[out] out_data`: 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.

```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.

Return
- ESP_OK: success
- or other return value from `cpp:func:spx_device_transmit`.

Parameters
- `spi`: SPI device handle representing the slave
- `[out] out_data`: 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.

```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.

Return
- ESP_OK: success
- or other return value from `cpp:func:spx_device_transmit`.

Parameters
- `spi`: SPI device handle representing the slave
- `flags`: SPI_TRANS_* flags to control the transaction mode of the transaction to send.

```c
esp_err_t essl_spi_wrdma(spx_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.
mode.

Return
• ESP_OK: success

or other return value from :cpp:func:spi_device_transmit.

Parameters
• 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.

```c
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.

Return
• ESP_OK: success

or other return value from :cpp:func:spi_device_transmit.

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.

```c
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.

Return
• ESP_OK: success

or other return value from :cpp:func:spi_device_transmit.

Parameters
• spi: SPI device handle representing the slave
• flags: SPI_TRANS_* flags to control the transaction mode of the transaction to send.

Structures

```c
struct essl_spi_config_t
```

Configuration of ESSL SPI device.

**Public Members**

```c
spi_device_handle_t *spi
```  
Pointer to SPI device handle.

```c
uint32_t tx_buf_size
```  
The pre-negotiated Master TX buffer size used by both the host and the slave.

```c
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.

```c
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.
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2.4.14 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-S3 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 Oct 5 09:35:35 2021 GMT.
- A pre-selected filter list of the name of the most commonly used root certificates, reducing the amount of certificates to around 35 while still having around 90% coverage according to market share 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:

```c
mbedtls_ssl_config conf;
mbedtls_ssl_config_init(&conf);
esp_crt_bundle_attach(&conf);
```

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 IDF, then the certificate list can be downloaded from Mozilla as described in *Updating the Certificate Bundle*.

**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**

* esp_err_t esp_crt_bundle_attach(void *conf)

  Attach and enable use of a bundle for certificate verification.

  Attach and enable use of a bundle for certificate verification through a verification callback. If no specific bundle has been set through esp_crt_bundle_set() it will default to the bundle defined in menuconfig and embedded in the binary.

  **Return**

  - ESP_OK if adding certificates was successful.
  - Other if an error occurred or an action must be taken by the calling process.

  **Parameters**

  - [in] conf: The config struct for the SSL connection.

* esp_err_t esp_crt_bundle_detach(mbedtls_ssl_config *conf)

  Disable and deallocate the certification bundle.

  **Parameters**

  - [in] conf: The config struct for the SSL connection.

* esp_err_t esp_crt_bundle_set(const uint8_t *x509_bundle)

  Set the default certificate bundle used for verification.

  Overrides the default certificate bundle. 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**

  - [in] x509_bundle: A pointer to the certificate bundle.

Code examples for this API section are provided in the protocols directory of ESP-IDF examples.
2.4.15 IP Network Layer

Documentation for IP Network Layer protocols (below the Application Protocol layer) are provided in Networking APIs.

2.5 Provisioning API

2.5.1 Protocol Communication

Overview

Protocol Communication (protocomm) component manages secure sessions and provides framework for multiple transports. The application can also use 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 application level -
  - protocomm_security0 (no security)
  - protocomm_security1 (curve25519 key exchange + AES-CTR encryption)
- Proof-of-possession (support with protocomm_security1 only)

Protocomm internally uses protobuf (protocol buffers) for secure session establishment. Though users can implement their own security (even without using protobuf). One can even use protocomm without any security layer.

Protocomm provides framework for various transports - WiFi (SoftAP+HTTPD), BLE, 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 the client still needs to establish session (only for protocomm_security1) by performing the two way handshake. See Unified Provisioning for more details about the secure handshake logic.

Transport Example (SoftAP + HTTP) with Security 1

For sample usage, see wifi_provisioning/src/scheme_softap.c

```c
/* 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 data length updated */
  *outbuf = malloc(inlen); /* This will 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;
}

/* Example function for launching a protocomm instance over HTTP */
```

(continues on next page)
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 protocomm server on top of HTTP */
    protocomm_httpd_start(pc, &pc_config);

    /* Create Proof of Possession object from pop_string. It must be valid
    * throughout the scope of protocomm endpoint. This need not be
    * static,
    * ie. could be dynamically allocated and freed at the time of
    * endpoint
    * removal */
    const static protocomm_security_pop_t pop_obj = {
        .data = (const uint8_t *) strdup(pop_string),
        .len = strlen(pop_string)
    };

    /* Set security for communication at 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", &protocomm_security1, &pop_obj);

    /* Private data passed to the endpoint must be valid throughout the
    * scope of protocomm endpoint. This need not be static, ie. 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 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;
}

/* Example function for stopping a protocomm instance */
void stop_pc(protocomm_t *pc)
{
    /* Remove endpoint identified by it's unique name */
    protocomm_remove_endpoint(pc, "echo_req_endpoint");
    /* Remove security endpoint identified by it's name */
}
Transport Example (BLE) with Security 0

For sample usage, see wifi_provisioning/src/scheme_ble.c

```c
/* Example function for launching a secure protocomm instance over BLE */
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 */
            0xfb, 0x34, 0x9b, 0x5f, 0x80, 0x00, 0x80, 0x00, 0x00, 0x00, 0xFF, 0xFF, 0x00, 0x00,
            0x00, 0x00, 0x00, 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 BLE */
    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", prtocomm_security0, NULL);
    protocomm_add_endpoint(pc, "echo_req_endpoint", echo_req_handler, NULL);
    return pc;
}

/* 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 BLE protocomm service */
    protocomm_BLE_stop(pc);
    protocomm_delete(pc);
}
```
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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.

Return

- 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

- [in] pc: Pointer to the protocomm instance to be deleted

esp_err_t protocomm_add_endpoint (protocomm_t *pc, const char *ep_name, protocomm_reg_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.

Return

- 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

Parameters

- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string
- [in] h: Endpoint handler function
- [in] priv_data: Pointer to private data to be passed as a parameter to the handler function on
call. Pass NULL if not needed.

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.

Return

- ESP_OK : Success
- ESP_ERR_NOT_FOUND : Endpoint with specified name doesn’t exist
- ESP_ERR_INVALID_ARG : Null instance/name arguments

Parameters

- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string


**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()`.

**Return**
- ESP_OK : Request handled successfully
- ESP_ERR_NO_MEM : Error allocating internal resource
- ESP_ERR_INVALID_ARG : Null instance/name arguments

**Parameters**
- [in] pc: Pointer to the protocomm instance
- [in] session_id: Unique ID for a communication session

**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()`.

**Return**
- ESP_OK : Request handled successfully
- ESP_ERR_INVALID_ARG : Null instance/name arguments

**Parameters**
- [in] pc: Pointer to the protocomm instance
- [in] session_id: Unique ID for a communication session

**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.

**Return**
- 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_ERRINVALID_ARG : Null instance/name arguments

**Parameters**
- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string
- [in] session_id: Unique ID for a communication session
- [in] inbuf: Input buffer contains input request data which is to be processed by the registered handler
- [in] inlen: Length of the input buffer
- [out] outbuf: Pointer to internally allocated output buffer, where the resulting response data output from the registered handler is to be stored
- [out] outlen: Buffer length of the allocated output buffer

**esp_err_t protocomm_set_security**(protocomm_t *pc, const char *ep_name, const protocomm_security_t *sec, const protocomm_security_pop_t *pop)

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` are readily available.
Return

- 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

Parameters

- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string
- [in] sec: Pointer to endpoint security instance
- [in] pop: Pointer to proof of possession for authenticating a client

```
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.

Return

- ESP_OK : Success
- ESP_ERR_NOT_FOUND: Endpoint with specified name doesn’t exist
- ESP_ERR_INVALID_ARG: Null instance/name arguments

Parameters

- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string

```
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().

Return

- 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

Parameters

- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string
- [in] version: Version identifier(name) string

```
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.

Return

- ESP_OK : Success
- ESP_ERR_NOT_FOUND: Endpoint with specified name doesn’t exist
- ESP_ERR_INVALID_ARG: Null instance/name arguments

Parameters

- [in] pc: Pointer to the protocomm instance
- [in] ep_name: Endpoint identifier(name) string

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_security_pop

Proof Of Possession for authenticating a secure session.

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_security

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

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 protocomm_security_pop_t *pop, 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_security_pop protocomm_security_pop_t
    ProofOfPossession for authenticating a secure session.

typedef void *protocomm_security_handle_t

typedef struct protocomm_security protocomm_security_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.

Header File

- components/protocomm/include/security/protocomm_security0.h

Header File

- components/protocomm/include/security/protocomm_security1.h

Header File

- 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.

    Return

    - 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

    Parameters

    - [in] pc: Protocomm instance pointer obtained from protocomm_new()
    - [in] config: Pointer to config structure for initializing HTTP server

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.

    Return

    - ESP_OK : Success
    - ESP_ERR_INVALID_ARG : Null / incorrect protocomm instance pointer

    Parameters

    - [in] pc: Same protocomm instance that was passed to protocomm_httpd_start()

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 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

PROTOCOL_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.

Return

• 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

Parameters

• [in] pc: Protocomm instance pointer obtained from protocomm_new()
• [in] config: Pointer to config structure for initializing BLE
**protocomm_ble_stop** *(protocomm_t *)pc*

Stop Bluetooth Low Energy based transport layer for provisioning.

**Note** You might want to optionally reclaim memory from Bluetooth. Refer to the documentation of `esp_bt_mem_release` in that case.

**Return**
- ESP_OK: Success
- ESP_FAIL: Simple BLE stop error
- ESP_ERR_INVALID_ARG: Null / incorrect protocomm instance

**Parameters**
- **[in]** pc: Same protocomm instance that was passed to `protocomm_ble_start()`

**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 [MAX_BLE_DEVNAME_LEN] device_name**
  BLE device name being broadcast at the time of provisioning

- **uint8_t [BLE_UUID128_VAL_LENGTH] serviceUuid**
  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

**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**
  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.

2.5.2 Unified Provisioning

Overview

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. Or developers can extend the device-side and phone-app side implementations to accommodate their requirements for sending additional configuration data. Following 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 too is left to the application to decide.

2. **Transport Flexibility**: The protocol can work on Wi-Fi (SoftAP + HTTP server) or on BLE as a transport protocol. The framework provides an ability to add support for any other transport easily as long as command-response behaviour can be supported on the transport.

3. **Security Scheme Flexibility**: It’s 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’s WPA2 protected or BLE with “just-works” security. Or the applications may consider the transport to be insecure and may want application level security. The unified provisioning framework allows 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

Unified provisioning subsystem supports Wi-Fi (SoftAP+HTTP server) and BLE (GATT based) transport schemes. Following points need to be considered while selecting the best possible transport for provisioning.

1. BLE based transport has an advantage that in the provisioning process, the BLE communication channel stays intact between the device and the client. That provides reliable provisioning feedback.

2. BLE 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 user to go out of the phone app.

3. BLE transport however consumes ~110KB memory at runtime. If the product does not use the BLE or BT functionality after provisioning is done, almost all the memory can be reclaimed back and can be added into the heap.

4. SoftAP based transport is highly interoperable; however as the same radio is shared between SoftAP and Station interface, the transport is not reliable in the phase when the Wi-Fi connection to external AP is attempted. Also, the client may roam back to different network when the SoftAP changes the channel at the time of Station connection.

5. SoftAP transport does not require much additional memory for the Wi-Fi use-cases.

6. SoftAP based provisioning requires the phone app user to go to “System Settings” to connect to Wi-Fi network hosted by the device in case of iOS. The discovery (scanning) as well as connection API is not available for the iOS applications.
Chapter 2. API Reference

Fig. 26: Typical Provisioning Process

1. Transport specific discovery and connection

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
Deciding on Security

Depending on the transport and other constraints the security scheme needs to be selected by the application developers. 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 has to be secured. 2. The client should authenticate the device it is connected to. 3. The device manufacturer may choose proof-of-possession - a unique per device secret to be entered on the provisioning client as a security measure to make sure that the user can provisions the device in the possession.

There are two levels of security schemes. The developer may select one or combination depending on requirements.

1. **Transport Security:** SoftAP provisioning may choose WPA2 protected security with unique per-device passphrase. Per-device unique passphrase can also act as a proof-of-possession. For BLE, “just-works” security can be used as a transport level security after understanding the level of security it provides.

2. **Application Security:** The unified provisioning subsystem provides application level security (security1) that provides data protection and authentication (through proof-of-possession) 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 to advertise 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 BLE transport device name or primary service included in the advertisement or combination of both can be used for discovery.

Architecture

The below diagram shows architecture of unified provisioning.

It relies on the base layer called **Protocol Communication** (Protocol Communication) which provides a framework for security schemes and transport mechanisms. Wi-Fi Provisioning layer uses Protools 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 application can directly use protocomm to register custom handlers.

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 logical channel for communication for specific type of information. For example security handshake happens on a different endpoint than 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 SoftAP+HTTP transport the end-point corresponds to URI whereas in case of BLE the end-point corresponds to 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 unified provisioning supports two security schemes: 1. Security0 - No security (No encryption) 2. Security1 - 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

Security1 scheme details 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:**
  - BLE Provisioning app on Play Store.
  - SoftAP Provisioning app on Play Store.
  - Source code on GitHub: esp-idf-provisioning-android.

- **iOS:**
  - BLE 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 thus more user centric, while the command line application is useful as a debugging tool for developers.

2.5.3 Wi-Fi Provisioning

Overview

This component provides APIs that control Wi-Fi provisioning service for receiving and configuring Wi-Fi credentials over SoftAP or BLE transport via secure Protocol Communication (protocomm) sessions. The set of
Fig. 28: Security

Diagram showing the process of generating key pairs and verifying devices. The process involves:
1. Generating key pair:
   - `(cli_privkey, cli_pubkey) = curve25519.keygen()`
   - `(dev_privkey, dev_pubkey) = curve25519.keygen()`
2. SessionCmd0 with `cli_pubkey`
3. SessionCmd1 with `cli_verify`
4. Verifying client with `check (dev_pubkey == aes_ctr_dec(cli_verify))`
5. Verifying device with `check (cli_pubkey == aes_ctr_dec(dev_verify))`
6. Shared key generation:
   - `shared_key(No PoP) = curve25519(dev_privkey, cli_pubkey)`
   - `shared_key(with PoP) = curve25519(dev_privkey, cli_pubkey) ^ SHA256(pop)`
7. SessionResp0 with `dev_pubkey, dev_rand`
8. SessionResp1 with `dev_verify`
**Chapter 2. API Reference**

`wifi_prov_mgr_` APIs help in quickly implementing a provisioning service having necessary features with minimal amount of code and sufficient flexibility.

**Initialization**  `wifi_prov_mgr_init()` is called to configure and initialize the provisioning manager and thus this must be called prior to invoking any other `wifi_prov_mgr_` APIs. Note that the manager relies on other components of IDF, namely NVS, TCP/IP, Event Loop and Wi-Fi (and optionally mDNS), hence these must be initialized beforehand. The manager can be de-initialized at any moment by making a call to `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 `wifi_prov_mgr_config_t` has a few fields to specify the behavior desired of the manager:

- **scheme**: This is used to specify the provisioning scheme. Each scheme corresponds to one of the modes of transport supported by protocomm. Hence, we have three options:
  - `wifi_prov_scheme_ble`: BLE transport and GATT Server for handling provisioning commands
  - `wifi_prov_scheme_softap`: Wi-Fi SoftAP transport and HTTP Server for handling provisioning commands
  - `wifi_prov_scheme_console`: Serial transport and console for handling provisioning commands

- **scheme_event_handler**: An event handler defined along with scheme. Choosing appropriate scheme specific event handler allows the manager to take care of certain matters automatically. Presently this is not used for either SoftAP or Console based provisioning, but is very convenient for BLE. To understand how, we must recall that Bluetooth requires quite some amount of memory to function and once provisioning is finished, the main application may want to reclaim back this memory (or part of it, if it needs to use either BLE or classic BT). Also, upon every future reboot of a provisioned device, this reclamation of memory needs to be performed again. To reduce this complication in using `wifi_prov_scheme_ble`, the scheme specific handlers have been defined, and depending upon the chosen handler, the BLE / classic BT / BTDM memory will be freed automatically when the provisioning manager is de-initialized. The available options are:
  - `WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BTDM` - Free both classic BT and BLE (BTDM) memory. Used when main application doesn’t require Bluetooth at all.
  - `WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BLE` - Free only BLE memory. Used when main application requires classic BT.
  - `WIFI_PROV_SCHEME_BLE_EVENT_HANDLER_FREE_BT` - Free only classic BT. Used when main application requires BLE. In this case freeing happens right when the manager is initialized.
  - `WIFI_PROV_EVENT_HANDLER_NONE` - Don’t use any scheme specific handler. Used when provisioning scheme is not BLE (i.e. SoftAP or Console), or when main application wants to handle the memory reclaiming on its own, or needs both BLE and classic BT to function.

- **app_event_handler** (Deprecated): It is now recommended to catch `WIFI_PROV_EVENT`'s that are emitted to the default event loop handler. See definition of `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:
                ESP_LOGI(TAG, "Provisioning started");
        }
    }
}
```

(continues on next page)
break;
case WIFI_PROV_CRED_RECV: {
    wifi_sta_config_t *wifi_sta_cfg = (wifi_sta_config_t *)event_data;
    ESP_LOGI(TAG, "Received Wi-Fi credentials
    \n    SSID : %s
    Password : %s",
    (const char *) wifi_sta_cfg->ssid,
    (const char *) wifi_sta_cfg->password);
    break;
}
case WIFI_PROV_CRED_FAIL: {
    wifi_prov_sta_fail_reason_t *reason = (wifi_prov_sta_fail_reason_t *)event_data;
    ESP_LOGE(TAG, "Provisioning failed!\n    Reason : %s"
    "\n    Please reset to factory and retry"
    "\n    provision",
    ("reason == WIFI_PROV_STA_AUTH_ERROR") ?
    "Wi-Fi station authentication failed" : "Wi-Fi_
    access-point not found");
    break;
}
case WIFI_PROV_CRED_SUCCESS: ESP_LOGI(TAG, "Provisioning successful");
    break;
case WIFI_PROV_END: /* De-initialize manager once provisioning is finished */
    wifi_prov_mgr_deinit();
    break;
default:
    break;
}
}

The manager can be de-initialized at any moment by making a call to `wifi_prov_mgr_deinit()`.

**Check Provisioning State** Whether 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 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 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
- main application must implement some logic to call `esp_wifi_` APIs for erasing the credentials at runtime
- 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 Provisioning Service** At the time of starting provisioning we need to specify a service name and the corresponding key. These translate to:

- Wi-Fi SoftAP SSID and passphrase, respectively, when scheme is `wifi_prov_scheme_softap`
- BLE Device name (service key is ignored) when 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/decryption of subsequent messages
• Security 0 is simply plain text communication. In this case the pop is simply ignored

See 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 will automatically finish only if it receives valid Wi-Fi AP credentials followed by successfully connection of device to the AP (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 won’t accept new credentials anymore, but the provisioning service will keep on running (only to convey failure to the client), until the device is restarted. Upon restart the provisioning state will turn out to be true this time (as credentials will be found in NVS), but device will again fail 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 Provisioning State.

### Waiting For Completion

Typically, the main application will wait for the provisioning to finish, then de-initialize the manager to free up resources and finally start 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’s and call :cpp:func:`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 manager once 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 BLE 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 hostname set by the main application is used, and the service type is internally set to _esp_wifi_prov.

When using BLE transport, a custom 128 bit UUID should be set using wifi_prov_scheme_ble_set_service_uuid(). This UUID will be included in the BLE advertisement and will correspond to the primary GATT service that provides provisioning endpoints as GATT characteristics. Each GATT characteristic will be formed using the primary service UUID as base, with different auto assigned 12th and 13th bytes (assume counting starts from 0th byte). Since, an endpoint characteristic UUID is auto assigned, it shouldn’t 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 will be 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</th>
<th>URI (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>Endpoint used for starting Wi-Fi scan and receiving scan results</td>
</tr>
<tr>
<td>prov-config</td>
<td>http://&lt;mdns-hostname&gt;.local/prov-config</td>
<td>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>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 un-encrypted, hence necessary information (that 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 no_pop capability is supported, which indicates that the service doesn’t require proof of possession for authentication. Any application related version / capabilities will be given by other labels (like 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 (this is not needed when 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 (the corresponding .proto files can be found under wifi_provisioning/proto) :

- **get_status** - For querying the Wi-Fi connection status. The device will respond with a status which will be one of connecting / connected / disconnected. If status is disconnected, a disconnection reason will also 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 start the Wi-Fi station

After session establishment, 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 scan is started in passive mode (this 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 120ms 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 will wait for at least 120ms after completing scan on a group of channels, and thus allow 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 4, will create 5 groups, with each group having 3 channels, except the last one which will have 14 % 3 = 2 channels. So, when scan is started, the first 3 channels will be scanned, followed by a 120ms 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 few channels in a group may slow down 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. BLE, this can be safely set to 0, and hence achieve the fastest overall scanning time.
  - **period_ms** (input) - Scan parameter specifying how long to wait on each channel
- **scan_status** - Gives the status of scanning process:
  - **scan_finished** (output) - When scan has finished this returns true
  - **result_count** (output) - This gives the total number of results obtained till now. If scan is yet happening this number will keep on updating
- **scan_result** - For fetching scan results. This can be called even if scan is still on going
  - **start_index** (input) - Starting index from where to fetch the entries from the results list
  - **count** (input) - Number of entries to fetch from the starting index
  - **entries** (output) - List of entries returned. Each entry consists of `ssid`, `channel` and `rssi` information

### 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 `protocomm` 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
void wifi_prov_mgr_init(config);
void wifi_prov_mgr_endpoint_create("custom-endpoint");
void wifi_prov_mgr_start_provisioning(security, pop, service_name, service_key);
void 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 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 will be stopped (and BLE / SoftAP turned off) automatically after responding to the next `get_status` command. If `get_status` command is not received by the device, the service will be stopped after a 30s timeout.

On the other hand, if device was not able to connect using the provided Wi-Fi credentials, due to incorrect SSID / passphrase, the service will keep running, and `get_status` will keep responding with disconnected status and reason for disconnection. Any further attempts to provide another set of Wi-Fi credentials, will be rejected. These credentials will be 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 will only be stopped 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 de-
vice to connect to some cloud service and obtain another set of credentials, and exchange this 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 de-
lay 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:**
  - BLE Provisioning app on Play Store.
  - SoftAP Provisioning app on Play Store.
  - Source code on GitHub: esp-idf-provisioning-android.

- **iOS:**
  - BLE 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 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

Return

- ESP_OK : Success
- ESP_FAIL : Fail

Parameters

- [in] config: Configuration structure

`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

```c
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.

**Return**

- **ESP_OK**: Retrieved provision state successfully
- **ESP_FAIL**: Wi-Fi not initialized
- **ESP_ERR_INVALID_ARG**: Null argument supplied
- **ESP_ERR_INVALID_STATE**: Manager not initialized

**Parameters**

- **[out]** provisioned: True if provisioned, else false

```c
esp_err_t wifi_prov_mgr_start_provisioning (wifi_prov_security_t security, const char *pop, 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

**Return**

- **ESP_OK**: Provisioning started successfully
- **ESP_FAIL**: Failed to start provisioning service
- **ESP_ERR_INVALID_STATE**: Provisioning manager not initialized or already started

**Parameters**

- **[in]** security: 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
- **[in]** pop: Pointer to proof of possession string (NULL if not needed). This is relevant only for protocomm security 1, in which case it is used for authenticating secure session
- **[in]** service_name: Unique name of the service. This translates to:
  - Wi-Fi SSID when provisioning mode is softAP
  - Device name when provisioning mode is BLE
- **[in]** service_key: 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

```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()

    // Return
    // • ESP_OK : Success
    // • ESP_ERR_INVALID_STATE : Manager not initialized or provisioning service already started

    // Parameters
    // • [in] cleanup_delay: 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.
```

```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()

    // Return
    // • 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

    // Parameters
```
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- [in] label: String indicating the application name.
- [in] version: String indicating the application version. There is no constraint on format.
- [in] capabilities: Array of strings with capabilities. These could be used by the client side app to know the application registered endpoint capabilities
- [in] total_capabilities: Size of capabilities array

```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.

proto comm 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

Return
- ESP_OK : Success
- ESP_FAIL : Failure

Parameters
- [in] ep_name: unique name of the endpoint

```c
esp_err_t wifi_prov_mgr_endpoint_register(const char *ep_name, proto comm_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

Return
- ESP_OK : Success
- ESP_FAIL : Failure

Parameters
- [in] ep_name: Name of the endpoint
- [in] handler: Endpoint handler function
- [in] user_ctx: User data

```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.

Parameters
- [in] ep_name: Name of the endpoint

```c
esp_err_t wifi_prov_mgr_event_handler(void *ctx, system_event_t *event)
```

Event handler for provisioning manager.

This is called from the main event handler and controls the provisioning manager’s internal state machine depending on incoming Wi-Fi events
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Note: This function is DEPRECATED, because events are now handled internally using the event loop library, esp_event. Calling this will do nothing and simply return ESP_OK.

Return
- ESP_OK: Event handled successfully

Parameters
- [in] ctx: Event context data
- [in] event: Event info

```c
esp_err_t wifi_prov_mgr_get_wifi_state (wifi_prov_sta_state_t *state)
```
Get state of Wi-Fi Station during provisioning.

Return
- ESP_OK: Successfully retrieved Wi-Fi state
- ESP_FAIL: Provisioning app not running

Parameters
- [out] state: Pointer to wifi_prov_sta_state_t variable to be filled

```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.

Return
- ESP_OK: Successfully retrieved Wi-Fi disconnect reason
- ESP_FAIL: Provisioning app not running

Parameters
- [out] reason: Pointer to wifi_prov_sta_fail_reason_t variable to be filled

```c
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 proto comm, then this API needs to be called.

Event WIFI_PROV_CRED_RECV is emitted after credentials have been applied and Wi-Fi station started

Return
- ESP_OK: Wi-Fi configured and started successfully
- ESP_FAIL: Failed to set configuration

Parameters
- [in] wifi_cfg: Pointer to Wi-Fi configuration structure

```c
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.

Return
- ESP_OK: Reset provisioning config successfully
- ESP_FAIL: Failed to reset provisioning config

```c
esp_err_t wifi_prov_mgr_reset_sm_state_on_failure (void)
```
Reset internal state machine and clear provisioned credentials.

This API can be used to restart provisioning in case invalid credentials are entered.

Return
- 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_scheme_softap` 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_scheme_console` 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

Enumerations

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:

WIFI_PROV_INIT
Emitted when the manager is initialized

WIFI_PROV_START
Indicates that provisioning has started

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

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
**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

**WIFI_PROV_END**
Signals that provisioning service has stopped

**WIFI_PROV_DEINIT**
Signals that manager has been de-initialized

```c
enum wifi_prov_security
Security modes supported by the Provisioning Manager.
These are same as the security modes provided by protocomm

Values:

WIFI_PROV_SECURITY_0 = 0
No security (plain-text communication)

WIFI_PROV_SECURITY_1
This secure communication mode consists of X25519 key exchange
• proof of possession (pop) based authentication
• AES-CTR encryption
```

**Header File**

- components/wifi_provisioning/include/wifi_provisioning/scheme_ble.h

**Functions**

```c
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 0000fff8-0000-1000-8000-00805f9b34fb.

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 atleast till provisioning is started. Upon start, the manager will store an internal copy of this UUID, and this data can be freed or invalidated afterwords.

**Return**

- ESP_OK : Success
- ESP_ERR_INVALID_ARG : Null argument

**Parameters**

- [in] uuid128: A custom 128 bit UUID

```c
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 \(mfg\_data\_len\) length exceeds this limit, the length will be truncated.

**Return**
- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Null argument

**Parameters**
- \[\text{in}\] \text{mfg\_data}: Custom manufacturer data
- \[\text{in}\] \text{mfg\_data\_len}: Manufacturer data length

**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**

```c
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**
- \[\text{in}\] \text{handle}: 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**

```c
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_protocomm_req_handler_t) using protocomm_add_endpoint()

**Structures**

```c
struct wifi_prov_sta_conn_info_t
```

WiFi STA connected status information.

**Public Members**

```c
char ip_addr[IP4ADDR_STRLEN_MAX]
```

IP Address received by station
Chapter 2. API Reference

**struct wifi_prov_config_get_data_t**

WiFi status data to be sent in response to get_status request from master.

**Public Members**

- `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)

**struct wifi_prov_config_set_data_t**

WiFi config data received by slave during set_config request from master.

**Public Members**

- `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

**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**

- `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 (eg. 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.
Chapter 2. API Reference

```c
wifi_prov_ctx_t *ctx
Context pointer to be passed to above handler functions upon invocation
```

**Type Definitions**

```c
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 be defined later in application code as per requirements.

```c
typedef struct wifi_prov_config_handlers wifi_prov_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**

```c
enum wifi_prov_sta_state_t
WiFi STA status for conveying back to the provisioning master.
```

**Values:**

- `WIFI_PROV_STA_CONNECTING`
- `WIFI_PROV_STA_CONNECTED`
- `WIFI_PROV_STA_DISCONNECTED`

```c
enum wifi_prov_sta_fail_reason_t
WiFi STA connection fail reason.
```

**Values:**

- `WIFI_PROV_STA_AUTH_ERROR`
- `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

### 2.6 Storage API

#### 2.6.1 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_fat_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`, use the POSIX lseek 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_vfs_fat_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_vfs_fat_sdmmc_mount`, `esp_vfs_fat_sdspi_mount` and `esp_vfs_fat_sdcard_unmount` wrap the steps described above and also handle SD card initialization. These two functions are described in the next section.

### 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.

<table>
<thead>
<tr>
<th>Return</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_OK</td>
<td>on success</td>
</tr>
<tr>
<td>ESP_ERR_INVALIDSTATE</td>
<td>if esp_vfs_fat_register was already called</td>
</tr>
<tr>
<td>ESP_ERR_NO_MEM</td>
<td>if not enough memory or too many VFSes already registered</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>base_path:</td>
<td>path prefix where FATFS should be registered</td>
</tr>
<tr>
<td>fat_drive:</td>
<td>FATFS drive specification; if only one drive is used, can be an empty string</td>
</tr>
<tr>
<td>max_files:</td>
<td>maximum number of files which can be open at the same time</td>
</tr>
<tr>
<td>[out] out_fs:</td>
<td>pointer to FATFS structure which can be used for FATFS f_mount call is returned via this argument.</td>
</tr>
</tbody>
</table>

### 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.

<table>
<thead>
<tr>
<th>Return</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_OK</td>
<td>on success</td>
</tr>
</tbody>
</table>
• ESP_ERR_INVALID_STATE if FATFS is not registered in VFS

Parameters
• base_path: path prefix where FATFS is registered. This is the same used when esp_vfs_fat_register was called

Using FatFs with VFS and SD cards

The header file fatfs/vfs/esp_vfs_fat.h defines convenience functions esp_vfs_fat_sdmmc_mount(), esp_vfs_fat_sdspi_mount() and esp_vfs_fat_sdcard_unmount(). These function 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_vfs_fat_sdmmc_unmount() unmounts the filesystem and releases the resources acquired by esp_vfs_fat_sdmmc_mount().

```
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 registeredin 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.

Return
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_sdmmc_mount was already called
• ESP_ERR_NO_MEM if memory cannot be allocated
• ESP_FAIL if partition cannot be mounted
• other error codes from SDMMC or SPI drivers, SDMMC protocol, or FATFS drivers

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 SDSPI_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(). (Deprecated) For SPI peripheral, pass a pointer to sdspi_slot_config_t structure initialized using SDSPI_SLOT_CONFIG_DEFAULT().
• mount_config: pointer to structure with extra parameters for mounting FATFS
• [out] out_card: if not NULL, pointer to the card information structure will be returned via this argument

```
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 registeredin 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.

**Return**  
- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_sdmmc_mount was already called
- ESP_ERR_NO_MEM if memory cannot be allocated
- ESP_FAIL if partition can not be mounted
- other error codes from SDMMC or SPI drivers, SDMMC protocol, or FATFS drivers

**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: structure initialized using SDSPI_DEVICE_CONFIG_DEFAULT().
- [out] out_card: 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.

```c
struct esp_vfs_fat_mount_config_t
```

Configuration arguments for esp_vfs_fat_sdmmc_mount and esp_vfs_fat_spiflash_mount 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.

**esp_err_t esp_vfs_fat_sdcardUnmount (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_spiflash_mount()

**Return**

- 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
Using FatFs with VFS in read-only mode

The header file `fatfs/vfs/esp_vfs_fat.h` also defines the convenience functions `esp_vfs_fat_rawflash_mount()` and `esp_vfs_fat_rawflash_unmount()`. 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.

```c
esp_err_t esp_vfs_fat_rawflash_mount(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.

**Return**

- 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_rawflash_mount was already called for the same partition
- ESP_ERR_NO_MEM if memory cannot be allocated
- ESP_FAIL if partition cannot be mounted
- other error codes from SPI flash driver, or FATFS drivers

**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

```c
esp_err_t esp_vfs_fat_rawflash_unmount(const char *base_path, const char *partition_label)
```

Unmount FAT filesystem and release resources acquired using esp_vfs_fat_rawflash_mount.

**Return**

- ESP_OK on success
- ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount hasn’t been called

**Parameters**

- `base_path`: path where partition should be registered (e.g. “/spiflash”)
- `partition_label`: label of partition to be unmounted

FatFs disk IO layer

FatFs has been extended with API functions that register the disk I/O driver at runtime.

They 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

```c
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 disk io 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) and except for generating partition also initializes wear levelling.

Current implementation supports short filenames, FAT12 and FAT16. Long file names support is the subject of the future work.

**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:
fatfs_create_rawflash_image(<partition> <base_dir> [FLASH_IN_PROCESS])

fatfs_create_spiflash_image respectively fatfs_create_rawflash_image must be called from project’s CMakeLists.txt.

If you decided because of 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 specified suitable size of the partition in the partition table.
3. flag FLASH_IN_PROJECT - optionally, user can opt to have the image automatically flashed together with the app binaries, partition tables, etc. on idf.py flash -p <PORT> by specifying FLASH_IN_PROJECT.

For example:

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.

2.6.2 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.
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):

```
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:

```
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:

```
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.
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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:

```csv
id,firmware_key,serial_no,device_no
1,1a2b3c4d5e6faabb,A1,101
2,1a2b3c4d5e6fccddd,,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:

```csv
key,type,encoding,value
key,namespace,,
key1,type1,encoding1,value1
key2,type2,encoding2,value2
```

An instance of an intermediate CSV file will be created for each device on an individual basis.

**Running the utility**

**Usage:**

```bash
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:**

```bash
python mfg_gen.py generate [-h] [--fileid FILEID] [--version {1,2}] [--keygen] [--keyfile KEYFILE] [--inputkey INPUTKEY] [--outdir OUTDIR]
```

conf values prefix size
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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:

<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>-fileid FILEID</td>
<td>Unique file identifier(any key in values file) for each filename suffix (Default: numeric value(1,2,3…))</td>
</tr>
<tr>
<td>-keygen</td>
<td>Generates key for encrypting NVS partition</td>
</tr>
<tr>
<td>-inputkey INPUTKEY</td>
<td>File having key for encrypting NVS partition</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 generate factory images for each device using the command below. A sample CSV file is provided with the utility:

```python
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:

```python
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:

```python
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:
# API Reference

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### Parameter | Description
--- | ---
-h, --help | show this help message and exit
-keyfile KEYFILE | Path to output encryption keys file
-outdir OUTDIR | Output directory to store files created. (Default: current directory)

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)

## 2.6.3 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 a `idf.py erase-flash` 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. 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()` returns an opaque handle, which is used in subsequent calls to the `nvs_entry_next()` and `nvs_entry_info()` functions.
- `nvs_entry_next()` returns iterator to the next key-value pair.
- `nvs_entry_info()` returns information about each key-value pair

If none or no other key-value pair was found for given criteria, `nvs_entry_find()` and `nvs_entry_next()` return NULL. In that case, the iterator does not have to be released. If the iterator is no longer needed, you can release it by using the function `nvs_release_iterator()`.

**Security, tampering, and robustness** NVS is not directly compatible with the ESP32-S3 flash encryption system. However, data can still be stored in encrypted form if NVS encryption is used together with ESP32-S3 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.
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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 nvs_flash_generate_keys() API function provided by nvs_flash.h. The API function will then write those keys onto the key-partition in encrypted form.

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 /dev/ttyUSB0 --partition-table-offset "nvs_key...
   --partition offset" write_partition --partition-name="name of nvs_key...
   --partition" --input "nvs_key partition"

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 nvspartition 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-S3 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`
  - 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-S3 module restarts.

    • value - tracks the number of the ESP32-S3 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 | <- states |
| | #11 | | #12 | | #14 | | | <- sequence numbers |
| +--------+ +--------+ +--------+ +--------+ |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| +------v------v------v------v------v------v------+
| | Sector 3 | | Sector 0 | | Sector 2 | | Sector 1 | <- physical sectors |
| +------------+ +------------+ +------------+ +------------+ |

Structure of a page  For now, we assume that flash sector size is 4096 bytes and that ESP32-S3 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-S3 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.
Page header and entry state bitmap are always written to flash unencrypted. Entries are encrypted if flash encryption feature of ESP32-S3 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, 0xef 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.

| NS (1) | Type (1) | Span (1) | ChunkIndex (1) | CRC32 (4) | Key (16) | Data... |
|--------+----------+----------+----------------+-----------+---------------+------|
| ~--(8) |          |          |                | +---------+-------+            |
| ~---+   | Primitive +-----------------------------|
| ~---+   | +----------> | Data (8) |
| ~ | Types +----------------------------------|
| ~---+   | +-> Fixed length == |
|        |                   |

(continues on next page)
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.

| NS=0 Type=uint8_t Key="wifi" Value=1 | Entry describing namespace "wifi"
| NS=1 Type=uint32_t Key="channel" Value=6 | Key "channel" in namespace "wifi"
| NS=0 Type=uint8_t Key="pwm" Value=2 | Entry describing namespace "pwm"
| NS=2 Type=uint16_t Key="channel" Value=20 | Key "channel" in namespace "pwm"

**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:

1. 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”)
2. If the NVS key partition obtained in the previous step is empty, generate and store new keys in that NVS key partition.
3. 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.

Return

- 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.

Return

- 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
- 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

Parameters

- [in] partition_label: Label of the partition. Must be no longer than 16 characters.

**esp_err_t nvs_flash_init_partition_ptr**(const esp_partition_t *partition)

Initialize NVS flash storage for the partition specified by partition pointer.

Return

- 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

Parameters
- [in] partition: pointer to a partition obtained by the ESP partition API.

\texttt{esp_err_t nvs\_flash\_deinit (void)}
Deinitialize NVS storage for the default NVS partition.
Default NVS partition is the partition with "nvs" label in the partition table.

Return
- 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 (const char* partition\_label)}
Deinitialize NVS storage for the given NVS partition.

Return
- ESP_OK on success
- ESP_ERR_NVS\_NOT\_INITIALIZED if the storage for given partition was not initialized prior to this call

Parameters
- [in] partition\_label: Label of the partition

\texttt{esp_err_t nvs\_flash\_erase (void)}
Erase the default NVS partition.
Erases all contents of the default NVS partition (one with label "nvs").

Note If the partition is initialized, this function first de-initializes it. Afterwards, the partition has to be ini-
tialized again to be used.

Return
- 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 (const char* part\_name)}
Erase specified NVS partition.

Erase all content of a specified NVS partition

Note If the partition is initialized, this function first de-initializes it. Afterwards, the partition has to be ini-
tialized again to be used.

Return
- ESP_OK on success
- 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)

Parameters
- [in] part\_name: Name (label) of the partition which should be erased

\texttt{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 ini-
tialized again to be used.

Return
- 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

Parameters
- [in] partition: pointer to a partition obtained by the ESP partition API.

\texttt{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.

**Return**
- 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

**Parameters**
- **[in]** `cfg`: Security configuration (keys) to be used for NVS encryption/decryption. If `cfg` is NULL, no encryption is used.

```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.

**Return**
- 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

**Parameters**
- **[in]** `partition_label`: Label of the partition. Note that internally, a reference to passed value is kept and it should be accessible for future operations
- **[in]** `cfg`: Security configuration (keys) to be used for NVS encryption/decryption. If `cfg` is NULL, no encryption/decryption is used.

```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.

**Return**
- ESP_OK, if `cfg` was read successfully;
- ESP_INVALID_ARG, if partition or `cfg`; 
- or error codes from esp_partition_write/erase APIs.

**Parameters**
- **[in]** `partition`: Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- **[out]** `cfg`: Pointer to nvss security configuration structure. Pointer must be non-NULL. Generated keys will be populated in this structure.

```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’.

**Return**
- 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.

**Parameters**
- **[in]** `partition`: Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- **[out]** `cfg`: Pointer to nvss security configuration structure. Pointer must be non-NULL.

**Structures**

```
struct nvs_sec_cfg_t

Key for encryption and decryption.
```
Chapter 2. API Reference

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

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.

Return
- 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.

Parameters
- [in] handle: Handle obtained from nvs_open function. Handles that were opened read only cannot be used.
- [in] key: Key name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
- [in] value: The value to set.

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.

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.

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.

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.

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.
Chapter 2. API Reference

**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.

**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.

**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.

**Return**

- 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

**Parameters**

- **[in]** handle: Handle obtained from `nvs_open` function. Handles that were opened read only cannot be used.
- **[in]** key: Key name. Maximal length is `(NVS_KEY_NAME_MAX_SIZE-1)` characters. Shouldn’t be empty.
- **[in]** value: 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.

**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.

```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.
```

**Return**

- ESP_OK if the value was retrieved successfully
- 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

**Parameters**

- **[in]** handle: Handle obtained from `nvs_open` function.
- **[in]** key: Key name. Maximal 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.

```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.

```c
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.

```c
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.

```c
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.

```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);
```

Return
• ESP_OK if the value was retrieved successfully
• 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

Parameters
• [in] handle: Handle obtained from nvs_open function.
• [in] key: Key name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
• [out] 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.
• [inout] length: A non-zero pointer to the variable holding the length of out_value. In case out_value a 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.

```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 *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.

Return
• ESP_OK if storage handle was opened successfully
• 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
• other error codes from the underlying storage driver

Parameters
• [in] name: Namespace name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
• [in] open_mode: 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] out_handle: If successful (return code is zero), handle will be returned in this argument.

```c
esp_err_t nvs_open_from_partition(const char *part_name, const char *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.

Return
• ESP_OK if storage handle was opened successfully
• 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
• other error codes from the underlying storage driver

Parameters
• [in] part_name: Label (name) of the partition of interest for object read/write/erase
• [in] name: Namespace name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
• [in] open_mode: 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] out_handle: If successful (return code is zero), handle will be returned in this argument.

`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.

Return
• 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 value is too long

Parameters
• [in] handle: Handle obtained from nvs_open function. Handles that were opened read only cannot be used.
• [in] key: Key name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.
• [in] value: The value to set.
• [in] length: 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.

`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.

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

Parameters
• [in] handle: Storage handle obtained with nvs_open. Handles that were opened read only cannot be used.
• [in] key: Key name. Maximal length is (NVS_KEY_NAME_MAX_SIZE-1) characters. Shouldn’t be empty.

`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.

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
• other error codes from the underlying storage driver

Parameters
• [in] handle: Storage handle obtained with nvs_open. Handles that were opened read only cannot be used.

`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.

**Return**
- 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

**Parameters**
- `[in] handle`: Storage handle obtained with `nvs_open`. Handles that were opened read only cannot be used.

```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**
- `[in] handle`: 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;
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);
```

**Return**
- 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_INVALID_ARG if `nvs_stats` equal to NULL.
- ESP_ERR_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.

**Parameters**
- `[in] part_name`: Partition name NVS in the partition table. If pass a NULL than will use `NVS_DEFAULT_PART_NAME`.
- `[out] nvs_stats`: Returns filled structure `nvs_stats_t`. It provides info about used memory the partition.

```c
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...

nvs_handle_t handle;
nvs_open("namespacel", 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;
}

Return
• 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_INVALID_ARG if used_entries equal to NULL.
• Other error codes from the underlying storage driver. Return param used_entries will be filled 0.

Parameters
• [in] handle: Handle obtained from nvs_open function.
• [out] used_entries: Returns amount of used entries from a namespace.

nvs_iterator_t nvs_entry_find(const char *part_name, const char *namespace_name, nvs_type_t type)
Create an iterator to enumerate NVS entries based on one or more parameters.

// Example of listing all the key-value pairs of any type under specified
--partition and namespace
nvs_iterator_t it = nvs_entry_find(partition, 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' \n", info.key, info.type);
};
// Note: no need to release iterator obtained from nvs_entry_find function when
// nvs_entry_find or nvs_entry_next function return NULL, indicating no...
--other
// element for specified criteria was found.
}

Return Iterator used to enumerate all the entries found, or NULL if no entry satisfying criteria was found.
Iterator obtained through this function has to be released using nvs_release_iterator when not used any more.

Parameters
• [in] part_name: Partition name
• [in] namespace_name: Set this value if looking for entries with a specific namespace. Pass NULL otherwise.
• [in] type: One of nvs_type_t values.

nvs_iterator_t nvs_entry_next (nvs_iterator_t iterator)
Returns next item matching the iterator criteria, NULL if no such item exists.

Note that any copies of the iterator will be invalid after this call.

Return NULL if no entry was found, valid nvs_iterator_t otherwise.

Parameters
• [in] iterator: Iterator obtained from nvs_entry_find function. Must be non-NULL.

void nvs_entry_info (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
**Chapter 2. API Reference**

- **[in] iterator**: Iterator obtained from `nvs_entry_find` or `nvs_entry_next` function. Must be non-NULL.
- **[out] out_info**: Structure to which entry information is copied.

```c
void nvs_release_iterator(nvs_iterator_t iterator)
```

*Release iterator.*

**Parameters**
- **[in] iterator**: Release iterator obtained from `nvs_entry_find` function. NULL argument is allowed.

**Structures**

```c
struct nvs_entry_info_t
```

*Information about entry obtained from `nvs_entry_info` function*

**Public Members**

- `char namespace_name[16]`
  *Namespace to which key-value belong*
- `char key[NVS_KEY_NAME_MAX_SIZE]`
  *Key of stored key-value pair*
- `nvs_type_t type`
  *Type of stored key-value pair*

```c
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`
  *Id 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*
Chapter 2. API Reference

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
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_DECR_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

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)
Chapter 2. API Reference

**NVS_KEY_NAME_MAX_SIZE**
Maximal length of NVS key name (including null terminator)

**Type Definitions**

```c
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**

```c
enum nvs_open_mode_t
Mode of opening the non-volatile storage.
Values:

NVSMlehemomeonly
Read only

NVSM READWRITE
Read and write

enum nvs_type_t
Types of variables.
Values:

NVSM _TYPE_U8 = 0x01
Type uint8_t

NVSM _TYPE_I8 = 0x11
Type int8_t

NVSM _TYPE_U16 = 0x02
Type uint16_t

NVSM _TYPE_I16 = 0x12
Type int16_t

NVSM _TYPE_U32 = 0x04
Type uint32_t

NVSM _TYPE_I32 = 0x14
Type int32_t

NVSM _TYPE_U64 = 0x08
Type uint64_t

NVSM _TYPE_I64 = 0x18
Type int64_t

NVSM _TYPE_STR = 0x21
Type string

NVSM _TYPE_BLOB = 0x42
Type blob

NVSM _TYPE_ANY = 0xff
Must be last
2.6.4 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. As of now, for the file type, only hex2bin, base64, string, and binary encoding is supported.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Value</td>
<td>Data value. Encoding and Value cells for the namespace field type should be empty. Encoding and Value of namespace is fixed and is not configurable. Any values in these cells are ignored.</td>
<td></td>
</tr>
</tbody>
</table>

Note: The first line of the CSV file should be the column header and it is not configurable. Comments (if provided) are allowed only as the first line of the CSV file, the following line then should always be the column header. Comments should always start with the # symbol.

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:

```bash
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>
</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>
</table>
```

(continues on next page)
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:

```
<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>
</tbody>
</table>
| --version {1,2} | Set multipage blob version.  
| | Version 1: Multipage blob support disabled.  
| | Version 2: Multipage blob support enabled.  
| | Default: Version 2 |
```

(continues on next page)
To generate encrypted NVS partition:

Usage:

```
python nvs_partition_gen.py encrypt [-h] [--version {1,2}] [--keygen]
--inputkey
```

Positional Arguments:

- `input` output size

You can run the utility to generate encrypted NVS partition using the command below: A sample CSV file is provided with the utility:

```
python nvs_partition_gen.py generate sample_singlepage_blob.csv sample.bin 0x3000
```

To generate only encryption keys:

Usage:

```
python nvs_partition_gen.py generate-key [-h] [--keyfile KEYFILE]
```

Optional Arguments:

```
-h, --help          show this help message and exit

--keyfile KEYFILE  Path to output encryption keys file

--outdir OUTDIR    Output directory to store files created. (Default: current directory)
```

You can run the utility to generate only encryption keys using the command below:

```
python nvs_partition_gen.py generate-key
```

(continues on previous page)
You can run the utility to encrypt NVS partition using the command below: A sample CSV file is provided with the utility:

```bash
inputkey INPUTKEY

<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>
<tr>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
<tr>
<td>--version {1,2}</td>
<td>Set multipage blob version.</td>
</tr>
<tr>
<td></td>
<td>Version 1 - Multipage blob support disabled.</td>
</tr>
<tr>
<td></td>
<td>Version 2 - Multipage blob support enabled.</td>
</tr>
<tr>
<td></td>
<td>Default: Version 2</td>
</tr>
<tr>
<td>--keygen</td>
<td>Generates key for encrypting NVS partition</td>
</tr>
<tr>
<td>--keyfile KEYFILE</td>
<td>Path to output encryption keys file</td>
</tr>
<tr>
<td>--inputkey INPUTKEY</td>
<td>File having key for encrypting NVS partition</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>Output directory to store files created</td>
</tr>
<tr>
<td></td>
<td>(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:

```
inputkey INPUTKEY

<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>
<tr>
<td>-h, --help</td>
<td>show this help message and exit</td>
</tr>
<tr>
<td>--version {1,2}</td>
<td>Set multipage blob version.</td>
</tr>
<tr>
<td></td>
<td>Version 1 - Multipage blob support disabled.</td>
</tr>
<tr>
<td></td>
<td>Version 2 - Multipage blob support enabled.</td>
</tr>
<tr>
<td></td>
<td>Default: Version 2</td>
</tr>
<tr>
<td>--keygen</td>
<td>Generates key for encrypting NVS partition</td>
</tr>
<tr>
<td>--keyfile KEYFILE</td>
<td>Path to output encryption keys file</td>
</tr>
<tr>
<td>--inputkey INPUTKEY</td>
<td>File having key for encrypting NVS partition</td>
</tr>
<tr>
<td>--outdir OUTDIR</td>
<td>Output directory to store files created</td>
</tr>
<tr>
<td></td>
<td>(Default: current directory)</td>
</tr>
</tbody>
</table>
```
To decrypt encrypted NVS partition:

**Usage:**

```python
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>
</tbody>
</table>

Note: Encryption key of the following format `<outdir>/keys/<timestamp>.bin` is created.

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 allowing the utility to generate encryption keys and store it in provided custom filename:

```python
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin
--0x3000 --keygen
```

• Encrypt by providing the encryption keys as input binary file:

```python
python nvs_partition_gen.py encrypt sample_singlepage_blob.csv sample_encr.bin
--0x3000 --inputkey sample_keys.bin
```
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:

```
python nvs_partition_gen.py generate sample_singlepage_blob.csv sample.bin 0x3000 --
--version 1
```

**Multipage 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.
- Utility supports using multilinestringswith `file` type and singlelinestringswith `data` type in the CSV file.
- 64-bit datatype is not yet supported.

### 2.6.5 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/include/driver/sdmmc_host.h and driver/include/driver/sdspli_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()`.

API Reference

Header File

- `components/sdmmc/include/sdmmc_cmd.h`

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.

**Return**

- ESP_OK on success
  - One of the error codes from SDMMC host controller

**Parameters**

- `host`: pointer to structure defining host controller
- `out_card`: pointer to structure which will receive information about the card when the function completes

`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

**Return**

- ESP_OK on success
Chapter 2. API Reference

- One of the error codes from SDMMC host controller

**Parameters**
- **card**: pointer to card information structure previously initialized using sdmmc_card_init

```c
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

**Return**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**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

```c
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

**Return**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**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

```c
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)

**Return**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**Parameters**
- **card**: pointer to card information structure previously initialized using sdmmc_card_init
- **function**: IO function number
- **reg**: byte address within IO function
- **[out] out_byte**: output, receives the value read from the card

```c
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)

**Return**
- ESP_OK on success
- One of the error codes from SDMMC host controller

**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] out_byte**: if not NULL, receives new byte value read from the card (read-after-write).

```c
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.

Return
- ESP_OK on success
- ESP_ERR_INVALID_SIZE if size exceeds 512 bytes
- One of the error codes from SDMMC host controller

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

```c
esp_err_t sdmmc_io_read_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.

Return
- ESP_OK on success
- ESP_ERR_INVALID_SIZE if size exceeds 512 bytes
- One of the error codes from SDMMC host controller

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

```c
esp_err_t sdmmc_io_write_bytes (sdmmc_card_t *card, uint32_t function, uint32_t addr, const void *src, 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.

Return
- 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

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.

```c
esp_err_t sdmmc_io_read_blocks (sdmmc_card_t *card, uint32_t function, uint32_t addr, void *dst, 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.

Return
- 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

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.

```c
esp_err_t sdmmc_io_enable_int (sdmmc_card_t *card)
```
Enable SDIO interrupt in the SDMMC host

**Return**
- **ESP_OK** on success
- **ESP_ERR_NOT_SUPPORTED** if the host controller does not support IO interrupts

**Parameters**
- **card**: pointer to card information structure previously initialized using sdmmc_card_init

```c
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.

**Return**
- **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

**Parameters**
- **card**: pointer to card information structure previously initialized using sdmmc_card_init
- **timeout_ticks**: time to wait for the interrupt, in RTOS 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.

**Return**
- **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**

**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.

```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
```

**Return**
- **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.

**Parameters**
• buffer: Buffer to parse
• buffer_size: Size of the buffer.
• fp: File pointer to print to, set to NULL to print to stdout.

Header File

• components/driver/include/driver/sdmmc_types.h

Structures

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 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
Chapter 2. API Reference

Public Members

int sd_spec
SD Physical layer specification version, reported by card

int bus_width
bus widths supported by card: BIT(0) — 1-bit bus, BIT(2) — 4-bit bus

struct sdmmc_ext_csd_t
Decoded values of Extended Card Specific Data

Public Members

uint8_t power_class
Power class used 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

esp_err_t error
error returned from transfer

int timeout_ms
response timeout, in milliseconds

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.
# Chapter 2. API Reference

## Public Members

- `uint32_t flags`
  - flags defining host properties

- `int slot`
  - slot number, to be passed to host functions

- `int max_freq_khz`
  - max frequency supported by the host

- `float io_voltage`
  - I/O voltage used by the controller (voltage switching is not supported)

- `esp_err_t (*init) (void)`
  - Host function to initialize the driver

- `esp_err_t (*set_bus_width) (int slot, size_t width)`
  - host function to set bus width

- `size_t (*get_bus_width) (int slot)`
  - host function to get bus width

- `esp_err_t (*set_bus_ddr_mode) (int slot, bool ddr_enable)`
  - host function to set DDR mode

- `esp_err_t (*set_card_clk) (int slot, uint32_t freq_khz)`
  - host function to set card clock frequency

- `esp_err_t (*do_transaction) (int slot, sdmmc_command_t *cmdinfo)`
  - host function to do a transaction

- `esp_err_t (*deinit) (void)`
  - host function to deinitialize the driver

- `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.

## 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

- `sdmmc_cid_t cid`
  - decoded CID (Card IDentification) register value

- `sdmmc_response_t raw_cid`
  - raw CID of MMC card to be decoded after the CSD is fetched in the data transfer mode

- `sdmmc_csd_t csd`
  - decoded CSD (Card-Specific Data) register value
Chapter 2. API Reference

`sdmmc_scr_t scr`
decoded SCR (SD card Configuration Register) value

`sdmmc_ext_csd_t ext_csd`
dedecoded 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

`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`
log2(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)

**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
2.6.6 SPI Flash API

Overview

The spi_flash component contains API functions related to reading, writing, erasing, memory mapping for data in the external flash. The spi_flash component also has higher-level API functions which work with partitions defined in the partition table.

Different from the API before 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 to external flash chips connected to not only SPI0/1 but also other SPI buses like SPI2.

**Note:** Instead of 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 to not only the main flash, but also external 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 IDF v4.0 are no longer atomic. A writing operation during another on-going read operation, on the overlapped flash address, may cause the return data from the read operation to be partly same as before, and partly updated as new written.

Kconfig option CONFIG_SPI_FLASH_USE_LEGACY_IMPL can be used to switch spi_flash_* functions back to the implementation before ESP-IDF v4.0. However, the code size may get bigger if you use the new API and the old API at the same time.

Encrypted reads and writes use the old implementation, even if CONFIG_SPI_FLASH_USE_LEGACY_IMPL is not enabled. As such, 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

Flash features of different vendors are operated in different ways and need special support. The fast/slow read and Dual mode (DOUT/DIO) of almost all 24-bits address flash chips 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

Octal mode (OPI) are supported on following chip types:

1. MXIC

**Type Definitions**

typedef uint32_t sdmmc_response_t[4]

SD/MMC command response buffer
Chapter 2. API Reference

To know how to configure menuconfig for a board with different Flash and PSRAM, please refer to the SPI Flash and External SPI RAM Configuration

The 32-bit address range of following chip type is supported:

1. W25Q256
2. GD25Q256

Users can also customize their 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:
   - `spi_flash_chip_drivers.c` (to provide the `default_registered_chips` structure)
   - Any of the `spi_flash_chip_*.c` files that matches your own flash model best
   - `CMakeLists.txt` and `linker.lf` files

   Modify the files above properly.

**Note:**

- When writing your own flash chip driver, you can set your flash chip capabilities through `spi_flash_chip_***(vendor)_get_caps` and points the function pointer `get_chip_caps` for protection to the `spi_flash_chip_***_get_caps` function. The steps are as follows.
  1. Please check whether your flash chip have the capabilities listed in `spi_flash_caps_t` by checking the flash datasheet.
  2. Write a function named `spi_flash_chip_***(vendor)_get_caps`. Take the example below as a reference, (if the flash support `suspend` and `read unique id`).
  3. Points the the pointer `get_chip_caps` (in `spi_flash_chip_t`) to the function mentioned above.

```
spi_flash_caps_t spi_flash_chip_*** (vendor)_get_caps (esp_flash_t *chip) {
    spi_flash_caps_t caps_flags = 0;
    // 32-bit-address flash is not supported
    flash-suspend is supported
    (continues on next page)
```
caps_flags |= SPI_FLASH_CHIP_CAP_SUSPEND;
    // flash read unique id.
caps_flags |= SPI_FLASH_CHIP_CAP_UNIQUE_ID;
    return caps_flags;
}

const spi_flash_chip_t esp_flash_chip_eon = {
    // Other function pointers
    .get_chip_caps = spi_flash_chip_eon_get_caps,
};

• You also can see how to implement this in the example storage/custom_flash_driver.

4. Add linking dependency from spi_flash component to the new custom_chip_driver component, by adding the following lines after the idf_component_register, in the CMakeLists.txt file of the custom_chip_driver component:

```
idf_component_get_property(spi_flash_lib spi_flash COMPONENT_LIB)
set_property(TARGET ${spi_flash_lib} APPEND PROPERTY INTERFACE_LINK_LIBRARIES $<LINK_ONLY:${COMPONENT_LIB}>)
```

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 esp_flash_* APIs, you need to have a chip initialized on a certain SPI bus.

1. Call `spi_bus_initialize()` to properly initialize an SPI bus. This functions initialize 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 onto the bus. This allocates memory, and fill 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. However, using esp_flash_* devices and spi_device_* devices on the same SPI bus is not supported yet.

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 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.

**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-S3, 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, 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 string 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.
Chapter 2. API Reference

**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.

**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 on partition tables can be found [here](#).

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()` - 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 `spi_flash_read()`, `spi_flash_write()`, `spi_flash_erase_range()`, but operate within partition boundaries.

**Note:** Application code should mostly use these `esp_partition_*` API functions instead of lower level `esp_flash_*` API functions. Partition table API functions do bounds checking and calculate correct offsets in flash, based on data stored in a partition table.

**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.

**Memory Mapping API**

ESP32-S3 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 `esp_spi_flash.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, provides support of some OS functions (e.g. lock, delay) in different stages (1st/2st 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-S3 memory-spi functionalities. However due to the speed limitations of ESP32-S3, the HAL layer can’t provide high-speed implementations to some reading commands (So we didn’t do it all). 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 `spi_flash_host_driver_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 `spi_flash_host_driver_t` are implemented, the `esp_flash` API can access to 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 after. Some chips need different command or value, 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 requires to use the bus monopolized during a period. (especially when the device doesn’t have CS wire, or the wire is controlled by the 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.

**See Also**

- *Partition Table documentation*
- *Over The Air Update (OTA) API* provides high-level API for updating app firmware stored in flash.
- *Non-Volatile Storage (NVS) API* provides a structured API for storing small pieces of data in SPI flash.

**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 does it by disabling interrupts/scheduler before performing the flash operation. - In a dual-core setup, this is slightly more complicated as the SDK needs to make sure that the other CPU is 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.
• 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`.

**Return**

- 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.

**Parameters**

- `out_chip`: Pointer to hold the initialized chip.
- `config`: Configuration of the chips to initialize.

```c
esp_err_t spi_bus_remove_flash_device(esp_flash_t *chip)
```

Remove a SPI Flash device from the SPI bus.

**Return**

- ESP_ERR_INVALID_ARG: The chip is invalid.
- ESP_OK: success.

**Parameters**

- `chip`: The flash device to remove.

**Structures**

```c
struct esp_flash_spi_device_config_t
```

Configurations for the SPI Flash to init.

**Public Members**

- `spi_host_device_t host_id`: Bus to use.
- `int cs_io_num`: GPIO pin to output the CS signal.
- `esp_flash_io_mode_t io_mode`: IO mode to read from the Flash.
- `esp_flash_speed_t speed`: Speed of the Flash clock.
- `int input_delay_ns`: Input delay of the data pins, in ns. Set to 0 if unknown.
- `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.

**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.
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.

Return ESP_OK on success, or a flash error code if initialisation fails.

Parameters
- chip: Pointer to SPI flash chip to use. If NULL, esp_flash_default_chip is substituted.

bool esp_flash_chip_driver_initialized(const esp_flash_t *chip)
Check if appropriate chip driver is set.

Return true if set, otherwise false.

Parameters
- chip: Pointer to SPI flash chip to use. If NULL, esp_flash_default_chip is substituted.

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] out_id: Pointer to receive ID value.

Return 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 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.

Return ESP_OK on success, or a flash error code if operation failed.

Parameters
- chip: Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
- [out] out_size: Detected size in bytes.

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] out_id: Pointer to receive unique ID value.

Return
- ESP_OK on success, or a flash error code if operation failed.
- ESP_ERR_NOT_SUPPORTED if the chip doesn’t support read id.

Esp_err_t esp_flash_erase_chip(esp_flash_t *chip)
Erase flash chip contents.

Return
- 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.

Parameters
- chip: Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()

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.

Parameters
• chip: Pointer to identify flash chip. 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.

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.

Return
• 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.

```
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_drvin use (via the ‘chip->drv’ field).

Return ESP_OK on success, or a flash error code if operation failed.

Parameters
• chip: Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
• [out] write_protected: Pointer to boolean, set to the value of the write protect flag.

```
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_drvin use (via the ‘chip->drv’ field).

Parameters
• chip: Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
• write_protect: Boolean value for the write protect flag

Return ESP_OK on success, or a flash error code if operation failed.

```
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_drvin use (via the ‘chip->drv’ field).

Return ESP_OK on success, or a flash error code if operation failed.

Parameters
• chip: Pointer to identify flash chip. Must have been successfully initialised via esp_flash_init()
• [out] out_regions: Pointer to receive a pointer to the array of protectable regions of the chip.
• [out] out_num_regions: Pointer to an integer receiving the count of protectable regions in the array returned in ‘regions’.

```
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_drvin use (via the ‘chip->drv’ field).

Return ESP_OK on success, or a flash error code if operation failed.

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]** `out_protected`: Pointer to a flag which is set based on the protected status for this region.

```c
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).

**Return** ESP_OK on success, or a flash error code if operation failed.

**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.

```c
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.

**Parameters**

- **chip**: Pointer to identify flash chip. 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.  

**Note** If on-chip flash encryption is used, this function returns raw (ie encrypted) data. Use the flash cache to transparently decrypt data.

**Return**

- 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.

```c
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. 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.  

**Return**

- 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_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.
Chapter 2. API Reference

Return
- ESP_OK: on success
- ESP_ERR_NOT_SUPPORTED: encrypted write not supported for this chip.
- ESP_ERR_INVALID_ARG: Either the address, buffer or length is invalid.
- or other flash error code from spi_flash_write_encrypted().

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.

```c
esp_err_t esp_flash_write_encrypted(esp.flash_t *chip, uint32_t address, void *buffer, uint32_t length)
```
Read and decrypt data from the SPI flash chip using on-chip hardware flash encryption.

Return
- ESP_OK: on success
- ESP_ERR_NOT_SUPPORTED: encrypted write not supported for this chip.
- or other flash error code from spi_flash_write_encrypted().

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 read from.
- out_buffer: Pointer to a buffer for the data to read to.
- length: Length (in bytes) of data to read.

```c
static 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.

Return true if flash works in quad mode, otherwise false

Parameters
- chip: Pointer to SPI flash chip to use. If NULL, esp_flash_default_chip is substituted.

Structures

```c
struct esp_flash_region_t
```
Structure for describing a region of flash.

Public Members

```c
uint32_t offset
```
Start address of this region.

```c
uint32_t size
```
Size of the region.

```c
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

```c
esp_err_t (*start)(void *arg)
```
Called before commencing any flash operation. Does not need to be recursive (ie it is called at most once for each call to ‘end’).
Chapter 2. API Reference

```c
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.
   \textbf{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.

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()). 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.

\textbf{Public Members}

\textbf{spi_flash_host_inst_t *host}
   Pointer to hardware-specific “host_driver” structure. Must be initialized before used.

\textbf{const spi_flash_chip_t *chip_drv}
   Pointer to chip-model-specific “adapter” structure. If NULL, will be detected during initialisation.

\textbf{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.

\textbf{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.

uint32_t chip_id
   Detected chip id.

uint32_t busy : 1
   This flag is used to verify chip’s status.

uint32_t reserved_flags : 31
   reserved.
```
Macros
SPI_FLASH_YIELD_REQ_YIELD
SPI_FLASH_YIELD_REQ_SUSPEND
SPI_FLASH_YIELD_STA_RESUME

Type Definitions
typedef struct spi_flash_chip_t spi_flash_chip_t
typedef struct esp_flash_t esp_flash_t

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.

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.CmdConf
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 : 8
   Read flash status register(2) command.

uint32_t sus_cmd : 8
   Flash suspend command.

uint32_t res_cmd : 8
   Flash resume command.

uint32_t reserved : 8
   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.

Parameters
   • address: The destination address in flash for the write operation.
   • buffer: Data for programming
   • 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
   Parameters
      • address: the address of written flash partition.
      • 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
Chapter 2. API Reference

**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 given buffer can be directly used to write

**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.

**Return** Length that can be actually written in one `program_page` call

**Parameters**

- **address**: Beginning flash address to write
- **len**: Length request to write
- **align_addr**: Output of the aligned address to write to
- **page_size**: Physical page size of the flash chip

**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 given buffer can be directly used to read

**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.

**Return** Length that can be actually read in one `read` call

**Parameters**

- **address**: Beginning flash address to read
- **len**: Length request to read
- **align_addr**: Output of the aligned address to read
- **page_size**: Physical page size of the flash chip

**uint32_t (**host_status**) (spi_flash_host_inst_t *host)**

Check the host status, 0: busy, 1: idle, 2: suspended.

**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.
void (*poll_cmd_done)(spi_flash_host_inst_t *host)
    Internal use, poll the HW until the last operation is done.

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.

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.

void (*resume)(spi_flash_host_inst_t *host)
    Resume flash from suspend manually

void (*suspend)(spi_flash_host_inst_t *host)
    Set flash in suspend status manually

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.

ESP_FLASH_SPEED_MIN
    Lowest speed supported by the driver, currently 5 MHz.

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 struct spi_flash_host_driver_s spi_flash_host_driver_t

Enumerations
enum 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.

Values:

ESP_FLASH_5MHZ = 0
    The flash runs under 5MHz.

ESP_FLASH_10MHZ
    The flash runs under 10MHz.

ESP_FLASH_20MHZ
    The flash runs under 20MHz.
**ESP_FLASH_26MHZ**
The flash runs under 26MHz.

**ESP_FLASH_40MHZ**
The flash runs under 40MHz.

**ESP_FLASH_80MHZ**
The flash runs under 80MHz.

**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.

**ESP_FLASH_SPEED_MAX**
The maximum frequency supported by the host is ESP_FLASH_SPEED_MAX-1.

```c
enum esp_flash_io_mode_t
```

Mode used for reading from SPI flash.

*Values:*

- **SPI_FLASH_SLOWRD** = 0
  Data read using single I/O, some limits on speed.
- **SPI_FLASH_FASTRD**
  Data read using single I/O, no limit on speed.
- **SPI_FLASH_DOUT**
  Data read using dual I/O.
- **SPI_FLASH_DIO**
  Both address & data transferred using dual I/O.
- **SPI_FLASH_QOUT**
  Data read using quad I/O.
- **SPI_FLASH_QIO**
  Both address & data transferred using quad I/O.
- **SPI_FLASH_OPI_STR** = SPI_FLASH_OPI_FLAG
  Only support on OPI flash, flash read and write under STR mode.
- **SPI_FLASH_OPI_DTR**
  Only support on OPI flash, flash read and write under DTR mode.
- **SPI_FLASH_READ_MODE_MAX**
  The fastest io mode supported by the host is ESP_FLASH_READ_MODE_MAX-1.

---

**API Reference - Partition Table**

**Header File**

- components/spi_flash/include/esp_partition.h

**Functions**

```c
esp_partition_iterator_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.

**Return** 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.

**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.

```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.

**Return** pointer to esp_partition_t structure, or NULL if no partition is found. This pointer is valid for the lifetime of the application.

**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.

```c
const esp_partition_t *esp_partition_get (esp_partition_iterator_t iterator)
```

Get esp_partition_t structure for given partition.

**Return** pointer to esp_partition_t structure. This pointer is valid for the lifetime of the application.

**Parameters**
• **iterator**: Iterator obtained using esp_partition_find. Must be non-NULL.

```c
esp_partition_iterator_t esp_partition_next (esp_partition_iterator_t iterator)
```

Move partition iterator to the next partition found.

Any copies of the iterator will be invalid after this call.

**Return** NULL if no partition was found, valid esp_partition_iterator_t otherwise.

**Parameters**
• **iterator**: Iterator obtained using esp_partition_find. Must be non-NULL.

```c
void esp_partition_iterator_release (esp_partition_iterator_t iterator)
```

Release partition iterator.

**Parameters**
• **iterator**: Iterator obtained using esp_partition_find. The iterator is allowed to be NULL, so it is not necessary to check its value before calling this function.

```c
const esp_partition_t *esp_partition_verify (const esp_partition_t *partition)
```

Verify partition data.

Given a pointer to partition data, verify this partition exists in the partition table (all fields match.)

This function is also useful to take partition data which may be in a RAM buffer and convert it to a pointer to the permanent partition data stored in flash.

Pointers returned from this function can be compared directly to the address of any pointer returned from esp_partition_get(), as a test for equality.

**Return**
• If partition not found, returns NULL.
• If found, returns a pointer to the esp_partition_t structure in flash. This pointer is always valid for the lifetime of the application.

**Parameters**
• **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.

```c
esp_err_t esp_partition_read (const esp_partition_t *partition, size_t src_offset, void *dst, size_t size)
```

Read data from the partition.
Partitions marked with an encryption flag will automatically be read and decrypted via a cache mapping.

**Return** 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.

**Parameters**
- `partition`: Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- `dst`: Pointer to the buffer where data should be stored. Pointer must be non-NULL and buffer must be at least ‘size’ bytes long.
- `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.

```c
esp_err_t esp_partition_read_raw(const esp_partition_t *partition, size_t src_offset, void *dst, size_t size)
```

Write data to the partition.

Before writing data to flash, corresponding region of flash needs to be erased. This can be done using esp_partition_erase_range function.

Partitions marked with an encryption flag will automatically be written via the spi_flash_write_encrypted() function. If writing to an encrypted partition, all write offsets and lengths must be multiples of 16 bytes. See the spi_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.

**Return** 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.

**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.

```c
esp_err_t esp_partition_write(const esp_partition_t *partition, size_t dst_offset, const void *src, 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.

**Return** 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.

**Parameters**
- `partition`: Pointer to partition structure obtained using esp_partition_find_first or esp_partition_get. Must be non-NULL.
- `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.

```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.

**Note** Prior to writing to flash memory, make sure it has been erased with esp_partition_erase_range call.
Return 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.

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.

```c
esp_err_t esp_partition_erase_range(const esp_partition_t *partition, size_t offset, size_t size)
```
Erase part of the partition.

Return 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.

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 4 kilobytes.
- `size`: Size of the range which should be erased, in bytes. Must be divisible by 4 kilobytes.

```c
esp_err_t esp_partition_mmap(const esp_partition_t *partition, size_t offset, size_t size,
                            spi_flash_mmap_memory_t memory, const void **out_ptr,
                            spi_flash_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 handler returned via `out_handle` argument to `spi_flash_munmap` function.

Return ESP_OK, if successful

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 `spi_flash_munmap` call

```c
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.

Return
- 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.

Parameters
Chapter 2. API Reference

- [in] `partition`: Pointer to info for partition containing app or data. (fields: address, size and type, are required to be filled).
- [out] `sha_256`: Returned SHA-256 digest for a given partition.

**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.

**Return**
- True: In case of the two firmware is equal.
- False: Otherwise

**Parameters**
- [in] `partition_1`: Pointer to info for partition 1 containing app or data. (fields: address, size and type, are required to be filled).
- [in] `partition_2`: Pointer to info for partition 2 containing app or data. (fields: address, size and type, are required to be filled).

**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.

**Return**
- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if `CONFIG_CONFIG_SPI_FLASH_USE_LEGACY_IMPL` is enabled
- 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

**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 can not 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] `out_partition`: Output, if non-NULL, receives the pointer to the resulting `esp_partition_t` structure

**esp_err_t esp_partition_deregister_external(const esp_partition_t *partition)**

Deregister the partition previously registered using `esp_partition_register_external`.

**Return**
- 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.

**Parameters**
- `partition`: pointer to the partition structure obtained from `esp_partition_register_external`.

**Structures**

**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

esp_partition_type_t type
    partition type (app/data)

esp_partition_subtype_t subtype
    partition subtype

uint32_t address
    starting address of the partition in flash

uint32_t size
    size of the partition, in bytes

char label[17]
    partition label, zero-terminated ASCII string

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.
```

**Type Definitions**

```c
typedef struct esp_partition_iterator_opaque_ *esp_partition_iterator_t
    Opaque partition iterator type.
```

**Enumerations**

```c
enum esp_partition_type_t
    Partition type.

    Note Partition types with integer value 0x00-0x3F are reserved for partition types defined by ESP-IDF. Any other integer value 0x40-0xFE can be used by individual applications, without restriction.

    Values:

    ESP_PARTITION_TYPE_APP = 0x00
        Application partition type.

    ESP_PARTITION_TYPE_DATA = 0x01
        Data partition type.

    ESP_PARTITION_TYPE_ANY = 0xff
        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:

    ESP_PARTITION_SUBTYPE_APP_FACTORY = 0x00
        Factory application partition.
```
ESP_PARTITION_SUBTYPE_APP_OTA_MIN = 0x10
Base for OTA partition subtypes.

ESP_PARTITION_SUBTYPE_APP_OTA_0 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 0
OTA partition 0.

ESP_PARTITION_SUBTYPE_APP_OTA_1 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 1
OTA partition 1.

ESP_PARTITION_SUBTYPE_APP_OTA_2 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 2
OTA partition 2.

ESP_PARTITION_SUBTYPE_APP_OTA_3 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 3
OTA partition 3.

ESP_PARTITION_SUBTYPE_APP_OTA_4 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 4
OTA partition 4.

ESP_PARTITION_SUBTYPE_APP_OTA_5 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 5
OTA partition 5.

ESP_PARTITION_SUBTYPE_APP_OTA_6 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 6
OTA partition 6.

ESP_PARTITION_SUBTYPE_APP_OTA_7 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 7
OTA partition 7.

ESP_PARTITION_SUBTYPE_APP_OTA_8 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 8
OTA partition 8.

ESP_PARTITION_SUBTYPE_APP_OTA_9 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 9
OTA partition 9.

ESP_PARTITION_SUBTYPE_APP_OTA_10 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 10
OTA partition 10.

ESP_PARTITION_SUBTYPE_APP_OTA_11 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 11
OTA partition 11.

ESP_PARTITION_SUBTYPE_APP_OTA_12 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 12
OTA partition 12.

ESP_PARTITION_SUBTYPE_APP_OTA_13 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 13
OTA partition 13.

ESP_PARTITION_SUBTYPE_APP_OTA_14 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 14
OTA partition 14.

ESP_PARTITION_SUBTYPE_APP_OTA_15 = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 15
OTA partition 15.

ESP_PARTITION_SUBTYPE_APP_OTA_MAX = ESP_PARTITION_SUBTYPE_APP_OTA_MIN + 16
Max subtype of OTA partition.

ESP_PARTITION_SUBTYPE_APP_TEST = 0x20
Test application partition.

ESP_PARTITION_SUBTYPE_DATA_OTA = 0x00
OTA selection partition.

ESP_PARTITION_SUBTYPE_DATA_PHY = 0x01
PHY init data partition.

ESP_PARTITION_SUBTYPE_DATA_NVS = 0x02
NVS partition.

ESP_PARTITION_SUBTYPE_DATA_COREDUMP = 0x03
COREDUMP partition.
ESP_PARTITION_SUBTYPE_DATA_NVS_KEYS = 0x04
Partition for NVS keys.

ESP_PARTITION_SUBTYPE_DATA_EFUSE_EM = 0x05
Partition for emulate eFuse bits.

ESP_PARTITION_SUBTYPE_DATA_UNDEFINED = 0x06
Undefined (or unspecified) data partition.

ESP_PARTITION_SUBTYPE_DATA_ESPHTTPD = 0x80
ESPHTTPD partition.

ESP_PARTITION_SUBTYPE_DATA_FAT = 0x81
FAT partition.

ESP_PARTITION_SUBTYPE_DATA_SPIFFS = 0x82
SPIFFS partition.

ESP_PARTITION_SUBTYPE_DATA_ANY = 0xff
Used to search for partitions with any subtype.

API Reference - Flash Encrypt

Header File

- components/bootloader_support/include/esp_flash_encrypt.h

Functions

static 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.

Return true if flash encryption is enabled.

esp_err_t esp_flash_encrypt_check_and_update (void)

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.

Return ESP_OK if all operations succeeded, ESP_ERR_FLASH_OP_FAIL if SPI flash fails,
ESP_ERR_FLASH_OP_TIMEOUT if flash times out.

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.

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-flashing 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

Return
void esp_flash_encryption_init_checks (void)
Check the flash encryption mode during startup.

Verifies the flash encryption config during startup:

Note This function is called automatically during app startup, it doesn’t need to be called from the app.

• 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

esp_err_t esp_flash_encryption_enable_secure_features (void)
Set all secure eFuse features related to flash encryption.

Return
• ESP_OK - Successfully

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:
ESP_FLASH_ENC_MODE_DISABLED
ESP_FLASH_ENC_MODE_DEVELOPMENT
ESP_FLASH_ENC_MODE_RELEASE

2.6.7 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.

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:
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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 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:

```
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:
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```
mkspiffs -c [src_folder] -b 4096 -p 256 -s 0x100000 spiffs.bin
```

To flash the image onto ESP32-S3 at offset 0x110000, run:

```
python esptool.py --chip esp32s3 --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.

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.

  Return

  - 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

  Parameters

  - `conf`: Pointer to `esp_vfs_spiffs_conf_t` configuration structure

- `esp_err_t esp_vfs_spiffs_unregister(const char *partition_label)`

  Unregister and unmount SPIFFS from VFS
Return
- ESP_OK if successful
- ESP_ERR_INVALID_STATE already unregistered

Parameters
- partition_label: Same label as passed to esp_vfs_spiffs_register.

bool esp_spiffs_mounted(const char *partition_label)
Check if SPIFFS is mounted

Return
- true if mounted
- false if not mounted

Parameters
- partition_label: Optional, label of the partition to check. If not specified, first partition with subtype=spiffs is used.

esp_err_t esp_spiffs_format(const char *partition_label)
Format the SPIFFS partition

Return
- ESP_OK if successful
- ESP_FAIL on error

Parameters
- partition_label: Same label as passed to esp_vfs_spiffs_register.

esp_err_t esp_spiffs_info(const char *partition_label, size_t *total_bytes, size_t *used_bytes)
Get information for SPIFFS

Return
- ESP_OK if success
- ESP_ERR_INVALID_STATE if not mounted

Parameters
- partition_label: Same label as passed to esp_vfs_spiffs_register
- [out] total_bytes: Size of the file system
- [out] used_bytes: Current used bytes in the file system

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.

2.6.8 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 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);
```

// 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);
```

// 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:

(continues on next page)
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/esp32/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 fscanf("%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(_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 *data, 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)
Registration a virtual filesystem for given path prefix.

Return ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered.

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 cannot 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.

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.

Return 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.

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).

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.

Return 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.

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.

```c
esp_err_t esp_vfs_unregister(const char *base_path)
```

Unregister a virtual filesystem for given path prefix.

**Return** ESP_OK if successful, ESP_ERR_INVALID_STATE if VFS for given prefix hasn’t been registered.

**Parameters**
- `base_path`: file prefix previously used in esp_vfs_register call

```c
esp_err_t esp_vfs_unregister_with_id(esp_vfs_id_t vfs_id)
```

Unregister a virtual filesystem with the given index.

**Return** ESP_OK if successful, ESP_ERR_INVALID_STATE if VFS for the given index hasn’t been registered.

**Parameters**
- `vfs_id`: The VFS ID returned by esp_vfs_register_with_id

```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.

**Return** 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.

**Parameters**
- `vfs_id`: VFS identificator returned by esp_vfs_register_with_id.
- `fd`: The registered file descriptor will be written to this address.

```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.

**Return** 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.

**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.

```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.

**Return** ESP_OK if the registration is successful, ESP_ERR_INVALID_ARG if the arguments are incorrect.

**Parameters**
- `vfs_id`: VFS identificator returned by esp_vfs_register_with_id.
- `fd`: File descriptor which should be unregistered.

```c
int esp_vfs_select(int nfds, fd_set *readfds, fd_set *writefds, fd_set *errorfds, struct timeval *timeout)
```

Synchronous I/O multiplexing which implements the functionality of POSIX select() for VFS.

**Return** The number of descriptors set in the descriptor sets, or -1 when an error (specified by errno) have occurred.

**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.
- `writefds`: 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.
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- `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.

```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 pTTRUE 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()`

**Return** A positive return value indicates the number of bytes read. -1 is return on failure and `errno` is set accordingly.

**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

```c
ssize_t esp_vfs_pwrite(int fd, const void *src, size_t size, off_t offset)
```

Implements the VFS layer of POSIX `pwrite()`

**Return** A positive return value indicates the number of bytes written. -1 is return on failure and `errno` is set accordingly.

**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

**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

```c
void *sem
```

semaphore instance

```c
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**

```c
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
```

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int (*\texttt{stat})(\texttt{const} char *\texttt{path}, \texttt{struct stat} *\texttt{st})  
\hspace{1cm} \textit{stat without context pointer}

int (*\texttt{link_p})(\texttt{void *}\texttt{ctx}, \texttt{const} char *\texttt{n1}, \texttt{const} char *\texttt{n2})  
\hspace{1cm} \textit{link with context pointer}

int (*\texttt{link})(\texttt{const} char *\texttt{n1}, \texttt{const} char *\texttt{n2})  
\hspace{1cm} \textit{link without context pointer}

int (*\texttt{unlink_p})(\texttt{void *}\texttt{ctx}, \texttt{const} char *\texttt{path})  
\hspace{1cm} \textit{unlink with context pointer}

int (*\texttt{unlink})(\texttt{const} char *\texttt{path})  
\hspace{1cm} \textit{unlink without context pointer}

int (*\texttt{rename_p})(\texttt{void *}\texttt{ctx}, \texttt{const} char *\texttt{src}, \texttt{const} char *\texttt{dst})  
\hspace{1cm} \textit{rename with context pointer}

int (*\texttt{rename})(\texttt{const} char *\texttt{src}, \texttt{const} char *\texttt{dst})  
\hspace{1cm} \textit{rename without context pointer}

\texttt{DIR} *(*\texttt{opendir_p})(\texttt{void *}\texttt{ctx}, \texttt{const} char *\texttt{name})  
\hspace{1cm} \textit{opendir with context pointer}

\texttt{DIR} *(*\texttt{opendir})(\texttt{const} char *\texttt{name})  
\hspace{1cm} \textit{opendir without context pointer}

\texttt{struct dirent} *(\texttt{readdir_p})(\texttt{void *}\texttt{ctx}, \texttt{DIR} *\texttt{pdir})  
\hspace{1cm} \textit{readdir with context pointer}

\texttt{struct dirent} *(\texttt{readdir})(\texttt{DIR} *\texttt{pdir})  
\hspace{1cm} \textit{readdir without context pointer}

int (*\texttt{readdir_r_p})(\texttt{void *}\texttt{ctx}, \texttt{DIR} *\texttt{pdir}, \texttt{struct dirent} *\texttt{entry}, \texttt{struct dirent **out_dirent})  
\hspace{1cm} \textit{readdir_r with context pointer}

int (*\texttt{readdir_r})(\texttt{DIR} *\texttt{pdir}, \texttt{struct dirent} *\texttt{entry}, \texttt{struct dirent **out_dirent})  
\hspace{1cm} \textit{readdir_r without context pointer}

long (*\texttt{telldir_p})(\texttt{void *}\texttt{ctx}, \texttt{DIR} *\texttt{pdir})  
\hspace{1cm} \textit{telldir with context pointer}

long (*\texttt{telldir})(\texttt{DIR} *\texttt{pdir})  
\hspace{1cm} \textit{telldir without context pointer}

void (*\texttt{seekdir_p})(\texttt{void *}\texttt{ctx}, \texttt{DIR} *\texttt{pdir}, long offset)  
\hspace{1cm} \textit{seekdir with context pointer}

void (*\texttt{seekdir})(\texttt{DIR} *\texttt{pdir}, long offset)  
\hspace{1cm} \textit{seekdir without context pointer}

int (*\texttt{closedir_p})(\texttt{void *}\texttt{ctx}, \texttt{DIR} *\texttt{pdir})  
\hspace{1cm} \textit{closedir with context pointer}

int (*\texttt{closedir})(\texttt{DIR} *\texttt{pdir})  
\hspace{1cm} \textit{closedir without context pointer}

int (*\texttt{mkdir_p})(\texttt{void *}\texttt{ctx}, \texttt{const} char *\texttt{name}, mode_t mode)  
\hspace{1cm} \textit{mkdir with context pointer}

int (*\texttt{mkdir})(\texttt{const} char *\texttt{name}, mode_t mode)  
\hspace{1cm} \textit{mkdir without context pointer}

int (*\texttt{rmdir_p})(\texttt{void *}\texttt{ctx}, \texttt{const} char *\texttt{name})  
\hspace{1cm} \textit{rmdir with context pointer}

int (*\texttt{rmdir})(\texttt{const} char *\texttt{name})  
\hspace{1cm} \textit{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)
    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 (*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 (*tgetattr_p)(void *ctx, int fd, struct termios *p)
    tgetattr with context pointer
int (*tgetattr)(int fd, struct termios *p)
    tgetattr 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
    tcgetsid without 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 (\r, LF) passed into stdin:
Chapter 2. API Reference

- 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

```c
void 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 (\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

**Note** this function is not thread safe w.r.t. writing to UART

**Parameters**
- **mode**: line endings to send to UART

```c
int 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 (\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

**Return** 0 if successed, or -1 when an error (specified by errno) have occurred.

**Parameters**
- **uart_num**: the UART number
- **mode**: line endings to send to UART

```c
int 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 (\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

**Note** this function is not thread safe w.r.t. writing to UART

**Return** 0 if successed, or -1 when an error (specified by errno) have occurred.

**Parameters**
- **uart_num**: the UART number
- **mode**: line endings to send to UART

```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.

**Parameters**
- **uart_num**: UART peripheral number
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 func-
    tions, read and write are blocking and interrupt-driven.

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
esp_err_t esp_vfs_eventfd_register (const esp_vfs_eventfd_config_t *config)
    Registers the event vfs.
    Return ESP_OK if successful, ESP_ERR_NO_MEM if too many VFSes are registered.

esp_err_t esp_vfs_eventfd_unregister (void)
    Unregisters the event vfs.
    Return ESP_OK if successful, ESP_ERR_INVALID_STATE if VFS for given prefix hasn’t been registered

int eventfd (unsigned int initval, int flags)

Structures
struct esp_vfs_eventfd_config_t
    Eventfd vfs initialization settings.

    Public Members

    size_t max_fds
        The maximum number of eventfds supported

Macros
EFD_SUPPORT_ISR
ESP_VFS_EVENTD_CONFIG_DEFAULT ()

2.6.9 Wear Levelling API

Overview

Most of flash memory and especially SPI flash that is used in ESP32-S3 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` - initialises the wear levelling module and mounts the specified partition
- `wl_unmount` - 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*
- *Partition Table documentation*

### Application Example

An example which 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 the `storage/wear_levelling/README.md` file for more information.

### High level API Reference

#### Header Files

- `fatfs/vfs/esp_vfs_fat.h`

#### Functions

```c
esp_err_t esp vfs_fat_spiflash_mount (const char *base_path, const char *partition_label, const esp vfs fat mount config *mount_config, wl handle *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.

Return
• 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 was already called
• ESP_ERR_NO_MEM if memory cannot be allocated
• ESP_FAIL if partition can not be mounted
• other error codes from wear levelling library, SPI flash driver, or FATFS drivers

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
• [out] wl_handle: wear levelling driver handle

struct esp_vfs_fat_mount_config_t
Configuration arguments for esp_vfs_fat_sdmmc_mount and esp_vfs_fat_spiflash_mount functions.

Public Members

bool format_if_mount_failed
If FAT partition can not be mounted, and this parameter is true, create partition table and format the filesystem.

int max_files
Max number of open files.

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.

esp_err_t esp_vfs_fat_spiflashUnmount (const char *base_path, wl_handle_t wl_handle)
Unmount FAT filesystem and release resources acquired using esp_vfs_fat_spiflash_mount.

Return
• ESP_OK on success
• ESP_ERR_INVALID_STATE if esp_vfs_fat_spiflash_mount hasn’t been called

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

Mid level API Reference

Header File
• components/wear_levelling/include/wear_levelling.h

Functions
esp_err_t wl_mount (const esp_partition_t *partition, wl_handle_t *out_handle)
Mount WL for defined partition.

Return
• 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;

Parameters
• partition: that will be used for access
• out_handle: handle of the WL instance

esp_err_t wlUnmount (wl_handle_t handle)
Unmount WL for defined partition.

Return
• ESP_OK, if the operation completed successfully;
• or one of error codes from lower-level flash driver.

Parameters
• handle: WL partition handle

esp_err_t wlEraseRange (wl_handle_t handle, size_t start_addr, size_t size)
Erase part of the WL storage.

Return
• 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.

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(...).

esp_err_t wlWrite (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
wlEraseRange function.

Note Prior to writing to WL storage, make sure it has been erased with wlEraseRange call.

Return
• 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.

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.

esp_err_t wlRead (wl_handle_t handle, size_t src_addr, void* dest, size_t size)
Read data from the WL storage.

Return
• 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.

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.
Chapter 2. API Reference

- size: Size of data to be read, in bytes.

```c
size_t wl_size(wl_handle_t handle)
```

Get size of the WL storage.

**Return** usable size, in bytes

**Parameters**

- handle: WL module handle that was initialized before

```c
size_t wl_sector_size(wl_handle_t handle)
```

Get sector size of the WL instance.

**Return** sector size, in bytes

**Parameters**

- handle: WL module handle that was initialized before

**Macros**

```c
WL_INVALID_HANDLE
```

**Type Definitions**

```c
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.

### 2.7 System API

#### 2.7.1 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-S3’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 esp32s3 image_info build/app.bin
```

(continues on next page)
Section 7: len 0x09600 load 0x40088400 file_offs 0x00016a08 SOC_IRAM
Segment 8: len 0x62e4c load 0x400d0018 file_offs 0x00020010 SOC_IROM
Segment 9: len 0x06cece load 0x40089a00 file_offs 0x00082e64 SOC_IROM
Segment 10: len 0x00000 load 0x400c0000 file_offs 0x00089b58 SOC_RTC_IRAM
Segment 11: len 0x00000 load 0x50000000 file_offs 0x00089b60 SOC_RTC_DATA
Segment 12: len 0x00000 load 0x50000004 file_offs 0x00089b6c SOC_RTC_DATA
Segment 13: len 0x00000 load 0x50000004 file_offs 0x00089b74 SOC_RTC_DATA
Checksum: e8 (valid) Validation Hash: ~407089ca0eae2bbf83b412979d3354b1c938a49cb7a0c997f240474ef2ec76b (valid)

You can also see the information on segments in the IDF logs while your application is booting:

| I (443) esp_image: segment 0: paddr=0x00020020 vaddr=0x3f400020 size=0x13ce0 | ...
| I (489) esp_image: segment 1: paddr=0x00033d08 vaddr=0x3ff80000 size=0x000000 ( 0) |
| I (530) esp_image: segment 2: paddr=0x00033d10 vaddr=0x3ff80000 size=0x000000 ( 0) |
| I (571) esp_image: segment 3: paddr=0x00033d18 vaddr=0x3ff80000 size=0x028e0 |
| I (612) esp_image: segment 4: paddr=0x00036600 vaddr=0x3ffbb28e0 size=0x000000 ( 0) |
| I (654) esp_image: segment 5: paddr=0x00036608 vaddr=0x40080000 size=0x004000 ( 0) |
| I (695) esp_image: segment 6: paddr=0x00036a10 vaddr=0x40080400 size=0x09600 |
| I (737) esp_image: segment 7: paddr=0x00040018 vaddr=0x400d0018 size=0x62e4c |
| I (847) esp_image: segment 8: paddr=0x000a2e6c vaddr=0x40089a00 size=0x06cece |
| I (888) esp_image: segment 9: paddr=0x000a9b60 vaddr=0x400c0000 size=0x000000 ( 0) |
| I (929) esp_image: segment 10: paddr=0x000a9b68 vaddr=0x50000000 size=0x000004 ( 4) |
| I (971) esp_image: segment 11: paddr=0x000a9b74 vaddr=0x50000004 size=0x000000 ( 0) |
| I (1012) esp_image: segment 12: paddr=0x000a9b7c vaddr=0x50000004 size=0x000000 ( 0) | ...

For more details on the type of memory segments and their address ranges, see ESP32-S3 Technical Reference Manual > System and Memory > Internal 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 SHA256 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 options CONFIG_SECURE_SIGNED_APPS_SCHEME is set to ECDSA then the application image will have additional 68 bytes for an ECDSA signature, which includes:
   - version word (4 bytes),
   - signature data (64 bytes).

Application Description

The DROM segment 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 for the elf application file.

* - The maximum length is 32 characters, including null-termination character. For example, if the length of PROJECT_NAME exceeds 32 characters, the excess characters will be disregarded.

This structure is useful for identification of images uploaded OTA 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 or not.

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**: 4
flash frequency (esp_image_spi_freq_t as uint8_t)

uint8_t **spi_size**: 4
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)

\texttt{esp\_chip\_id} / chip_id
  Chip identification number

uint8_t min_chip_rev
  Minimum chip revision supported by image

uint8_t reserved[8]
  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).

\texttt{struct esp\_image\_segment\_header\_t}
  Header of binary image segment.

\textbf{Public Members}

uint32_t load_addr
  Address of segment

uint32_t data_len
  Length of data

\texttt{struct esp\_app\_desc\_t}
  Description about application.

\textbf{Public Members}

uint32_t magic_word
  Magic word ESP_APP_DESC_MAGIC_WORD

uint32_t secure_version
  Secure version

uint32_t reserv1[2]
  reserv1

c char version[32]
  Application version

c char project_name[32]
  Project name

c char time[16]
  Compile time

c char date[16]
  Compile date

c char idf_ver[32]
  Version IDF

uint8_t app_elf_sha256[32]
  sha256 of elf file

uint32_t reserv2[20]
  reserv2
Chapter 2. API Reference

**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.

**ESP_APP_DESC_MAGIC_WORD**
The magic word for the `esp_app_desc` structure that is in DROM.

**Enumerations**

`enum esp_chip_id_t`

ESP chip ID.

*Values:*

- `ESP_CHIP_ID_ESP32 = 0x0000`
  
  chip ID: ESP32

- `ESP_CHIP_ID_ESP32S2 = 0x0002`
  
  chip ID: ESP32-S2

- `ESP_CHIP_ID_ESP32C3 = 0x0005`
  
  chip ID: ESP32-C3

- `ESP_CHIP_ID_ESP32S3 = 0x0009`
  
  chip ID: ESP32-S3

- `ESP_CHIP_ID_ESP32C2 = 0x000C`
  
  chip ID: ESP32-C2

- `ESP_CHIP_ID_INVALID = 0xFFFF`

  Invalid chip ID (we defined it to make sure the esp_chip_id_t is 2 bytes size)

`enum esp_image_spi_mode_t`

SPI flash mode, used in `esp_image_header_t`.

*Values:*

- `ESP_IMAGE_SPI_MODE_QIO`
  
  SPI mode QIO

- `ESP_IMAGE_SPI_MODE_QOUT`
  
  SPI mode QOUT

- `ESP_IMAGE_SPI_MODE_DIO`
  
  SPI mode DIO

- `ESP_IMAGE_SPI_MODE_DOUT`
  
  SPI mode DOUT

- `ESP_IMAGE_SPI_MODE_FAST_READ`
  
  SPI mode FAST_READ

- `ESP_IMAGE_SPI_MODE_SLOW_READ`
  
  SPI mode SLOW_READ

`enum esp_image_spi_freq_t`

SPI flash clock frequency.

*Values:*

- `ESP_IMAGE_SPI_SPEED_40M`
  
  SPI clock frequency 40 MHz

- `ESP_IMAGE_SPI_SPEED_26M`
  
  SPI clock frequency 26 MHz
Chapter 2. API Reference

ESP_IMAGE_SPI_SPEED_20M
SPI clock frequency 20 MHz

ESP_IMAGE_SPI_SPEED_80M = 0xF
SPI clock frequency 80 MHz

enum esp_image_flash_size_t
Supported SPI flash sizes.

Values:

ESP_IMAGE_FLASH_SIZE_1MB = 0
SPI flash size 1 MB

ESP_IMAGE_FLASH_SIZE_2MB
SPI flash size 2 MB

ESP_IMAGE_FLASH_SIZE_4MB
SPI flash size 4 MB

ESP_IMAGE_FLASH_SIZE_8MB
SPI flash size 8 MB

ESP_IMAGE_FLASH_SIZE_16MB
SPI flash size 16 MB

ESP_IMAGE_FLASH_SIZE_32MB
SPI flash size 32 MB

ESP_IMAGE_FLASH_SIZE_64MB
SPI flash size 64 MB

ESP_IMAGE_FLASH_SIZE_128MB
SPI flash size 128 MB

ESP_IMAGE_FLASH_SIZE_MAX
SPI flash size MAX

2.7.2 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-S3 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 info 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.
Chapter 2. API Reference

Return 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 initiating any data transfer using esp_apptrace_buffer_get and esp_apptrace_write. 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.

Return non-NULL on success, otherwise NULL.

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.

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.

Return ESP_OK on success, otherwise see esp_err_t

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.

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.

Return ESP_OK on success, otherwise see esp_err_t

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.

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.

Return Number of bytes written.

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.

int esp_apptrace_vprintf(const char *fmt, va_list ap)
vprintf-like function to send log messages to host.

Return Number of bytes written.

Parameters
• fmt: Address of format string.
• ap: List of arguments.

esp_err_t esp_apptrace_flush(esp_apptrace_dest_t dest, uint32_t tmo)
Flushes remaining data in trace buffer to host.

Return ESP_OK on success, otherwise see esp_err_t
Chapter 2. API Reference

**Parameters**
- **dest**: Indicates HW interface to flush data on.
- **tmo**: Timeout for operation (in us). Use ESP_APTRACE_TMO_INFINITE to wait indefinitely.

```c
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.

**Return** ESP_OK on success, otherwise see esp_err_t

**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_APTRACE_TMO_INFINITE to wait indefinitely.

```c
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.

**Return** ESP_OK on success, otherwise see esp_err_t

**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_APTRACE_TMO_INFINITE to wait indefinitely.

```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.

**Return** non-NULL on success, otherwise NULL.

**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_APTRACE_TMO_INFINITE to wait indefinitely.

```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.

**Return** ESP_OK on success, otherwise see esp_err_t

**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_APTRACE_TMO_INFINITE to wait indefinitely.

```c
bool esp_apptrace_host_is_connected(esp_apptrace_dest_t dest)
```
Checks whether host is connected.

**Return** true if host is connected, otherwise false

**Parameters**
- **dest**: Indicates HW interface to use.

```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.

**Return** non zero file handle on success, otherwise 0

**Parameters**
- **dest**: Indicates HW interface to use.
- **path**: Path to file.
- **mode**: Mode string. See fopen for details.
**Chapter 2. API Reference**

```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.

Return Zero on success, otherwise non-zero. See fclose for details.
Parameters
• dest: Indicates HW interface to use.
• stream: File handle returned by esp_apptrace_fopen.
```

```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.

Return Number of written items. See fwrite for details.
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.
```

```c
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.

Return Number of read items. See fread for details.
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.
```

```c
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.

Return Zero on success, otherwise non-zero. See fseek for details.
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.
```

```c
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.

Return Current position in file. See ftell for details.
Parameters
• dest: Indicates HW interface to use.
• stream: File handle returned by esp_apptrace_fopen.
```

```c
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.).

Return ESP_OK on success, otherwise see esp_err_t
Parameters
• dest: Indicates HW interface to use.
```

```c
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:

ESP_APPTRACE_DEST_JTAG = 1
JTAG destination.

ESP_APPTRACE_DEST_TRAX = ESP_APPTRACE_DEST_JTAG
xxx_TRAX name is obsolete, use more common xxx_JTAG

ESP_APPTRACE_DEST_UART0
UART0 destination.

ESP_APPTRACE_DEST_MAX = ESP_APPTRACE_DEST_UART0

ESP_APPTRACE_DEST_NUM

Header File

- components/app_trace/include/esp_sysview_trace.h

Functions

static esp_err_t esp_sysview_flush (uint32_t tmo)
Flushes remaining data in SystemView trace buffer to host.

Return ESP_OK.

Parameters

- tmo: Timeout for operation (in us). Use ESP_APPTRACE_TMO_INFINITE to wait indefinitely.

int esp_sysview_vprintf(const char *format, va_list args)
vprintf-like function to send log messages to the host.

Return Number of bytes written.

Parameters

- format: Address of format string.
- args: List of arguments.

esp_err_t esp_sysview_heap_trace_start (uint32_t tmo)
Starts SystemView heap tracing.

Return ESP_OK on success, ESP_ERR_TIMEOUT if operation has been timed out.

Parameters

- tmo: Timeout (in us) to wait for the host to be connected. Use -1 to wait forever.

esp_err_t esp_sysview_heap_trace_stop (void)
Stops SystemView heap tracing.

Return 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.
2.7.3 The Async memcpy API

Overview

ESP32-S3 has a DMA engine which can help to offload internal memory copy operations from the CPU in an asynchronous way.

The async memcpy API wraps all DMA configurations and operations, the signature of `esp_async_memcpy()` is almost the same to the standard libc one.

Thanks to the benefit of the DMA, we don’t have to wait for each memory copy to be done before we issue another memcpy request. By the way, it’s still possible to know when memcpy is finished by listening in the memcpy callback function.

Configure and Install driver

`esp_async_memcpy_install()` is used to install the driver with user’s configuration. Please note that async memcpy has to be called with the handle returned from `esp_async_memcpy_install()`.

Driver configuration is described in `async_memcpy_config_t`: backlog: This is used to configured the maximum number of DMA operation that can be working at the background at the same time. `sram_trans_align`: Declare SRAM alignment for both data address and copy size, set to zero if the data has no restriction in alignment. If set to a quadruple value (i.e. 4X), the driver will enable the burst mode internally, which is helpful for some performance related application. `psram_trans_align`: Declare PSRAM alignment for both data address and copy size. User has to give it a valid value (only 16, 32, 64 are supported) if the destination of memcpy is located in PSRAM. The default alignment (i.e. 16) will be applied if it’s set to zero. Internally, the driver configures the size of block used by DMA to access PSRAM, according to the alignment. flags: This is used to enable some special driver features.

`ASYNC_MEMCPY_DEFAULT_CONFIG` provides a default configuration, which specifies the backlog to 8.

```
async_memcpy_config_t config = ASYNC_MEMCPY_DEFAULT_CONFIG();
// update the maximum data stream supported by underlying DMA engine
config.backlog = 16;
async_memcpy_t driver = NULL;
ESP_ERROR_CHECK(esp_async_memcpy_install(&config, &driver)); // install driver, return driver handle
```

Send memory copy request

`esp_async_memcpy()` is the API to send memory copy request to DMA engine. It must be called after driver is installed successfully. This API is thread safe, so it can be called from different tasks.

Different from the libc version of `memcpy`, user should also pass a callback to `esp_async_memcpy()`, if it’s necessary to be notified when the memory copy is done. The callback is executed in the ISR context, make sure you won’t violate the the restriction applied to ISR handler.

Besides that, the callback function should reside in IRAM space by applying `IRAM_ATTR` attribute. The prototype of the callback function is `async_memcpy_isr_cb_t`, please note that, the callback function should return true if it wakes up a high priority task by some API like `xSemaphoreGiveFromISR()`.

```
SemaphoreHandle_t semphr; // already initialized in somewhere

// Callback implementation, running in ISR context
static IRAM_ATTR bool my_async_memcpy_cb(async_memcpy_t mcp_hdl, async_memcpy_event_t *event, void *cb_args) {
    SemaphoreHandle_t sem = (SemaphoreHandle_t)cb_args;
    BaseType_t high_task_wakeup = pdFALSE;
    SemphrGiveInISR(semphr, &high_task_wakeup); // high_task_wakeup set to pdTRUE
    if some high priority task unblocked
}
```

(continues on next page)
return high_task_wakeup == pdTRUE;
}

// Called from user's context
ESP_ERROR_CHECK(esp_async_memcpy(driver_handle, to, from, copy_len, my_async_ -memcpy_cb, my_semaphore));
// Do something else here
SemphrTake(my_semaphore, ...); // wait until the buffer copy is done

Uninstall driver (optional)

esp_async_memcpy_uninstall() is used to uninstall asynchronous memcpy driver. It’s not necessary to uninstall the driver after each memcpy operation. If you know your application won’t use this driver anymore, then this API can recycle the memory for you.

API Reference

Header File

- components/esp_hw_support/include/esp_async_memcpy.h

Functions

esp_err_t esp_async_memcpy_install(const async_memcpy_config_t *config, async_memcpy_t *asmcp)
Install async memcpy driver.

Return
- ESP_OK: Install async memcpy driver successfully
- ESP_ERR_INVALID_ARG: Install async memcpy driver failed because of invalid argument
- ESP_ERR_NO_MEM: Install async memcpy driver failed because out of memory
- ESP_FAIL: Install async memcpy driver failed because of other error

Parameters
- [in] config: Configuration of async memcpy
- [out] asmcp: Handle of async memcpy that returned from this API. If driver installation is failed, asmcp would be assigned to NULL.

esp_err_t esp_async_memcpy_uninstall(async_memcpy_t asmcp)
Uninstall async memcpy driver.

Return
- ESP_OK: Uninstall async memcpy driver successfully
- ESP_ERR_INVALID_ARG: Uninstall async memcpy driver failed because of invalid argument
- ESP_FAIL: Uninstall async memcpy driver failed because of other error

Parameters
- [in] asmcp: Handle of async memcpy driver that returned from esp_async_memcpy_install

esp_err_t esp_async_memcpy(async_memcpy_t asmcp, void *dst, void *src, size_t n,
async_memcpy_isr_cb_t cb_isr, void *cb_args)
Send an asynchronous memory copy request.

Return
- ESP_OK: Send memory copy request successfully
- ESP_ERR_INVALID_ARG: Send memory copy request failed because of invalid argument
- ESP_FAIL: Send memory copy request failed because of other error

Note The callback function is invoked in interrupt context, never do blocking jobs in the callback.

Parameters
- [in] asmcp: Handle of async memcpy driver that returned from esp_async_memcpy_install
- [in] dst: Destination address (copy to)
- [in] src: Source address (copy from)
Chapter 2. API Reference

• [in] n: Number of bytes to copy
• [in] cb_isr: Callback function, which got invoked in interrupt context. Set to NULL can bypass the callback.
• [in] cb_args: User defined argument to be passed to the callback function

Structures

struct async_memcpy_event_t
Type of async memcpy event object.

Public Members

void *data
Event data

struct async_memcpy_config_t
Type of async memcpy configuration.

Public Members

uint32_t backlog
Maximum number of streams that can be handled simultaneously

size_t sram_trans_align
DMA transfer alignment (both in size and address) for SRAM memory

size_t psram_trans_align
DMA transfer alignment (both in size and address) for PSRAM memory

uint32_t flags
Extra flags to control async memcpy feature

Macros

ASYNC_MEMCPY_DEFAULT_CONFIG()
Default configuration for async memcpy.

Type Definitions

typedef struct async_memcpy_context_t *async_memcpy_t
Type of async memcpy handle.

typedef bool (*async_memcpy_isr_cb_t)(async_memcpy_t *mcp_hdl, async_memcpy_event_t *event, void *cb_args)
Type of async memcpy interrupt callback function.

Return Whether a high priority task is woken up by the callback function

Note User can call OS primitives (semaphore, mutex, etc) in the callback function. Keep in mind, if any OS primitive wakes high priority task up, the callback should return true.

Parameters

• mcp_hdl: Handle of async memcpy
• event: Event object, which contains related data, reserved for future
• cb_args: User defined arguments, passed from esp_async_memcpy function

2.7.4 Console

ESP-IDF provides console component, which includes building blocks needed to develop an interactive console over serial port. This component includes following facilities:

• Line editing, provided by linenoise library. This includes handling of backspace and arrow keys, scrolling through command history, command auto-completion, and argument hints.
Chapter 2. API Reference

- 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 facilities 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 ‘backspace’ key, navigating within the command using left/right keys, navigating to previously typed commands using up/down keys, and performing autocompletion using ‘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 idf_monitor.py (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.

```
linenoiseClearScreen()
```

Clear terminal screen using an escape sequence and position the cursor at the top left corner.

```
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 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.

```
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. If you need optimize RAM memory usage, you can do it by this function by setting a value less than default 4 KB.

**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 completed line once ‘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 user presses ‘tab’ key, linenoise library invokes 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.

`console` component 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 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 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 up/down arrows.

`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 `\` (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()`
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()`.

Likewise, if your REPL environment is based on USB_SERIAL_JTAG device, you only need to call `esp_console_new_repl_usb_serial_jtag()` at first step. And call other functions as usual.

**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 based on `console` component and can be treated as “tools” when developing applications. For example, `peripherals/i2c/i2c_tools`, `wifi/ipperf`.

**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

  **Note** Call this once before using other console module features

  **Return**
  - 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

  **Parameters**
  - `config`: console configuration

- `esp_err_t esp_console_deinit(void)`

  de-initialize console module

  **Note** Call this once when done using console module functions

  **Return**
  - 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.

  **Return**
  - ESP_OK on success
  - ESP_ERR_NO_MEM if out of memory
  - ESP_ERR_INVALID_ARG if command description includes invalid arguments

  **Parameters**
  - `cmd`: pointer to the command description; can point to a temporary value

- `esp_err_t esp_console_run(const char *cmdline, int *cmd_ret)`

  Run command line.

  **Return**
  - 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

Parameters
• cmdline: command line (command name followed by a number of arguments)
• [out] cmd_ret: return code from the command (set if command was run)

size_t esp_console_split_argv (char *line, char **argv, size_t argv_size)
Split command line into arguments in place.

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.

Return  number of arguments found (argc)

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)

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:

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*.

Return  string containing the hint text. This string is persistent and should not be freed (i.e. linenoiseSetFree-HintsCallback should not be used).

Parameters
• buf: line typed by the user
• [out] color: ANSI color code to be used when displaying the hint
• [out] bold: set to 1 if hint has to be displayed in bold

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.

Return
• 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.

**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

**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.

**Return**
- ESP_OK on success
- ESP_FAIL Parameter error

**Parameters**
- [in] dev_config: UART device configuration
- [in] repl_config: REPL configuration
- [out] ret_repl: return REPL handle after initialization succeed, return NULL otherwise

## esp_err_t esp_console_new_repl_usb_cdc(const esp_console_dev_usb_cdc_config_t *dev_config, const esp_console_repl_config_t *repl_config, esp_console_repl_t **ret_repl)

Establish a console REPL environment over USB CDC.

**Note** This is an all-in-one function to establish the environment needed for REPL, includes:
- Initializes linenoise
- Spawn new thread to run REPL in the background

**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.

**Return**
- ESP_OK on success
- ESP_FAIL Parameter error

**Parameters**
- [in] dev_config: USB CDC configuration
- [in] repl_config: REPL configuration
- [out] ret_repl: return REPL handle after initialization succeed, return NULL otherwise

## 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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE, if repl has started already

**Parameters**
- [in] repl: REPL handle returned from esp_console_new_repl_xxx

### 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_dev_usb_cdc_config_t
    Parameters for console device: USB CDC.

Note It’s an empty structure for now, reserved for future

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.

Return

• ESP_OK on success
• ESP_FAIL on errors

Parameters

• [in] repl: REPL handle returned from esp_console_new_repl_xxx

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()

ESP_CONSOLE_DEV_CDC_CONFIG_DEFAULT()

Type Definitions

typedef struct linenoiseCompletions linenoiseCompletions

typedef int (*esp_console_cmd_func_t)(int argc, char **argv)

Console command main function.

Return

console command return code, 0 indicates “success”

Parameters

• argc: number of arguments
• argv: array with argc entries, each pointing to a zero-terminated string argument

typedef struct esp_console_repl_s esp_console_repl_t

Type defined for console REPL.

2.7.5 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.
Chapter 2. API Reference

Hardware description

The ESP32-S3 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-S3 Technical Reference Manual > eFuse Controller (eFuse) [PDF]. Some eFuse bits are available for user applications.

ESP32-S3 has 11 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 entirely for system purposes;
- EFUSE_BLK2 is used entirely for system purposes;
- EFUSE_BLK3 or EFUSE_BLK_USER_DATA can be used for user purposes;
- EFUSE_BLK4 or EFUSE_BLK_KEY0 can be used as key (for secure_boot or flash_encryption) or for user purposes;
- EFUSE_BLK5 or EFUSE_BLK_KEY1 can be used as key (for secure_boot or flash_encryption) or for user purposes;
- EFUSE_BLK6 or EFUSE_BLK_KEY2 can be used as key (for secure_boot or flash_encryption) or for user purposes;
- EFUSE_BLK7 or EFUSE_BLK_KEY3 can be used as key (for secure_boot or flash_encryption) or for user purposes;
- EFUSE_BLK8 or EFUSE_BLK_KEY4 can be used as key (for secure_boot or flash_encryption) or for user purposes;
- EFUSE_BLK9 or EFUSE_BLK_KEY5 can be used as key (for secure_boot or flash_encryption) or for user purposes;
- EFUSE_BLK10 or EFUSE_BLK_SYS_DATA_PART2 is reserved for system purposes.

Each block is divided into 8 32-bits registers.

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:

```
# field_name, efuse_block(EFUSE_BLK0..EFUSE_BLK10), 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_BLK10.

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.

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:

```
# Factory MAC address #

MAC_FACTORY, EFUSE_BLK0, 72, 8, Factory MAC addr [0]
MAC_FACTORY, EFUSE_BLK0, 64, 8, Factory MAC addr [1]
MAC_FACTORY, EFUSE_BLK0, 56, 8, Factory MAC addr [2]
MAC_FACTORY, EFUSE_BLK0, 48, 8, Factory MAC addr [3]
MAC_FACTORY, EFUSE_BLK0, 40, 8, Factory MAC addr [4]
MAC_FACTORY, EFUSE_BLK0, 32, 8, Factory MAC addr [5]
MAC_FACTORY_CRC, EFUSE_BLK0, 80, 8, CRC8 for factory MAC address
```

This field will available in code as ESP_EFUSE_MAC_FACTORY and ESP_EFUSE_MAC_FACTORY_CRC.

### Structured efuse fields

```
WR_DIS,    EFUSE_BLK0,  0,  32, Write protection
WR_DIS.RD_DIS, WR_DIS,   EFUSE_BLK0,  0,  1, Write protection for...
  --FIELD_1, WR_DIS.FIELD_1, EFUSE_BLK0,  1,  1, Write protection for...
  --FIELD_2, WR_DIS.FIELD_2, EFUSE_BLK0,  2,  4, Write protection for...
---FIELD_2.B1, WR_DIS.FIELD_2.B1, EFUSE_BLK0,  2,  2, Write protection for...
  ---FIELD_2.B2, WR_DIS.FIELD_2.B2, EFUSE_BLK0,  4,  2, Write protection for...
  ---FIELD_3, WR_DIS.FIELD_3, EFUSE_BLK0,  5,  1, Write protection for...
  ---FIELD_3.ALIAS, WR_DIS.FIELD_3.ALIAS, EFUSE_BLK0,  5,  1, Write protection for...
    ---FIELD_3 (just a alias for WR_DIS.FIELD_3)
  ---FIELD_4, WR_DIS.FIELD_4, EFUSE_BLK0,  7,  1, Write protection for...
```

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.
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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_RD_DIS, ESP_EFUSE_WR_DIS_FIELD_2_B1, etc.

**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 esp32s3/esp_efuse_table.csv
```

After generation in the folder $IDF_PATH/components/efuse/esp32s3 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 esp32s3/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**

Coding schemes are used to protect against data corruption. ESP32-S3 supports two coding schemes:

- **None**. EFUSE_BLK0 is stored with four backups, meaning each bit is stored four times. This backup scheme is automatically applied by the hardware and is not visible to software. EFUSE_BLK0 can be written many times.
- **RS**. EFUSE_BLK1 - EFUSE_BLK10 use Reed-Solomon coding scheme that supports up to 5 bytes of automatic error correction. Software will encode the 32-byte EFUSE_BLKx using RS (44, 32) to generate a 12-byte check code, and then burn the EFUSE_BLKx and the check code into eFuse at the same time. The eFuse Controller automatically decodes the RS encoding and applies error correction when reading back the eFuse block. Because the RS check codes are generated across the entire 256-bit eFuse block, each block can only be written to one time.

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 Reed-Solomon 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 reset 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_chip_ver()`, `esp_efuse_get_pkg_ver()`.

eFuse API for keys

EFUSE_BLK_KEY0 - EFUSE_BLK_KEY5 are intended to keep up to 6 keys with a length of 256-bits. Each key has an `ESP_EFUSE_KEY_PURPOSE_x` field which defines the purpose of these keys. The purpose field is described in `esp_efuse_purpose_t`.

The purposes like `ESP_EFUSE_KEY_PURPOSE_XTS_AES...` are used for flash encryption.

The purposes like `ESP_EFUSE_KEY_PURPOSE_SECURE_BOOT_DIGEST...` are used for secure boot.

There are some eFuse APIs useful to work with states of keys.

- `esp_efuse_get_purpose_field()` - Returns a pointer to a key purpose for an eFuse key block.
- `esp_efuse_get_key()` - Returns a pointer to a key block.
- `esp_efuse_set_key_purpose()` - Sets a key purpose for an eFuse key block.
- `esp_efuse_set_key_purpose_dis_write()` - Sets a write protection of the key purpose field for an eFuse key block.
- `esp_efuse_find_unused_key_block()` - Search for an unused key block and return the first one found.
Chapter 2. API Reference

- `esp_efuse_count_unused_key_blocks()` - Returns the number of unused eFuse key blocks in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX
- `esp_efuse_get_digest_revoke()` - Returns the status of the Secure Boot public key digest revocation bit.
- `esp_efuse_set_digest_revoke()` - Sets the Secure Boot public key digest revocation bit.
- `esp_efuse_get_write_protect_of_digest_revoke()` - Returns a write protection of the Secure Boot public key digest revocation bit.
- `esp_efuse_set_write_protect_of_digest_revoke()` - Sets a write protection of the Secure Boot public key digest revocation bit.

How to add a new field

1. Find a free bits for field. Show `esp_efuse_table.csv` file or run `idf.py show-effuse-table` or the next command:

```
$ ./efuse_table_gen.py esp32s3/esp_efuse_table.csv --info
```

<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_FLASH_CRYPT_CNT</td>
<td>EFUSE_BLK0</td>
<td>2</td>
<td>1</td>
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<tr>
<td>2</td>
<td>WR_DIS_BLK1</td>
<td>EFUSE_BLK0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>WR_DIS_BLK2</td>
<td>EFUSE_BLK0</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>WR_DIS_BLK3</td>
<td>EFUSE_BLK0</td>
<td>9</td>
<td>1</td>
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<tr>
<td>5</td>
<td>RD_DIS_BLK1</td>
<td>EFUSE_BLK0</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>RD_DIS_BLK2</td>
<td>EFUSE_BLK0</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>RD_DIS_BLK3</td>
<td>EFUSE_BLK0</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>FLASH_CRYPT_CNT</td>
<td>EFUSE_BLK0</td>
<td>20</td>
<td>7</td>
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<tr>
<td>9</td>
<td>MAC_FACTORY</td>
<td>EFUSE_BLK0</td>
<td>32</td>
<td>8</td>
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<td>EFUSE_BLK0</td>
<td>64</td>
<td>8</td>
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<tr>
<td>14</td>
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<td>EFUSE_BLK0</td>
<td>72</td>
<td>8</td>
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<td>15</td>
<td>MAC_FACTORY_CRC</td>
<td>EFUSE_BLK0</td>
<td>80</td>
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<tr>
<td>16</td>
<td>CHIP_VER_DIS_APP_CPU</td>
<td>EFUSE_BLK0</td>
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<td>EFUSE_BLK0</td>
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<td>ADC_VREF_AND_SDIO_DREF</td>
<td>EFUSE_BLK0</td>
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<td>XPD_SDIO_REG</td>
<td>EFUSE_BLK0</td>
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<tr>
<td>24</td>
<td>SDIO_TIEH</td>
<td>EFUSE_BLK0</td>
<td>143</td>
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<tr>
<td>25</td>
<td>SDIO_FORCE</td>
<td>EFUSE_BLK0</td>
<td>144</td>
<td>1</td>
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<td>26</td>
<td>ENCRYPT_CONFIG</td>
<td>EFUSE_BLK0</td>
<td>188</td>
<td>4</td>
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<td>CONSOLE_DEBUG_DISABLE</td>
<td>EFUSE_BLK0</td>
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<td>ABS_DONE_0</td>
<td>EFUSE_BLK0</td>
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<td>DISABLE_JTAG</td>
<td>EFUSE_BLK0</td>
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<td>EFUSE_BLK0</td>
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<td>DISABLE_DL_CACHE</td>
<td>EFUSE_BLK0</td>
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<td>1</td>
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<td>33</td>
<td>ENCRYPT_FLASH_KEY</td>
<td>EFUSE_BLK1</td>
<td>0</td>
<td>256</td>
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<tr>
<td>34</td>
<td>SECURE_BOOT_KEY</td>
<td>EFUSE_BLK2</td>
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<td>256</td>
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<tr>
<td>35</td>
<td>MAC_CUSTOM_CRC</td>
<td>EFUSE_BLK3</td>
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<td>8</td>
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<tr>
<td>36</td>
<td>MAC_CUSTOM</td>
<td>EFUSE_BLK3</td>
<td>8</td>
<td>48</td>
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<td>37</td>
<td>ADC1_TP_LOW</td>
<td>EFUSE_BLK3</td>
<td>96</td>
<td>7</td>
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<td>ADC1_TP_HIGH</td>
<td>EFUSE_BLK3</td>
<td>103</td>
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<td>ADC2_TP_LOW</td>
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<td>112</td>
<td>7</td>
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<tr>
<td>40</td>
<td>ADC2_TP_HIGH</td>
<td>EFUSE_BLK3</td>
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<td>41</td>
<td>SECURE_VERSION</td>
<td>EFUSE_BLK3</td>
<td>128</td>
<td>32</td>
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<td>42</td>
<td>MAC_CUSTOM_VER</td>
<td>EFUSE_BLK3</td>
<td>184</td>
<td>8</td>
</tr>
</tbody>
</table>

(continues on next page)
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Used bits in eFuse table:

<table>
<thead>
<tr>
<th>EFUSE_BLK0</th>
</tr>
</thead>
<tbody>
<tr>
<td>[2 2] [7 9] [16 18] [20 27] [32 87] [96 109] [111 111] [136 144] [188 .. 191] [194 194] [196 196] [198 201]</td>
</tr>
</tbody>
</table>

EFUSE_BLK1
[0 255]

EFUSE_BLK2
[0 255]

EFUSE_BLK3
[0 55] [96 159] [184 191]

Note: Not printed ranges are free for using. (bits in EFUSE_BLK0 are reserved for Espressif)

Parsing eFuse CSV input file $IDF_PATH/components/efuse/esp32s3/esp_efuse_table.csv ...

Verifying eFuse table...

The number of bits not included in square brackets is free (bits in EFUSE_BLK0 are reserved for Espressif). All fields are checked for overlapping.

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.

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).

espefuse.py esptool includes a useful tool for reading/writing ESP32-S3 eFuse bits - espefuse.py.

```
espefuse.py -p PORT summary
Connecting....
Detecting chip type... ESP32-S3
espefuse.py v3.1-dev
EFUSE_NAME (Block) Description = [Meaningful, Value] [Readable/Writeable] (Hex Value)

<table>
<thead>
<tr>
<th>Calibration fuses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP_SENSOR_CAL (BLOCK2) Temperature calibration</td>
</tr>
<tr>
<td>ADC1_MODE0_D2 (BLOCK2) ADC1 calibration 1</td>
</tr>
<tr>
<td>ADC1_MODE1_D2 (BLOCK2) ADC1 calibration 2</td>
</tr>
</tbody>
</table>
```

(continues on next page)
ADC1_MODE2_D2 (BLOCK2) ADC1 calibration 3
-28 R/W (0x87)

ADC1_MODE3_D2 (BLOCK2) ADC1 calibration 4
-24 R/W (0x86)

ADC2_MODE0_D2 (BLOCK2) ADC2 calibration 5
12 R/W (0x03)

ADC2_MODE1_D2 (BLOCK2) ADC2 calibration 6
8 R/W (0x02)

ADC2_MODE2_D2 (BLOCK2) ADC2 calibration 7
12 R/W (0x03)

ADC2_MODE3_D2 (BLOCK2) ADC2 calibration 8
16 R/W (0x04)

ADC1_MODE0_D1 (BLOCK2) ADC1 calibration 9
-20 R/W (0b100101)

ADC1_MODE1_D1 (BLOCK2) ADC1 calibration 10
-12 R/W (0b100011)

ADC1_MODE2_D1 (BLOCK2) ADC1 calibration 11
-12 R/W (0b100011)

ADC1_MODE3_D1 (BLOCK2) ADC1 calibration 12
-12 R/W (0b100011)

ADC2_MODE0_D1 (BLOCK2) ADC2 calibration 13
-4 R/W (0b100011)

ADC2_MODE1_D1 (BLOCK2) ADC2 calibration 14
-12 R/W (0b100011)

ADC2_MODE2_D1 (BLOCK2) ADC2 calibration 15
-8 R/W (0b100010)

ADC2_MODE3_D1 (BLOCK2) ADC2 calibration 16
-8 R/W (0b100010)

Config fuses:

DIS_ICACHE (BLOCK0) Disables ICache
False R/W (0b0)

DIS_DCACHE (BLOCK0) Disables DCache
False R/W (0b0)

DIS_DOWNLOAD_ICACHE (BLOCK0) Disables Icache when SoC is in download mode
False R/W (0b0)

DIS_DOWNLOAD_DCACHE (BLOCK0) Disables Dcache when SoC is in download mode
False R/W (0b0)

DIS_FORCE_DOWNLOAD (BLOCK0) Disables forcing chip into download mode
False R/W (0b0)

DIS_CAN (BLOCK0) Disables the TWAI Controller
False R/W (0b0)

DIS_BOOT_REMAP (BLOCK0) Disables capability to Remap RAM
False R/W (0b0)

FLASH_TPUW (BLOCK0) Configures flash startup delay after SoC power-up
0 R/W (0x0)

15, delay is 7. 5 ms

DIS_LEGACY_SPI_BOOT (BLOCK0) Disables Legacy SPI boot mode
False R/W (0b0)

UART_PRINT_CHANNEL (BLOCK0) Selects the default UART for printing boot msg
UART0 R/W (0b0)

DIS_USB DOWNLOAD_MODE (BLOCK0) Disables use of USB in UART
False R/W (0b0)

UART PRINT CONTROL (BLOCK0) Sets the default UART boot message output mode
Enabled R/W (0b0)

FLASH_TYPE (BLOCK0) Selects SPI flash type
4 data lines R/W (0b0)

FORCE_SEND_RESUME (BLOCK0) Forces ROM code to send an SPI flash resume command
False R/W (0b0)
d during SPI boot

BLOCK_USR_DATA (BLOCK3) User data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
-- 00 00 00 00 00 00 00 00 00 00 R/W

Efuse fuses:

WR_DIS (BLOCK0) Disables programming of...
--individual eFuses = 0 R/W (0x00000000)
RD_DIS (BLOCK0) Disables software reading from...
--BLOCK4-10 = 0 R/W (0b00000000)

Identity fuses:

BLOCK0_VERSION (BLOCK0) BLOCK0 efuse version
-- = 0 R/W (0b0)
SECURE_VERSION (BLOCK0) Secure version (used by ESP-IDF...ure)
--anti-rollback feat = 0 R/W (0x0000)
MAC (BLOCK1) Factory MAC Address
= 7c:df:a1:00:3a:6e: (OK) R/W
WAFFER_VERSION (BLOCK1) WAFFER version
-- = A R/W (0b000)
PKG_VERSION (BLOCK1) Package version
= ESP32-S3, QFN 7x7 56 pins R/W (0x0)
BLOCK1_VERSION (BLOCK1) BLOCK1 efuse version
-- = 0 R/W (0b000)
OPTIONAL_UNIQUE_ID (BLOCK2) Optional unique 128-bit ID
-- = 7d 33 b8 bb 0b 13 b3 c8 71 37 0e e8 7c ab d5 92 R/W
WAFER_VERSION (BLOCK2) Version of BLOCK2
-- = With calibration R/W (0b001)
CUSTOM_MAC (BLOCK3) Custom MAC Address
= 00:00:00:00:00:00 (OK) R/W

Security fuses:

SOFTWARE_JTAG (BLOCK0) Software disables JTAG. When...
--software disabled, JT = False R/W (0b000)
--by HMAC peripheral
HARD_DIS_JTAG (BLOCK0) Hardware disables JTAG...
--permanently = False R/W (0b0)
DIS_DOWNLOAD_MANUAL_ENCRYPT (BLOCK0) Enables flash encryption when...
--in download boot mode = False R/W (0b0)
SPI_BOOT_CRYPT_CNT (BLOCK0) Enables encryption and...
--decription, when an SPI boot mode = Disable R/W (0b000)
--3 bits are set, disabled otherwise
--1 or 3 bits are set, enabled when 1 or 2 bits are set
SECURE_BOOT_KEY_REVOKE0 (BLOCK0) If set, revokes use of secure...
--boot key digest 0 = False R/W (0b0)
SECURE_BOOT_KEY_REVOKE1 (BLOCK0) If set, revokes use of secure...
--boot key digest 1 = False R/W (0b0)
SECURE_BOOT_KEY_REVOKE2 (BLOCK0) If set, revokes use of secure...
--boot key digest 2 = False R/W (0b0)
KEY_PURPOSE_0 (BLOCK0) KEY0 purpose
-- = USER R/W (0x0)
KEY_PURPOSE_1 (BLOCK0) KEY1 purpose
-- = USER R/W (0x0)
KEY_PURPOSE_2 (BLOCK0) KEY2 purpose
-- = USER R/W (0x0)
KEY_PURPOSE_3 (BLOCK0) KEY3 purpose
-- = USER R/W (0x0)
KEY_PURPOSE_4 (BLOCK0) KEY4 purpose
- = USER R/W (0x0)
KEY_PURPOSE_5 (BLOCK0) KEY5 purpose
- = USER R/W (0x0)
SECURE_BOOT_EN (BLOCK0) Enables secure boot
- = False R/W (0b0)
SECURE_BOOT_AGGRESSIVE_REVOKE (BLOCK0) Enables aggressive secure boot
--key revocation mode = False R/W (0b0)
DIS_DOWNLOAD_MODE (BLOCK0) Disables all Download boot modes
--mode (read/write flag = False R/W (0b0)

SECURE_BOOT_AGGRESSIVE_REVOKE (BLOCK0) Enables aggressive secure boot
--key revocation mode = False R/W (0b0)

DIS_DOWNLOAD_MODE (BLOCK0) Disables all Download boot modes
--mode (read/write flag = False R/W (0b0)

SECURE_BOOT_ENABLED (BLOCK0) Enables secure boot
--mode (False R/W (0b0)

ENABLE_SECURITY_DOWNLOAD (BLOCK0) Enables secure UART download
mode (read/write flag = False R/W (0b0)

BLOCK_KEY0 (BLOCK4) (0 errors):
Purpose: USER
Encryption key0 or user data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BLOCK_KEY1 (BLOCK5) (0 errors):
Purpose: USER
Encryption key1 or user data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BLOCK_KEY2 (BLOCK6) (0 errors):
Purpose: USER
Encryption key2 or user data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BLOCK_KEY3 (BLOCK7) (0 errors):
Purpose: USER
Encryption key3 or user data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BLOCK_KEY4 (BLOCK8) (0 errors):
Purpose: USER
Encryption key4 or user data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BLOCK_KEY5 (BLOCK9) (0 errors):
Purpose: USER
Encryption key5 or user data
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

BLOCK_SYS_DATA2 (BLOCK10) System data (part 2)
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
- 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

SPI_Pad_Config fuses:
SPI_PAD_CONFIG_CLK (BLOCK1) SPI CLK pad
- = R/W (0b000000)
SPI_PAD_CONFIG_Q (BLOCK1) SPI Q (D1) pad
- = R/W (0b000000)
SPI_PAD_CONFIG_D (BLOCK1) SPI D (D0) pad
- = R/W (0b000000)
SPI_PAD_CONFIG_CS (BLOCK1) SPI CS pad
- = R/W (0b000000)
SPI_PAD_CONFIG_CS (BLOCK1) SPI CS pad
- = R/W (0b000000)
SPI_PAD_CONFIG_HD (BLOCK1) SPI HD (D3) pad
- = R/W (0b000000)
SPI_PAD_CONFIG_WP (BLOCK1) SPI WP (D2) pad
- = R/W (0b000000)
SPI_PAD_CONFIG_DQS (BLOCK1) SPI DQS pad
- = R/W (0b000000)
SPI_PAD_CONFIG_D4 (BLOCK1) SPI D4 pad
→  0 R/W (0b000000)
SPI_PAD_CONFIG_D5 (BLOCK1) SPI D5 pad
→  0 R/W (0b000000)
SPI_PAD_CONFIG_D6 (BLOCK1) SPI D6 pad
→  0 R/W (0b000000)
SPI_PAD_CONFIG_D7 (BLOCK1) SPI D7 pad
→  0 R/W (0b000000)

Usb Config fuses:
DIS_USB (BLOCK0) Disables the USB OTG hardware
→  False R/W (0b0)
USB_EXCHG_PINS (BLOCK0) Exchanges USB D+ and D- pins
→  False R/W (0b0)
EXT_PHY_ENABLE (BLOCK0) Enables external USB PHY
→  False R/W (0b0)
USB_FORCE_NOPERSIST (BLOCK0) Forces to set USB BVALID to 1
→  False R/W (0b0)

Vdd_Spi Config fuses:
VDD_SPI_FORCE (BLOCK0) Force using VDD_SPI_XPD and VDD_ure VDD_SPI LDO
→ SPI_TIEH to config = False R/W (0b0)
VDD_SPI_XPD (BLOCK0) The VDD_SPI regulator is powered
→ on = False R/W (0b0)
VDD_SPI_TIEH (BLOCK0) The VDD_SPI power supply voltage
→ at reset = Connect to 1.8V LDO R/W (0b0)
PIN_POWER_SELECTION (BLOCK0) Sets default power supply for
→ GP1033..37, set when = VDD3P3_CPU R/W (0b0)
SPI flash is initialized

Wdt Config fuses:
WDT_DELAY_SEL (BLOCK0) Selects RTC WDT timeout
→ threshold at startup  = 0 R/W (0b00)
Flash voltage (VDD_SPI) determined by GPIO45 on reset (GPIO45=High: VDD_
→ SPI pin is powered from internal 1.8V LDO
GPIO45=Low or NC: VDD_SPI pin is powered directly from VDD3P3_RTC_IO via_
→ resistor Rspi. Typically this voltage is 3.3 V).

To get a dump for all eFuse registers.
espedefuse.py -p PORT dump
Connecting....
Detecting chip type... ESP32-S3
BLOCK0  ( ) [0 ] read_regs: 00000000 00000000...
→00000000 00000000 00000000 00000000
MAC_SPI_8M_0 (BLOCK1) [1 ] read_regs: a1003a6e 00007cdf...
→00000000 00000000 00000000 00000000
BLOCK_SYS_DATA (BLOCK2) [2 ] read_regs: bbb8337d c8b3130b...
→e80e3771 92d5ab7c 8787ae10 02038687 38e50403 8628a386
BLOCK_USR_DATA (BLOCK3) [3 ] read_regs: 00000000 00000000...
→00000000 00000000 00000000 00000000 00000000 00000000
BLOCK_KEY0 (BLOCK4) [4 ] read_regs: 00000000 00000000...
→00000000 00000000 00000000 00000000 00000000 00000000
BLOCK_KEY1 (BLOCK5) [5 ] read_regs: 00000000 00000000...
→00000000 00000000 00000000 00000000 00000000 00000000
BLOCK_KEY2 (BLOCK6) [6 ] read_regs: 00000000 00000000...
→00000000 00000000 00000000 00000000 00000000 00000000
BLOCK_KEY3 (BLOCK7) [7 ] read_regs: 00000000 00000000...
→00000000 00000000 00000000 00000000 00000000 00000000


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.

**Return**

- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.

**Parameters**

- [in] field: A pointer to the structure describing the fields of efuse.
- [out] dst: A pointer to array that will contain the result of reading.
- [in] dst_size_bits: 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.

```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.

**Return**

- 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.

**Parameters**

- [in] field: A pointer to the structure describing the fields of efuse.

```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 not set sequentially, they will still be counted.

**Note** Please note that reading in the batch mode does not show uncommitted changes.

**Return**

- ESP_OK: The operation was successfully completed.
- ESP_ERR_INVALID_ARG: Error in the passed arguments.

**Parameters**

- [in] field: A pointer to the structure describing the fields of efuse.
- [out] out_cnt: A pointer that will contain the number of programmed as “1” bits.

```c
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.

Return
- 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_CODING: Error range of data does not match the coding scheme.

Parameters
- [in] field: A pointer to the structure describing the fields of efuse.
- [in] src: A pointer to array that contains the data for writing.
- [in] src_size_bits: The number of bits required to write.

`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.

Return
- 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.

Parameters
- [in] field: A pointer to the structure describing the fields of efuse.
- [in] cnt: Required number of programmed as “1” bits.

`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.

Return
- 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.

Parameters
- [in] field: Pointer to the structure describing the efuse field.

`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.

Return
- 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.

Parameters
- [in] blk: Block number of eFuse. (EFUSE_BLK1, EFUSE_BLK2 and EFUSE_BLK3)

`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.

Return
Chapter 2. API Reference

• 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.

Parameters

• [in] blk: Block number of eFuse. (EFUSE_BLK1, EFUSE_BLK2 and EFUSE_BLK3)

int esp_efuse_get_field_size (const esp_efuse_desc_t *field[])  
Returns the number of bits used by field.

Parameters

• [in] field: A pointer to the structure describing the fields of efuse.

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.

Return Value of register

Parameters

• [in] blk: Block number of eFuse.
• [in] num_reg: The register number in the block.

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)

Return

• ESP_OK: The operation was successfully completed.
• ESP_ERR_EFUSE_REPEATED_PROG: Error repeated programming of programmed bits is strictly forbidden.

Parameters

• [in] blk: Block number of eFuse.
• [in] num_reg: The register number in the block.
• [in] val: Value to write.

esp_efuse_coding_scheme_t esp_efuse_get_coding_scheme (esp_efuse_block_t blk)  
Returns 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.

Return Return efuse coding scheme for blocks

Parameters

• [in] blk: Block number of eFuse.

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.

Return

• ESP_OK: The operation was successfully completed.
• ESP_ERR_INVALD_ARG: Error in the passed arguments.
• ESP_ERR_CODING: Error range of data does not match the coding scheme.

Parameters

• [in] blk: Block number of eFuse.
• [in] dst_key: A pointer to array that will contain the result of reading.
• [in] size_bits: The number of bits required to read.
### 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.

**Return**
- 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

**Parameters**
- [in] blk: Block number of eFuse.
- [in] src_key: A pointer to array that contains the key for writing.
- [in] size_bits: The number of bits required to write.

### uint8_t esp_efuse_get_chip_ver(void)

Returns chip version from efuse.

**Return** chip version

### uint32_t esp_efuse_get_pkg_ver(void)

Returns chip package from efuse.

**Return** chip package

### 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 thread safe, if calling code updates efuse values from multiple tasks then this is caller’s responsibility to serialize.

### 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.

**Return**
- 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.

### 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.

**Return**
- 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

**Parameters**
- log_scheme: Supported ROM log scheme

### esp_err_t esp_efuse_enable_rom_secure_download_mode(void)

Switch ROM Download Mode to Secure Download mode via eFuse.

Permanently enables Secure Download mode. This mode limits the use of ROM Download Mode functions to simple flash read, write and erase operations, plus a command to return a summary of currently enabled security features.
Note If Secure Download mode is already enabled, this function does nothing and returns success.
Note Disabling the ROM Download Mode also disables Secure Download Mode.

Return
- ESP_OK If the eFuse was successfully burned, or had already been burned.
- ESP_ERR_INVALID_STATE ROM Download Mode has been disabled via eFuse, so Secure Download mode is unavailable.

uint32_t esp_efuse_read_secure_version(void)
Return secure_version from eFuse field.

Parameters

bool esp_efuse_check_secure_version(uint32_t secure_version)
Check secure_version from app and secure_version from eFuse field.

Return
- True: If version of app is equal or more than secure_version from eFuse.

Parameters
- secure_version: Secure version from app.

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.

Return
- 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.

Parameters
- [in] secure_version: Secure version from app.

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.

Note Please note that reading in the batch mode does not show uncommitted changes.

Example of using the batch writing mode.

```c
// 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.
```

(continues on next page)
// 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.

Return
• ESP_OK: Successful.

\texttt{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.

Return
• ESP_OK: Successful.
• ESP_ERR_INVALID_STATE: Tha batch mode was not set.

\texttt{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.

Return
• ESP_OK: Successful.
• ESP_ERR_INVALID_STATE: The deferred writing mode was not set.

\textbf{bool esp_efuse_block_is_empty (esp_efuse_block_t block)}
Checks that the given block is empty.

Return
• True: The block is empty.
• False: The block is not empty or was an error.

\textbf{bool esp_efuse_get_key_dis_read (esp_efuse_block_t block)}
Returns a read protection for the key block.

Return True: The key block is read protected False: The key block is readable.

Parameters
• \texttt{[in]} block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

\textbf{esp_err_t esp_efuse_set_key_dis_read (esp_efuse_block_t block)}
Sets a read protection for the key block.

Return
• 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.

Parameters
• \texttt{[in]} block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

\textbf{bool esp_efuse_get_key_dis_write (esp_efuse_block_t block)}
Returns a write protection for the key block.
Return True: The key block is write protected False: The key block is writeable.

Parameters

• [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**esp_err_t** esp_efuse_set_key_dis_write(esp_efuse_block_t block)

Sets a write protection for the key block.

Return

• 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.

Parameters

• [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

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)

Return

• True if key block is unused,
• False if key block is used or the specified block index is not a key block.

Parameters

• block: key block to check.

bool esp_efuse_find_purpose (esp_efuse_purpose_t purpose, esp_efuse_block_t *block)

Find a key block with the particular purpose set.

Return

• True: If found,
• False: If not found (value at block pointer is unchanged).

Parameters

• [in] purpose: Purpose to search for.
• [out] block: 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.

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 key purpose, it returns always True.

Return True: The key purpose is write protected. False: The key purpose is writeable.

Parameters

• [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

esp_efuse_purpose_t esp_efuse_get_key_purpose (esp_efuse_block_t block)

Returns the current purpose set for an efuse key block.

Return

• Value: If Successful, it returns the value of the purpose related to the given key block.
• ESP_EFUSE_KEY_PURPOSE_MAX: Otherwise.

Parameters

• [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

const esp_efuse_desc_t **esp_efuse_get_purpose_field(esp_efuse_block_t block)

Returns a pointer to a key purpose for an efuse key block.

To get the value of this field use esp_efuse_read_field_blob() or esp_efuse_get_key_purpose().

Parameters

• [in] block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

Return Pointer: If Successful returns a pointer to the corresponding efuse field otherwise NULL.
**const esp_efuse_desc_t** **esp_efuse_get_key**(esp_efuse_block_t block)

Returns a pointer to a key block.

- **Return** Pointer: If successful returns a pointer to the corresponding efuse field otherwise NULL.
- **Parameters**
  - **[in]** block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**esp_err_t** **esp_efuse_set_key_purpose**(esp_efuse_block_t block, esp_efuse_purpose_t purpose)

Sets a key purpose for an efuse key block.

- **Return**
  - 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.
- **Parameters**
  - **[in]** block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX
  - **[in]** purpose: Key purpose.

**esp_err_t** **esp_efuse_set_keypurpose_dis_write**(esp_efuse_block_t block)

Sets a write protection of the key purpose field for an efuse key block.

- **Return**
  - 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.
- **Parameters**
  - **[in]** block: A key block in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX

**esp_efuse_block_t** **esp_efuse_find_unused_key_block**(void)

Search for an unused key block and return the first one found.

- **Return** First unused key block, or EFUSE_BLK_KEY_MAX if no unused key block is found.

**unsigned** **esp_efuse_count_unused_key_blocks**(void)

Return the number of unused efuse key blocks in the range EFUSE_BLK_KEY0..EFUSE_BLK_KEY_MAX.

**bool** **esp_efuse_get_digest_revoke**(unsigned num_digest)

Returns the status of the Secure Boot public key digest revocation bit.

- **Return**
  - True: If key digest is revoked,
  - False: If key digest is not revoked.
- **Parameters**
  - **[in]** num_digest: The number of digest in range 0..2

**esp_err_t** **esp_efuse_set_digest_revoke**(unsigned num_digest)

Sets the Secure Boot public key digest revocation bit.

- **Return**
  - 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.
- **Parameters**
  - **[in]** num_digest: The number of digest in range 0..2

**bool** **esp_efuse_get_write_protect_of_digest_revoke**(unsigned num_digest)

Returns a write protection of the Secure Boot public key digest revocation bit.
### esp_err_t esp_efuse_set_write_protect_of_digest_revoke(unsigned num_digest)

Sets a write protection of the Secure Boot public key digest revocation bit.

**Return**
- 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.

**Parameters**
- `[in] num_digest`: The number of digest in range 0..2

### 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.

**Return**
- 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.

**Parameters**
- `[in] block`: 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).
- `[in] purpose`: Purpose to set for this key. Purpose must be already unset.
- `[in] key`: Pointer to data to write.
- `[in] key_size_bytes`: Bytes length of data to write.

### 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.

**Return**
- 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_NOT_ENOUGHUNUSED_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.

**Parameters**
- `[in] purposes`: Array of purposes (purpose[number_of_keys]).
- `[in] keys`: Array of keys (uint8_t keys[number_of_keys][32]). Each key is 32 bytes long.
- `[in] number_of_keys`: The number of keys to write (up to 6 keys).

### esp_err_t esp_secure_boot_read_key_digests(ets_secure_boot_key_digests_t *trusted_keys)

Read key digests from efuse. Any revoked/missing digests will be marked as NULL.

**Return**
- ESP_OK: Successful.
- ESP_FAIL: If trusted_keys is NULL or there is no valid digest.

**Parameters**
- `[in] num_digest`: The number of digest in range 0..2
structures

```c
struct esp_efuse_desc_t
{
    uint8_t bit_start; // Start bit [0..255]
    uint8_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.
- **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

```c
enum esp_efuse_rom_log_scheme_t
{
    ESP_EFUSE_ROM_LOG_ALWAYS_ON, // Always enable ROM logging
    ESP_EFUSE_ROM_LOG_ON_GPIO_LOW, // ROM logging is enabled when specific GPIO level is low during start up
    ESP_EFUSE_ROM_LOG_ON_GPIO_HIGH, // ROM logging is enabled when specific GPIO level is high during start up
    ESP_EFUSE_ROM_LOG_ALWAYS_OFF, // Disable ROM logging permanently
};
```
2.7.6 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_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.

Return string error message
Parameters
- code: esp_err_t error code

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.

Return buf containing the string error message
Parameters
- code: esp_err_t error code
- [out] buf: 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).

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

**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**
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**
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**

```c
typedef int esp_err_t
```

### 2.7.7 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_err_t ret = esp_https_ota(&config);
    if (ret == ESP_OK) {
        esp_restart();
    } else {
        return ESP_FAIL;
    }
    return ESP_OK;
}
```

**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](#).

**API Reference**

**Header File**

- components/esp_https_ota/include/esp_https_ota.h

**Functions**

```c
esp_err_t esp_https_ota(const esp_http_client_config_t *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 `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.

**Return**

- ESP_OK: OTA data updated, next reboot will use specified partition.
- ESP_FAIL: For generic failure.
- ESP_ERR_INVALID_ARG: Invalid argument
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- 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.

Parameters

- [in] config: pointer to esp_http_client_config_t structure.

**esp_err_t esp_https_ota_begin** (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.

Return

- ESP_OK: HTTPS OTA Firmware upgrade context initialised and HTTPS connection established
- ESP_FAIL: For generic failure.
- ESP_ERR_INVALID_ARG: Invalid argument (missing/incorrect config, certificate, etc.)
- For other return codes, refer documentation in app_update component and esp_http_client component in esp-idf.

Parameters

- [in] ota_config: pointer to esp_https_ota_config_t structure
- [out] handle: pointer to an allocated data of type esp_https_ota_handle_t which will be initialised in this function

**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.

Return

- 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
- 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.

Parameters

- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

**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.

Return

- false
- true

Parameters

- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

**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

**Return**
- ESP_OK: Clean-up successful
- ESP_ERR_INVALID_STATE
- ESP_ERR_INVALID_ARG: Invalid argument
- ESP_ERR_OTA_VALIDATE_FAILED: Invalid app image

**Parameters**
- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

```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

**Return**
- 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

**Parameters**
- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

```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.

**Return**
- 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

**Parameters**
- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure
- [out] new_app_info: pointer to an allocated esp_app_desc_t structure

```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.

**Return**
- -1 On failure
- total bytes read so far

**Parameters**
- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

```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())

**Return**
- -1 On failure or chunked encoding
• total bytes of image

**Parameters**

- [in] https_ota_handle: pointer to esp_https_ota_handle_t structure

**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

```c
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

```c
bool partial_http_download
```

Enable Firmware image to be downloaded over multiple HTTP requests

```c
int max_http_request_size
```

Maximum request size for partial HTTP download

**Macros**

```c
ESP_ERR_HTTPS_OTA_BASE
```

```c
ESP_ERR_HTTPS_OTA_IN_PROGRESS
```

**Type Definitions**

```c
typedef void *esp_https_ota_handle_t
```

```c
typedef esp_err_t (*http_client_init_cb_t)(esp_http_client_handle_t)
```

### 2.7.8 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()`
- `pthread_attr_getstacksize()` / `pthread_attr_setstacksize()`
- `pthread_attr_getdetachstate()` / `pthread_attr_setdetachstate()`

**Once**

- `pthread_once()`

Static initializer constant `PTHREAD_ONCE_INITIALIZER` 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

---

**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

---

**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
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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.

**Return** A default configuration structure.

`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

**Return**
- 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

**Parameters**
- `cfg`: The pthread config parameters

```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.

**Return**
- ESP_OK if the configuration was available
- ESP_ERR_NOT_FOUND if a configuration wasn’t previously set

**Parameters**
- `p`: Pointer to the pthread config structure that will be updated with the currently configured parameters

```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**

- `size_t stack_size`
  - The stack size of the pthread.
- `size_t prio`
  - The thread’s priority.
- `bool inherit_cfg`
  - Inherit this configuration further.
- `const char *thread_name`
  - The thread name.
- `int pin_to_core`
  - The core id to pin the thread to. Has the same value range as xCoreId argument of xTaskCreatePinnedToCore.

**Macros**

```c
PTHREAD_STACK_MIN
```

### 2.7.9 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 changes in state of other components without application involvement. For instance, a high level connection handling library may subscribe to events produced by the Wi-Fi subsystem directly and act on those events. This also simplifies event processing by serializing and deferring code execution to another context.
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
    // 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.
```

(continues on next page)
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:

```
ESP_EVENT_DEFINE_BASE(EVENT_BASE)
```

**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:

```
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.

```
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<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 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.

Return

- 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

Parameters

- [in] event_loop_args: configuration structure for the event loop to create
- [out] event_loop: handle to the created event loop

`esp_err_t esp_event_loop_delete(esp_event_loop_handle_t event_loop)`

Delete an existing event loop.

Return

- ESP_OK: Success
- Others: Fail

Parameters

- [in] event_loop: event loop to delete, must not be NULL

`esp_err_t esp_event_loop_create_default(void)`

Create default event loop.

Return

- ESP_OK: Success
- 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_default(void)`

Delete the default event loop.

Return

- ESP_OK: Success
- Others: Fail
The API reference for the ESP32 system events in the ESP-IDF includes two primary functions: `esp_event_loop_run` and `esp_event_handler_register`.

### `esp_event_loop_run`  

**Definition:**  
`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.

**Return**
- ESP_OK: Success
- Others: Fail

**Parameters**
- `[in]` `event_loop`: event loop to dispatch posted events from, must not be NULL
- `[in]` `ticks_to_run`: number of ticks to run the loop

### `esp_event_handler_register`  

**Definition:**  
`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.

**Note** This function is obsolete and will be deprecated soon, please use `esp_event_handler_instance_register()` instead.

- 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

**Return**
- 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

**Parameters**
- `[in]` `event_base`: the base ID of the event to register the handler for
- `[in]` `event_id`: the ID of the event to register the handler for
- `[in]` `event_handler`: the handler function which gets called when the event is dispatched
- `[in]` `event_handler_arg`: data, aside from event data, that is passed to the handler when it is called
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** This function is obsolete and will be deprecated soon, please use esp_event_handler_instance_register_with() instead.

**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

**Return**
- 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

**Parameters**
- `[in] event_loop`: the event loop to register this handler function to, must not be NULL
- `[in] event_base` : the base ID of the event to register the handler for
- `[in] event_id`: the ID of the event to register the handler for
- `[in] event_handler`: the handler function which gets called when the event is dispatched
- `[in] event_handler_arg`: data, aside from event data, that is passed to the handler when it is called

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

**Return**
- 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

**Parameters**
- `[in] event_loop`: the event loop to register this handler function to, must not be NULL
- `[in] event_base`: the base ID of the event to register the handler for
- `[in] event_id`: the ID of the event to register the handler for
- `[in] event_handler`: the handler function which gets called when the event is dispatched
• [in] event_handler_arg: data, aside from event data, that is passed to the handler when it is called
• [out] instance: 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.

`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

**Return**
- 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

**Parameters**
- [in] event_base: the base ID of the event to register the handler for
- [in] event_id: the ID of the event to register the handler for
- [in] event_handler: the handler function which gets called when the event is dispatched
- [in] event_handler_arg: data, aside from event data, that is passed to the handler when it is called
- [out] instance: 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.

`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** This function is obsolete and will be deprecated soon, please use esp_event_handler_instance_unregister() instead.

**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.

**Return** ESP_OK success
**Return** ESP_ERR_INVALID_ARG invalid combination of event base and event ID
**Return** others fail

**Parameters**
- [in] event_base: the base of the event with which to unregister the handler
- [in] event_id: the ID of the event with which to unregister the handler
- [in] event_handler: the handler to unregister


**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.

**Note** This function is obsolete and will be deprecated soon, please use `esp_event_handler_instance_unregister_with()` instead.

**Return**
- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

**Parameters**
- `[in] event_loop`: the event loop with which to unregister this handler function, must not be NULL
- `[in] event_base`: the base of the event with which to unregister the handler
- `[in] event_id`: the ID of the event with which to unregister the handler
- `[in] event_handler`: the handler to unregister

**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.

**Return**
- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail

**Parameters**
- `[in] event_loop`: the event loop with which to unregister this handler function, must not be NULL
- `[in] event_base`: the base of the event with which to unregister the handler
- `[in] event_id`: the ID of the event with which to unregister the handler
- `[in] instance`: the instance object of the registration to be unregistered

**esp_err_t esp_event_handler_instance_unregister**(esp_event_base_t event_base, int32_t event_id, esp_event_handler_instance_t instance)

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.

**Return**
- ESP_OK: Success
- ESP_ERR_INVALID_ARG: Invalid combination of event base and event ID
- Others: Fail
Parameters

• [in] event_base: the base of the event with which to unregister the handler
• [in] event_id: the ID of the event with which to unregister the handler
• [in] instance: the instance object of the registration to be unregistered

*esp_err_t* esp_event_post *(esp_event_base_t event_base, int32_t event_id, const void *event_data, size_t event_data_size, TickType_t ticks_to_wait)*

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.

Return

• 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

Parameters

• [in] event_base: the event base that identifies the event
• [in] event_id: the ID that identifies the event
• [in] event_data: the data, specific to the event occurrence, that gets passed to the handler
• [in] event_data_size: the size of the event data
• [in] ticks_to_wait: number of ticks to block on a full event queue

*esp_err_t* esp_event_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, TickType_t ticks_to_wait)*

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.

Return

• 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

Parameters

• [in] event_loop: the event loop to post to, must not be NULL
• [in] event_base: the event base that identifies the event
• [in] event_id: the ID that identifies the event
• [in] event_data: the data, specific to the event occurrence, that gets passed to the handler
• [in] event_data_size: the size of the event data
• [in] ticks_to_wait: number of ticks to block on a full event queue

*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

Return

• 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

Parameters
Chapter 2. API Reference

- [in] event_base: the event base that identifies the event
- [in] event_id: the event ID that identifies the event
- [in] event_data: the data, specific to the event occurrence, that gets passed to the handler
- [in] event_data_size: the size of the event data; max is 4 bytes
- [out] task_unblocked: 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 existed.

```c
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

**Return**
- 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

**Parameters**
- [in] event_loop: the event loop to post to, must not be NULL
- [in] event_base: the event base that identifies the event
- [in] event_id: the event ID that identifies the event
- [in] event_data: the data, specific to the event occurrence, that gets passed to the handler
- [in] event_data_size: the size of the event data
- [out] task_unblocked: 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 existed.

```c
esp_err_t esp_event_dump(FILE *file)
```

Dumps statistics of all event loops.

Dumps event loop info in the format:

```
<table>
<thead>
<tr>
<th>event loop</th>
<th>handler</th>
<th>handler</th>
<th>...</th>
</tr>
</thead>
</table>
```

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
```

(continues on next page)
total_invoked - number of times this handler has been invoked
total_runtime - total amount of time used for invoking this handler

Note this function is a noop when CONFIG_ESP_EVENT_LOOP_PROFILING is disabled

Return
- ESP_OK: Success
- ESP_ERR_NO_MEM: Cannot allocate memory for event loops list
- Others: Fail

Parameters
- [in] file: the file stream to output to

Structures
struct esp_event_loop_args_t
Configuration for creating event loops.

Public Members

int32_t queue_size
size of the event loop queue

const char *task_name
name of the event loop task; if NULL, a dedicated task is not created for event loop

UBaseType_t task_priority
priority of the event loop task, ignored if task name is NULL

uint32_t task_stack_size
stack size of the event loop task, ignored if task name is NULL

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)

ESP_EVENT_ANY_BASE
register handler for any event base

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

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

Legacy event loop

API Reference

Header File

- components/esp_event/include/esp_event_legacy.h

Functions

`esp_err_t esp_event_send(system_event_t *event)`

Send an event to event task.

Other task/modules, such as the tcpip_adapter, can call this API to send an event to event task

**Note** This API is part of the legacy event system. New code should use event library API in esp_event.h

**Return** ESP_OK: succeed
**Return** others: fail

**Parameters**

- `event`: Event to send

`esp_err_t esp_event_send_internal(system_event_t *event)`

Send an event to event task.

Other task/modules, such as the tcpip_adapter, can call this API to send an event to event task

**Note** This API is used by Wi-Fi Driver only.

**Return** ESP_OK: succeed
**Return** others: fail

**Parameters**

- `event_base`: the event base that identifies the event
- `event_id`: the event ID that identifies the event
- `event_data`: the data, specific to the event occurrence, that gets passed to the handler
- `event_data_size`: the size of the event data
- `ticks_to_wait`: number of ticks to block on a full event queue

`esp_err_t esp_event_process_default(system_event_t *event)`

Default event handler for system events.

This function performs default handling of system events. When using esp_event_loop APIs, it is called automatically before invoking the user-provided callback function.

**Note** This API is part of the legacy event system. New code should use event library API in esp_event.h

Applications which implement a custom event loop must call this function as part of event processing.

**Return** ESP_OK if an event was handled successfully

**Parameters**

- `event`: pointer to event to be handled

void `esp_event_set_default_eth_handlers(void)`

Install default event handlers for Ethernet interface.

**Note** This API is part of the legacy event system. New code should use event library API in esp_event.h

void `esp_event_set_default_wifi_handlers(void)`

Install default event handlers for Wi-Fi interfaces (station and AP)

**Note** This API is part of the legacy event system. New code should use event library API in esp_event.h
**esp_err_t esp_event_loop_init (system_event_cb_t cb, void *ctx)**

Initialize event loop.

Create the event handler and task

**Note** This API is part of the legacy event system. New code should use event library API in esp_event.h

**Return**
- ESP_OK: succeed
- others: fail

**Parameters**
- cb: application specified event callback, it can be modified by call esp_event_set_cb
- ctx: reserved for user

**system_event_cb_t esp_event_loop_set_cb (system_event_cb_t cb, void *ctx)**

Set application specified event callback function.

**Note** This API is part of the legacy event system. New code should use event library API in esp_event.h

**Attention** 1. If cb is NULL, means application doesn’t need to handle If cb is not NULL, it will be called when an event is received, after the default event callback is completed

**Return** old callback

**Parameters**
- cb: application callback function
- ctx: argument to be passed to callback

**Unions**

**union system_event_info_t**

# include <esp_event_legacy.h> Union of all possible system_event argument structures

**Public Members**

**system_event_sta_connected_t**

- **connected**
  ESP32 station connected to AP

**system_event_sta_disconnected_t**

- **disconnected**
  ESP32 station disconnected to AP

**system_event_sta_scan_done_t**

- **scan_done**
  ESP32 station scan (APs) done

**system_event_sta_authmode_change_t**

- **auth_change**
  the auth mode of AP ESP32 station connected to changed

**system_event_sta_got_ip_t**

- **got_ip**
  ESP32 station got IP, first time got IP or when IP is changed

**system_event_sta_wps_er_pin_t**

- **sta_er_pin**
  ESP32 station WPS enrollee mode PIN code received

**system_event_sta_wps_fall_reason_t**

- **sta_er_fail_reason**
  ESP32 station WPS enrollee mode failed reason code received

**system_event_sta_wps_success_t**

- **sta_er_success**
  ESP32 station WPS enrollee success

**system_event_ap_staconnected_t**

- **sta_connected**
  a station connected to ESP32 soft-AP

**system_event_ap_stadisconnected_t**

- **sta_disconnected**
  a station disconnected to ESP32 soft-AP

**system_event_ap_probe_req_rx_t**

- **ap_proberreqrecv**
  ESP32 soft-AP receive probe request packet
Chapter 2. API Reference

system_event_ftm_report_t ftm_report
Report of FTM procedure

system_event_ap_staipassigned_t ap_staipassigned
ESP32 soft-AP assign an IP to the station

system_event_got_ip6_t got_ip6
ESP32 station or ap or ethernet ipv6 addr state change to preferred

Structures
struct system_event_t
Event, as a tagged enum

Public Members

system_event_id_t event_id
event ID

system_event_info_t event_info
event information

Macros
SYSTEM_EVENT_AP_STA_GOT_IP6

Type Definitions
typedef wifi_event_sta_wps_fail_reason_t system_event_sta_wps_fail_reason_t
Argument structure of SYSTEM_EVENT_STA_WPS_ER_FAILED event
typedef wifi_event_sta_scan_done_t system_event_sta_scan_done_t
Argument structure of SYSTEM_EVENT_SCAN_DONE event
typedef wifi_event_sta_connected_t system_event_sta_connected_t
Argument structure of SYSTEM_EVENT_STA_CONNECTED event
typedef wifi_event_sta_disconnected_t system_event_sta_disconnected_t
Argument structure of SYSTEM_EVENT_STA_DISCONNECTED event
typedef wifi_event_sta_authmode_change_t system_event_sta_authmode_change_t
Argument structure of SYSTEM_EVENT_STA_AUTHMODE_CHANGE event
typedef wifi_event_sta_wps_er_pin_t system_event_sta_wps_er_pin_t
Argument structure of SYSTEM_EVENT_STA_WPS_ER_PIN event
typedef wifi_event_sta_wps_er_success_t system_event_sta_wps_er_success_t
Argument structure of SYSTEM_EVENT_STA_WPS_ER_SUCCESS event
typedef wifi_event_ap_staconnected_t system_event_ap_staconnected_t
Argument structure of event
typedef wifi_event_ap_stadisconnected_t system_event_ap_stadisconnected_t
Argument structure of event
typedef wifi_event_probe_req_rx_t system_event_probe_req_rx_t
Argument structure of event
typedef wifi_event_ftm_report_t system_event_ftm_report_t
Argument structure of SYSTEM_EVENT_FTM_REPORT event
typedef ip_event_ap_staipassigned_t system_event_ap_staipassigned_t
Argument structure of event
typedef ip_event_got_ip_t system_event_sta_got_ip_t
Argument structure of event
typedef ip_event_got_ip6_t system_event_got_ip6_t
Argument structure of event

typedef esp_err_t (*system_event_handler_t)(esp_event_base_t event_base, int32_t event_id, void *event_data, size_t event_data_size, TickType_t ticks_to_wait)
Event handler function type

typedef esp_err_t (*system_event_cb_t)(void *ctx, system_event_t *event)
Application specified event callback function.

Note This API is part of the legacy event system. New code should use event library API in esp_event.h

Return
• ESP_OK: succeed
• others: fail

Parameters
• ctx: reserved for user
• event: event type defined in this file

Enumerations
enum system_event_id_t
System event types enumeration

Values:

SYSTEM_EVENT_WIFI_READY = 0
ESP32 Wi-Fi ready

SYSTEM_EVENT_SCAN_DONE
ESP32 finish scanning AP

SYSTEM_EVENT_STA_START
ESP32 station start

SYSTEM_EVENT_STA_STOP
ESP32 station stop

SYSTEM_EVENT_STA_CONNECTED
ESP32 station connected to AP

SYSTEM_EVENT_STA_DISCONNECTED
ESP32 station disconnected from AP

SYSTEM_EVENT_STA_AUTHMODE_CHANGE
the auth mode of AP connected by ESP32 station changed

SYSTEM_EVENT_STA_GOT_IP
ESP32 station got IP from connected AP

SYSTEM_EVENT_STA_LOST_IP
ESP32 station lost IP and the IP is reset to 0

SYSTEM_EVENT_STA_BSS_RSSI_LOW
ESP32 station connected BSS rssi goes below threshold

SYSTEM_EVENT_STA_WPS_ER_SUCCESS
ESP32 station wps succeeds in enrollee mode

SYSTEM_EVENT_STA_WPS_ER_FAILED
ESP32 station wps fails in enrollee mode

SYSTEM_EVENT_STA_WPS_ER_TIMEOUT
ESP32 station wps timeout in enrollee mode

SYSTEM_EVENT_STA_WPS_ER_PIN
ESP32 station wps pin code in enrollee mode
Chapter 2. API Reference

SYSTEM_EVENT_STA_WPS_ER_PBC_OVERLAP
   ESP32 station wps overlap in enrollee mode

SYSTEM_EVENT_AP_START
   ESP32 soft-AP start

SYSTEM_EVENT_AP_STOP
   ESP32 soft-AP stop

SYSTEM_EVENT_AP_STACONNECTED
   a station connected to ESP32 soft-AP

SYSTEM_EVENT_AP_STADISCONNECTED
   a station disconnected from ESP32 soft-AP

SYSTEM_EVENT_AP_STAIPASSIGNED
   ESP32 soft-AP assign an IP to a connected station

SYSTEM_EVENT_AP_PROBEREQRECVED
   Receive probe request packet in soft-AP interface

SYSTEM_EVENT_ACTION_TX_STATUS
   Receive status of Action frame transmitted

SYSTEM_EVENT_ROC_DONE
   Indicates the completion of Remain-on-Channel operation status

SYSTEM_EVENT_STA_Beacon_TIMEOUT
   ESP32 station beacon timeout

SYSTEM_EVENT_FTM_REPORT
   Receive report of FTM procedure

SYSTEM_EVENT_GOT_IP6
   ESP32 station or ap or ethernet interface v6IP addr is preferred

SYSTEM_EVENT_ETH_START
   ESP32 ethernet start

SYSTEM_EVENT_ETH_STOP
   ESP32 ethernet stop

SYSTEM_EVENT_ETH_CONNECTED
   ESP32 ethernet phy link up

SYSTEM_EVENT_ETH_DISCONNECTED
   ESP32 ethernet phy link down

SYSTEM_EVENT_ETH_GOT_IP
   ESP32 ethernet got IP from connected AP

SYSTEM_EVENT_ETH_LOST_IP
   ESP32 ethernet lost IP and the IP is reset to 0

SYSTEM_EVENT_MAX
   Number of members in this enum

2.7.10 FreeRTOS

Overview

This section contains documentation of FreeRTOS types, functions, and macros. It is automatically generated from FreeRTOS header files.

Note: ESP-IDF FreeRTOS is based on Vanilla FreeRTOS v10.4.3
• For more information about the SMP changes of ESP-IDF FreeRTOS, see ESP-IDF FreeRTOS (SMP).
• For more information about the features added to ESP-IDF FreeRTOS, see FreeRTOS Supplemental Features.

Configuration

Vanilla FreeRTOS allows ports and applications to configure the kernel by adding various `#define config...` macros to `FreeRTOSConfig.h`. Through these macros, the kernel’s scheduling behavior and various kernel features can be enabled or disabled. However, in ESP-IDF FreeRTOS, the "`FreeRTOSConfig.h`" file is considered a private and must not be modified by users. Any FreeRTOS configuration that is exposed to the user will be done so via menuconfig.

ESP-IDF FreeRTOS can be configured in the project configuration menu (`idf.py menuconfig`) under Component Config/FreeRTOS. The following section highlights some of the ESP-IDF FreeRTOS configuration options. For a full list of ESP-IDF FreeRTOS configurations, see Project Configuration.

- **CONFIG_FREERTOS_UNICORE** will run ESP-IDF FreeRTOS only on CPU0. Note that this is not equivalent to running Vanilla FreeRTOS. Futhermore, this option may affect behavior of components other than freertos. For more details regarding the effects of running ESP-IDF FreeRTOS on a single core, refer to ESP-IDF FreeRTOS Single Core. Alternatively, users can also search for occurrences of CONFIG_FREERTOS_UNICORE in the ESP-IDF components.
- **CONFIG_FREERTOS_ASSERT_ON_UNTESTED_FUNCTION** will trigger a halt in functions in ESP-IDF FreeRTOS that have not been fully tested in an SMP context.
- **CONFIG_FREERTOS_TASK_FUNCTION_WRAPPER** will enclose all task functions within a wrapper function. In the case that a task function mistakenly returns (i.e., does not call `vTaskDelete()`), the call flow will return to the wrapper function. The wrapper function will then log an error and abort the application, as illustrated below:

```
E (25) FreeRTOS: FreeRTOS task should not return. Aborting now!
abort() was called at PC 0x40085c53 on core 0
```

ESP-IDF FreeRTOS Applications

Unlike Vanilla FreeRTOS, users must not call `vTaskStartScheduler()`. Instead, ESP-IDF FreeRTOS is started automatically. The entry point is a user defined `void app_main(void)` function.

- Typically, users would spawn the rest of their applications task from `app_main`.
- The `app_main` function is allowed to return at any point (i.e., before the application terminates).
- The `app_main` function is called from the `main` task.

The `main` task is one of multiple tasks that are automatically spawned by ESP-IDF during startup. These tasks are:

```
<table>
<thead>
<tr>
<th>Task Name</th>
<th>Affinity</th>
<th>Priority</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Task (main)</td>
<td>CPU0</td>
<td>1</td>
<td>Task that simply calls app_main. This task will self delete when app_main returns</td>
</tr>
<tr>
<td>Idle Tasks (IDLEx)</td>
<td>CPU0 and CPU1</td>
<td>0</td>
<td>Idle tasks created for (and pinned to) each CPU</td>
</tr>
<tr>
<td>IPC Tasks (ipc)</td>
<td>CPU0 and CPU1</td>
<td>24</td>
<td>IPC tasks created for (and pinned to) each CPU. IPC tasks are used to implement the IPC feature. See Inter-Processor Call for more details.</td>
</tr>
</tbody>
</table>
```

Task API

Header File

- components/freertos/FreeRTOS-Kernel/include/freertos/task.h
Chapter 2. API Reference

Functions

** BaseType_t xTaskCreatePinnedToCore**(TaskFunction_t pvTaskCode, const char *const pcName, const uint32_t usStackDepth, void *const pvParameters, UBaseType_t uxPriority, TaskHandle_t *const pxCreatedTask, const BaseType_t xCoreID)

Create a new task with a specified affinity.

This function is similar to xTaskCreate, but allows setting task affinity in SMP system.

**Return** pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

**Parameters**

- **pvTaskCode**: 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**: 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 (portNUM_PROCESSORS - 1) will cause the function to fail.

**static BaseType_t xTaskCreate**(TaskFunction_t pvTaskCode, const char *const pcName, const uint32_t 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;
}
```

(continues on next page)
Create the task, 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 automatic stack variable it might no longer exist, or at least have been corrupted, by the time the new task attempts to access it.

```c
xTaskCreate( vTaskCode, "NAME", STACK_SIZE, &ucParameterToPass, tskIDLE_PRIORITY, &xHandle );
```

Use the handle to delete the task.
```
if( xHandle != NULL )
{
    vTaskDelete( xHandle );
}
```

Return pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

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
- pvTaskCode: 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: Used to pass back a handle by which the created task can be referenced.

```c
TaskHandle_t xTaskCreateStaticPinnedToCore( TaskFunction_t pvTaskCode, 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.

This function is similar to xTaskCreateStatic, but allows specifying task affinity in an SMP system.

Return 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 errorCOULD_NOT_ALLOCATE_REQUIRED_MEMORY is returned.

Parameters
- pvTaskCode: 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 `(portNUM_PROCESSORS - 1)` will cause the function to fail.

```c
static TaskHandle_t xTaskCreateStatic(
    TaskFunction_t pvTaskCode, 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 [http://www.freertos.org/a00111.html](http://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.
    }
}

// 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.
    )
```

(continues on next page)
tskIDLE_PRIORITY, // Priority at which the task is created. xStack,  // Array to use as the task's stack. pxTaskBuffer }; // Variable to hold the task's data...

\[...

Return: 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 error COULD_NOT_ALLOCATE_REQUIRED_MEMORY is returned.

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:
- pvTaskCode: 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.

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.

return pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

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 referenced.

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,     // ulStackDepth - the stack size DEFINED IN WORDS.
    NULL,    // pvParameters - passed into the task function as the function's parameters.
};
```

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```c
{ (UL | 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.

  // 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.
  { // Base address                        | Length | Parameters
    { 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.

return pdPASS if the task was successfully created and added to a ready list, otherwise an error code defined in the file projdefs.h

**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. If configSUPPORT_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 referenced.

**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
```
Chapter 2. API Reference

(continued from previous 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.
static PRIVILEGED_DATA StaticTask_t xTaskBuffer;
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 BYTES.
    NULL,  // pvParameters - passed into the task function as the function-
            // parameters.
    ( const 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.
    
    // Base address Length Parameters
    { cReadWriteArray, 32, portMPU_REGION_READ_WRITE },
    { cReadOnlyArray, 32, portMPU_REGION_READ_ONLY },
    { cPrivilegedOnlyAccessArray, 128, portMPU_REGION_PRIVILEGED_READ-
      WRITE }
    
    &xTaskBuffer; // Holds the task's data structure.
};

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( ;; );
}
```

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:

```
// Define an array of MemoryRegion_t structures that configures an MPU region
// allowing read/write access for 1024 bytes starting at the beginning of the
// ucOneKByte array. The other two of the maximum 3 definable regions are
// unused so set to zero.
static const MemoryRegion_t xAltRegions[ portNUM_CONFIGURABLE_REGIONS ] = {
    // Base address Length Parameters
    { ucOneKByte, 1024, portMPU_REGION_READ_WRITE },
    { 0, 0, 0 },

    (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
• xTask: The handle of the task being updated.
• pxRegions: A pointer to an MemoryRegion_t structure that contains the new memory region
definitions.

void vTaskDelete (TaskHandle_t xTaskToDelete)
INCLUDEnedefine 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:

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.

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.

INCLUDEnedefine 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.

Example usage:

```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.
    }
}
```
Return 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.

Parameters

• pxPreviousWakeTime: Pointer to a variable that holds the time at which the task was last unblocked. The variable must be initialised 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.

 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 called 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.

Return If the task referenced by xTask was not in the Blocked state then pdFAIL is returned. Otherwise pdPASS is returned.

Parameters

• xTask: The handle of the task to remove from the Blocked state.

 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:

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 ) )
}
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```c
{
    // Our priority (obtained using NULL handle) is higher.
}
```

Return  The priority of xTask.

Parameters

- `xTask`: Handle of the task to be queried. Passing a NULL handle results in the priority of the calling task being returned.

`UBaseType_t uxTaskPriorityGetFromISR(const TaskHandle_t xTask)`

A version of `uxTaskPriorityGet()` that can be used from an ISR.

`eTaskState eTaskGetState(TaskHandle_t xTask)`

INCLUDE_eTaskGetStatemust 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.

Return  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.

Parameters

- `xTask`: Handle of the task to be queried.

`void vTaskGetInfo(TaskHandle_t xTask, TaskStatus_t *pxTaskStatus, BaseType_t xGetFreeStackSpace, eTaskState eState)`

Include USE_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.

```c
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.

```c
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 );
}
```

(continues on next page)
The created task will not run during this period, unless another task calls vTaskResume( xHandle ).

//...  

// Suspend ourselves.
void 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.

#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:

#include "vTaskSuspend"  

void vAFункция( void )
{
TaskHandle_t xHandle;

// Create a task, storing the handle.
void vTaskCreate( vTaskCode, "NAME", STACK_SIZE, NULL, tskIDLE_PRIORITY, &xHandle,
);
//...

// Use the handle to suspend the created task.
void vTaskSuspend( xHandle );
//...

// The created task will not run during this period, unless another task calls vTaskResume( xHandle ).
//...

// Resume the suspended task ourselves.
void 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.
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.

**Return** 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.

**Parameters**
- xTaskToResume: Handle to the task being readied.

```c
void vTaskStartScheduler (void)  
Starts the real time kernel tick processing. After calling the kernel has control over which tasks are executed and when.

NOTE: In ESP-IDF the scheduler is started automatically during application startup, vTaskStartScheduler() should not be called from ESP-IDF applications.

See the demo application file main.c for an example of creating tasks and starting the kernel.

Example usage:

```c
void vAFunction( 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 ()
}
```

```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 ();
    }
```

(continues on next page)
void vAFunction( 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
// xTaskEndScheduler(). 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:

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();
        }
    }
}
```

**Return** If resuming the scheduler caused a context switch then pdTRUE is returned, otherwise pdFALSE is returned.

TickType_t `xTaskGetTickCount` (void)

**Return** 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.

**Return** The count of ticks since vTaskStartScheduler was called.

UBaseType_t `uxTaskGetNumberOfTasks` (void)

**Return** 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)

**Return** 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.

**Return** 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.

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.

Return 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.

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.

configSTACK_DEPTH_TYPE uxTaskGetStackHighWaterMark2(TaskHandle_t xTask)
Returns the start of the stack associated with xTask.

INCLUDE_uxTaskGetStackHighWaterMark2 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 words, so on a 32 bit machine a value of 1 means 4 bytes) 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.

Return The smallest amount of free stack space there has been (in words, so actual spaces on the stack rather than bytes) since the task referenced by xTask was created.

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.

uint8_t *pxTaskGetStackStart(TaskHandle_t xTask)
Returns the start of the stack associated with xTask.

INCLUDE_pxTaskGetStackStart must be set to 1 in FreeRTOSConfig.h for this function to be available.

Returns the lowest stack memory address, regardless of whether the stack grows up or down.

Return A pointer to the start of the stack.

Parameters
- xTask: Handle of the task associated with the stack returned. Set xTask to NULL to return the stack of the calling task.

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.

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.
TaskHookFunction_t xTaskGetApplicationTaskTagFromISR(TaskHandle_t xTask)

Returns the pxHookFunction value assigned to the task xTask. Can be called from an interrupt service routine.

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.

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.

Return Pointer value

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.

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.

void vApplicationGetIdleTaskMemory(StaticTask_t **ppxIdleTaskTCBBuffer, StackType_t **ppxIdleTaskStackBuffer, 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

Parameters
- ppxIdleTaskTCBBuffer: A handle to a statically allocated TCB buffer
- ppxIdleTaskStackBuffer: 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
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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.

TaskHandle_t xTaskGetIdleTaskHandle ( void )

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.

UBaseType_t uxTaskGetSystemState ( TaskStatus_t *pxTaskStatusArray, const UBaseType_t uxArraySize, uint32_t *const pulTotalRunTime )

configUSE_TRACE_FACILITY must be defined as 1 in FreeRTOSConfig.h for uxTaskGetSystemState() to be available.

uxTaskGetSystemState() populates a 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.

NOTE: This function is intended for debugging use only as its use results in the scheduler remaining suspended for an extended period.

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,
(continues on next page)
// 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
    / 100 / ulTotalRunTime;
    if( ulStatsAsPercentage > 0UL )
    {
        sprintf( pcWriteBuffer, "%s	%lu	%lu%%
", 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	%lu	<1%%
", pxTaskStatusArray[ x ].pcTaskName, pxTaskStatusArray[ x ].ulRunTimeCounter );
    }
    pcWriteBuffer += strlen( ( char * ) pcWriteBuffer );
}
// The array is no longer needed, free the memory it consumes.
vPortFree( pxTaskStatusArray );

Return 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.

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.

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 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. 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.

**Return** 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 portCONFIGURE_TIMER_FOR_RUN_TIME_STATS() and portGET_RUN_TIME_COUNTER_VALUE() macros.

```c
BaseType_t xTaskGenericNotify(TaskHandle_t xTaskToNotify, UBaseType_t uxIndexToNotify, uint32_t ulValue, eNotifyAction eAction, uint32_t* pulPreviousNotificationValue)
```


**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:

  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.

  pulPreviousNotificationValue - Can be used to pass out the subject task’s notification value before any bits are modified by the notify function.

Return Dependent on the value of eAction. See the description of the eAction parameter.

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 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 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.

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 config-TASK_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:
  - 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.

Return Dependent on the value of eAction. See the description of the eAction parameter.

Parameters
- `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.

```c
BaseType_t xTaskGenericNotifyWait (UBaseType_t uxIndexToWaitOn, uint32_t ulBitsToClearOnEntry, uint32_t ulBitsToClearOnExit, uint32_t *pulNotificationValue, TickType_t xTicksToWait)
```

Waits for a direct to task notification to be pending at a given index within an array of direct to task notifications. See https://www.FreeRTOS.org/RTOS-task-notifications.html for details.

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 lightweight 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.

**Return** If a notification was received (including notifications that were already pending when xTaskNotifyWait was called) then pdPASS is returned. Otherwise pdFAIL is returned.

**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 checks to see if any notifications are pending, and optionally blocks if no notifications are pending. Setting ulBitsToClearOnEntry to ULONG_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 ULONG_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.

```c
void vTaskGenericNotifyGiveFromISR(TaskHandle_t xTaskToNotify, UBaseType_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 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{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 \texttt{xSemaphoreGiveFromISR()} API function, the equivalent action that instead uses a task notification is \texttt{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 \texttt{ulTaskNotificationTakeIndexed()} API function rather than the \texttt{xTaskNotifyWaitIndexed()} API function.

\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{xTaskNotifyFromISR()} is the original API function, and remains backward compatible by always operating on the notification value at index 0 within the array. Calling \texttt{xTaskNotifyGiveFromISR()} is equivalent to calling \texttt{xTaskNotifyGiveIndexedFromISR()} with the \texttt{uxIndexToNotify} parameter set to 0.

\textbf{Parameters}

- \texttt{xTaskToNotify}: The handle of the task being notified. The handle to a task can be returned from the \texttt{xTaskCreate()} API function used to create the task, and the handle of the currently running task can be obtained by calling \texttt{xTaskGetCurrentTaskHandle()}.
- \texttt{uxIndexToNotify}: The index within the target task’s array of notification values to which the notification is to be sent. \texttt{uxIndexToNotify} must be less than \texttt{configTASK_NOTIFICATION_ARRAY_ENTRIES}. \texttt{xTaskNotifyGiveFromISR()} does not have this parameter and always sends notifications to index 0.
- \texttt{pxHigherPriorityTaskWoken}: \texttt{vTaskNotifyGiveFromISR()} will set \texttt{*pxHigherPriorityTaskWoken} to \texttt{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 \texttt{vTaskNotifyGiveFromISR()} sets this value to \texttt{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.

\begin{verbatim}
uint32_t ulTaskGenericNotifyTake (UBaseType_t uxIndexToWaitOn, BaseType_txClearCountOnExit, TickType_t xTicksToWait)
\end{verbatim}

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.

See \url{https://www.FreeRTOS.org/RTOS-task-notifications.html} for details.

\texttt{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 (\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.

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.
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 xSemaphoreTake() API function, the equivalent action that instead uses a task notification is ulTaskNotifyTakeIndexed().

When a task is using its notification value as a binary or counting semaphore other tasks should send notifications to it using the xTaskNotifyGiveIndexed() macro, or xTaskNotifyIndex() function with the eAction parameter set to eIncrement.

ulTaskNotifyTakeIndexed() can either clear the task’s notification value at the array index specified by the 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 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 xTaskNotifyWaitIndexed() will return when a notification is pending, ulTaskNotifyTakeIndexed() will return when the task’s notification value is not zero.

**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. ulTaskNotifyTake() is the original API function, and remains backward compatible by always operating on the notification value at index 0 in the array. Calling ulTaskNotifyTake() is equivalent to calling ulTaskNotifyTakeIndexed() with the uxIndexToWaitOn parameter set to 0.

**Return** The task’s notification count before it is either cleared to zero or decremented (see the xClearCountOnExit parameter).

**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 non-zero. uxIndexToWaitOn must be less than configTASK_NOTIFICATION_ARRAY_ENTRIES. xTaskNotifyTake() does not have this parameter and always waits for notifications on index 0.
- **xClearCountOnExit**: if xClearCountOnExit is 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 xClearCountOnExit is not 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.
- **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 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 pdMS_TO_TICKS(value_in_ms) can be used to convert a time specified in milliseconds to a time specified in ticks.

BaseType_t xTaskGenericNotifyStateClear(TaskHandle_t xTask, UBaseType_t uxIndexToClear)


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.

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. 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.

Return pdTRUE if the task’s notification state was set to eNotWaitingNotification, otherwise pdFALSE.

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 configTASK_NOTIFICATION_ARRAY_ENTRIES. ulTaskNotifyStateClear() does not have this parameter and always acts on the notification at index 0.

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.

Return The value of the target task’s notification value before the bits specified by ulBitsToClear were cleared.

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 configTASK_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.

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:
Driver library function used to receive `uxWantedBytes` from an Rx buffer that is filled by a UART interrupt. If there are not enough bytes in the Rx buffer then the task enters the Blocked state until it is notified that more data has been placed into the buffer. If there is still not enough data then the task re-enters the Blocked state, and `xTaskCheckForTimeOut()` is used to re-calculate the Block time to ensure the total amount of time spent in the Blocked state does not exceed `MAX_TIME_TO_WAIT`. This continues until either the buffer contains at least `uxWantedBytes` bytes, or the total amount of time spent in the Blocked state reaches `MAX_TIME_TO_WAIT` at which point the task reads however many bytes are available up to a maximum of `uxWantedBytes`.

```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;
}
```

Return If timeout has occurred, `pdTRUE` is returned. Otherwise `pdFALSE` is returned and `pxTicksToWait` is updated to reflect the number of remaining ticks.

See [https://www.FreeRTOS.org/xTaskCheckForTimeOut.html](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.

```c
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.

```c
void taskYIELD ()
```

Macro for forcing a context switch.

```c
void taskENTER_CRITICAL ()
```

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!

```c
void taskENTER_CRITICAL_FROM_ISR ()
```

```c
void taskENTER_CRITICAL_ISR ()
```

```c
void taskEXIT_CRITICAL ()
```

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!

```c
void taskEXIT_CRITICAL_FROM_ISR (x)
```

```c
void taskEXIT_CRITICAL_ISR ()
```

```c
void taskDISABLE_INTERRUPTS ()
```

Macro to disable all maskable interrupts.

```c
void taskENABLE_INTERRUPTS ()
```

Macro to enable microcontroller interrupts.

```c
void taskSCHEDULER_SUSPENDED
```

```c
void taskSCHEDULER_NOT_STARTED
```

```c
void taskSCHEDULER_RUNNING
```

```c
void vTaskDelayUntil (pxPreviousWakeTime, xTimeIncrement)
```

```c
void xTaskNotify (xTaskToNotify, ulValue, eAction)
```

```c
void 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 pulPreviousNotifyValue parameter.

xTaskNotifyAndQueryFromISR (xTaskToNotify, ulValue, eAction, pulPreviousNotificationValue, pxHigherPriorityTaskWoken)

xTaskNotifyWait (ulBitsToClearOnEntry, ulBitsToClearOnExit, pulNotificationValue, xTicksToWait)

xTaskNotifyWaitIndexed (uxIndexToWaitOn, ulBitsToClearOnEntry, ulBitsToClearOnExit, pulNotificationValue, xTicksToWait)

xTaskNotifyGive (xTaskToNotify)
Sends a direct to 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.

**Return** `xTaskNotifyGive()` is a macro that calls `xTaskNotify()` with the `eAction` parameter set to `eIncrement` - so `pdlPASS` is always returned.

**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.

```c
xTaskNotifyGiveIndexed (xTaskToNotify, uxIndexToNotify)
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**
```c
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**
```c
enum eTaskState
    Task states returned by `eTaskGetState`.
    Values:
    eRunning = 0
    eReady
    eBlocked
    eSuspended
    eDeleted
```

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Chapter 2. API Reference

```c
enum eNotifyAction
{
    eNoAction = 0,
    eSetBits,
    eIncrement,
    eSetValueWithOverwrite,
    eSetValueWithoutOverwrite,
}
```

```c
enum eSleepModeStatus
{
    eAbortSleep = 0,
    eStandardSleep,
    eNoTasksWaitingTimeout,
}
```

Queue API

Header File

- components/freertos/FreeRTOS-Kernel/include/freertos/queue.h

Functions

```c
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 * ) );

    // ...
    if( xQueue1 != 0 )
```

(continues on next page)


{ 
    // 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.

Return pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

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).

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.
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.
```c
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.
```c
pxMessage = & xMessage;
xQueueSend( xQueue, ( void * ) &pxMessage, ( TickType_t ) 0 );
```

Task to peek the data from the queue.
```c
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 ) ) {
            // pcRxedMessage now points to the struct AMessage variable posted
            // by vATask, but the item still remains on the queue.
        }
    }
    // ... Rest of task code.
}
```

Return pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

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.

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().

Return pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

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.

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 ) )
        {
            // pxRxedMessage now points to the struct AMessage variable posted by vATask.
        }
    }
    // ... Rest of task code.
}
```

Return pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

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.

**UBaseType_t uxQueueMessagesWaiting(const QueueHandle_t xQueue)**

Return the number of messages stored in a queue.

**Return** The number of messages available in the queue.

**Parameters**

- **xQueue**: A handle to the queue being queried.

**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.

**Return** The number of spaces available in the queue.

**Parameters**

- **xQueue**: A handle to the queue being queried.

**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.

**BaseType_t xQueueGenericSendFromISR(QueueHandle_t xQueue, const void *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 );

        // 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();
    }

    // (continues on next page)
```
Return  pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

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.
- [out] pxHigherPriorityTaskWoken: xQueueGenericSendFromISR() 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 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).

```c
BaseType_t xQueueGiveFromISR(QueueHandle_t xQueue, BaseType_t *const pxHigherPriorityTaskWoken)
```

```c
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';
    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;
}
```

(continues on next page)
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 ();
}

Return  pdTRUE if an item was successfully received from the queue, otherwise pdFALSE.

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.
• [out] pxHigherPriorityTaskWoken: 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.

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.

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.

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.

Return 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.

Parameters
• xQueue: The handle of the queue the name of which will be returned.

QueueHandle_t xQueueGenericCreate(const UBaseType_t uxQueueLength, const UBaseType_t uxItemSize, const uint8_t ucQueueType)
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.

QueueHandle_t xQueueGenericCreateStatic(const UBaseType_t uxQueueLength, const UBaseType_t uxItemSize, uint8_t *pucQueueStorage, StaticQueue_t *pxStaticQueue, const uint8_t ucQueueType)
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.

QueueSetHandle_t xQueueCreateSet(const 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.

Return If the queue set is created successfully then a handle to the created queue set is returned. Otherwise NULL is returned.

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.

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.
Chapter 2. API Reference

Note 1: 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.

Return 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.

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.

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.

Return 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.

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.

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 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.

Return 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.

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.

QueueSetMemberHandle_t xQueueSelectFromSetFromISR (QueueSetHandle_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). 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.
}
```

Return If the queue is successfully create then a handle to the newly created queue is returned. If the queue cannot be created then 0 is returned.

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.

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...
    &xQueueBuffer ); // The buffer that will hold the...

    // 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.
}

Return
If the queue is created then a handle to the created queue is returned. If pxQueueBuffer is NULL
then NULL is returned.

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.
- 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.

xQueueSendToFront( xQueue, pvItemToQueue, 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:

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 );
}

// ... Rest of task code.

Return pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

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.

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:

struct AMessage
{
    char ucMessageID;
    char ucData[ 20 ];
} xMessage;

(continues on next page)
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 )
    {
        // 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.
}

Return pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

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.

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:

```
struct AMessage
{

```

(continues on next page)
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 )
    {
        // 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.
}

Return pdTRUE if the item was successfully posted, otherwise errQUEUE_FULL.

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.

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:

```c
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!
    }
    // ...
}
```

Return 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.

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.

xQueueSendToFrontFromISR (xQueue, pvItemToQueue, pxHigherPriorityTaskWoken)

This is a macro that calls xQueueGenericSendFromISR().

Post an item to the front 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.
    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 ();
  }
}
Return pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.
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.
  • [out] pxHigherPriorityTaskWoken: xQueueSendToFromFromISR() 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 xQueueSendToFromFromISR() sets this value to pdTRUE then a context switch should be requested before the interrupt is exited.

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
(continues on next page)
// 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 ();
}

Return pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

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.
- [out] pxHigherPriorityTaskWoken: xQueueSendToBackFromISR() will set pxHigherPriorityTaskWoken to pdTRUE if sending to the queue caused a task to unblock, and the un-
  blocked 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.

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:

QueueHandle_t xQueue;

void vFunction( void *pvParameters )
{
    // Create a queue to hold one uint32_t value. It is strongly
    // recommended 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 )
{
    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 a...
    context
    // switch so this interrupt returns directly to the unblocked task.
    portYIELD_FROM_ISR(); // or portEND_SWITCHING_ISR() depending on the port.
}

Return 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.

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.
• [out] pxHigherPriorityTaskWoken: xQueueOverwriteFromISR() will set *pxHigher-
PriorityTaskWoken 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 xQueueOverwriteFromISR() sets this
value to pdTRUE then a context switch should be requested before the interrupt is exited.

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 xQueueSendToFrontFromISR() and xQueueSendToBack-
FromISR() 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 )
    {
(continues on next page)```
// Actual macro used here is port specific.
portYIELD_FROM_ISR();
}
}

Return  pdTRUE if the data was successfully sent to the queue, otherwise errQUEUE_FULL.

Parameters

• xQueue: The handle to the queue on which the item to be placed is.
• 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.
• [out] pxHigherPriorityTaskWoken: xQueueSendFromISR() will set *pxHigherPriority
  TaskWoken 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.

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
Queuesets 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 a 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)

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

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 xSemaphoreCreateBinary
Static() 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 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 )
{
    // Semaphore cannot be used before a call to vSemaphoreCreateBinary().
    // 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.
    }
}
```

**Return** 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](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.

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;
StaticSemaphore_t xSemaphoreBuffer;
void vATask( void *pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateBinary() or
    // 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
    // dynamic memory allocation, and therefore the function will not return
    // NULL.
    xSemaphore = xSemaphoreCreateBinaryStatic( &xSemaphoreBuffer );
```

(continues on next page)
// Rest of task code goes here.
}

Return If the semaphore is created then a handle to the created semaphore is returned. If pxSemaphoreBuffer is NULL then NULL is returned.

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.

xSemaphoreTake (xSemaphore, xBlockTime)

Macro to obtain a semaphore. The semaphore must have previously been created with a call to xSemaphoreCreateBinary(), xSemaphoreCreateMutex() or xSemaphoreCreateCounting().

param xSemaphore A handle to the semaphore being taken - obtained when the semaphore was created.

param 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).

Example usage:

SemaphoreHandle_t xSemaphore = NULL;

// A task that creates a semaphore.
void vATask( void * pvParameters )
{
    // Create the semaphore to guard a shared resource.
    vSemaphoreCreateBinary( xSemaphore );
}

// 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.
    }
}

Return pdTRUE if the semaphore was obtained. pdFALSE if xBlockTime expired without the semaphore
becoming available.

\textbf{\texttt{xSemaphoreTakeRecursive}} \texttt{(xMutex, xBlockTime)}

*Macro* to recursively obtain, or ‘take’, a mutex type semaphore. The mutex must have previously been created using a call to \texttt{xSemaphoreCreateRecursiveMutex();}

c\texttt{onfigUSE_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 \texttt{xSemaphoreCreateMutex().}

A mutex used recursively can be ‘taken’ repeatedly by the owner. The mutex doesn’t become available again until the owner has called \texttt{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 \textit{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 \textit{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 \textit{not} be just sequential calls \textit{as} this would make
            // no sense. Instead the calls are likely to be buried inside
            // a more \textit{complex} call structure.
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );
            xSemaphoreTakeRecursive( xMutex, ( TickType_t ) 10 );

            // The mutex has now been 'taken' three times, so will \textit{not} be
            // available to another task until it has also been given back
            // three times. Again it \textit{is} unlikely that real code would have
            // these calls sequentially, but instead buried \textit{in} a more \textit{complex}
            // call structure. This \textit{is} just for illustrative purposes.
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );
            xSemaphoreGiveRecursive( xMutex );

            // Now the mutex can be taken by other tasks.
        }
        else
        {
            // We could \textit{not} obtain the mutex \textit{and} can therefore \textit{not} access
            // the shared resource safely.
        }
    }
    else
    { // Task could not obtain mutex
```

(continues on next page)
Return  pdTRUE if the semaphore was obtained. pdFALSE if xBlockTime expired without the semaphore becoming available.

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.

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.
    vSemaphoreCreateBinary( xSemaphore );

    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.
            }
        }
    }
}
```

Return  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.

**Parameters**

- `xSemaphore`: A handle to the semaphore being released. This is the handle returned when the semaphore was created.

**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.
        }
    }
}
```

(continues on next page)
else
{
    // We could not obtain the mutex and can therefore not access
    // the shared resource safely.
}
}

Return  pdTRUE if the semaphore was given.

Parameters

• `xMutex`: A handle to the mutex being released, or ‘given’. This is the handle returned by `xSemaphoreCreateMutex();`

**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?
}
```

(continues on next page)
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.
}

Return pdTRUE if the semaphore was successfully given, otherwise errQUEUE_FULL.

Parameters
• xSemaphore: A handle to the semaphore being released. This is the handle returned when the
  semaphore was created.
• pxHigherPriorityTaskWoken: xSemaphoreGiveFromISR() will set *pxHigherPriority-
  TaskWoken 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.

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).

Return pdTRUE if the semaphore was successfully taken, otherwise pdFALSE

Parameters
• xSemaphore: A handle to the semaphore being taken. This is the handle returned when the
  semaphore was created.
• [out] pxHigherPriorityTaskWoken: xSemaphoreTakeFromISR() will set *pxHigher-
  PriorityTaskWoken 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.

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
mutex type semaphores cannot be used from within interrupt service routines.

see \texttt{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:

\begin{verbatim}
SemaphoreHandle_t xSemaphore;
void vATask( void * pvParameters )
{
    // Semaphore cannot be used before a call to xSemaphoreCreateMutex().
    // This \texttt{is} a macro so \texttt{pass} the variable \texttt{in} directly.
    xSemaphore = xSemaphoreCreateMutex();

    if( xSemaphore != NULL )
    {
        // The semaphore was created successfully.
        // The semaphore can now be used.
    }
}
\end{verbatim}

\textbf{return} 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.

\texttt{xSemaphoreCreateMutexStatic()}\,(\texttt{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 \texttt{xSemaphoreCreateMutex()} then the required memory is automatically dynamically allocated inside the \texttt{xSemaphoreCreateMutex()} function. (see \url{https://www.FreeRTOS.org/a00111.html}). if a mutex is created using \texttt{xSemaphoreCreateMutexStatic()} then the application writer must provided the memory. \texttt{xSemaphoreCreateMutexStatic()} therefore allows a mutex to be created without using any dynamic memory allocation.

mutexes created using this function can be accessed using the \texttt{xSemaphoreTake()} and \texttt{xSemaphoreGive()} macros. the \texttt{xSemaphoreTakeRecursive()} and \texttt{xSemaphoreGiveRecursive()} macros must not be used.

this type of semaphore uses a priority inheritance mechanism so a task ‘taking’ a semaphore \textbf{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 \texttt{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:

\begin{verbatim}
SemaphoreHandle_t xSemaphore;
StaticSemaphore_t xMutexBuffer;
void vATask( void * pvParameters )
{
    // A mutex cannot be used before it has been created. xMutexBuffer \texttt{is}
    // into \texttt{xSemaphoreCreateMutexStatic()} so no dynamic memory allocation \texttt{is}
    // attempted.
    xSemaphore = xSemaphoreCreateMutexStatic( &xMutexBuffer );

    // As no dynamic memory allocation was performed, xSemaphore cannot be NULL,
    // so there \texttt{is} no need to check it.
}
\end{verbatim}
**Return**  If the mutex was successfully created then a handle to the created mutex is returned. If pxMutexBuffer was NULL, then NULL is returned.

**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.

**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 http://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 vSemaphoreCreateBinary() 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.
        // 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.

**Return**  xSemaphore Handle to the created mutex semaphore. Should be of type SemaphoreHandle_t.

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 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.

**Return** 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.

**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.

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](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.
    }
}
```

Return Handle to the created semaphore. Null if the semaphore could not be created.

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.

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](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.
}
```

**Return** 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.

**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.

**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.

**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.

**Type Definitions**

```c
typedef QueueHandle_t SemaphoreHandle_t
```
Timer API

Header File

- components/freertos/FreRTOS-Kernel/include/freertos/timers.h

Functions

TimerHandle_t xTimerCreate(const char * const pcTimerName, const TickType_t xTimerPeriodInTicks, UBaseType_t uxAutoReload, void * const pvTimerID, TimerCallbackFunction_t pxCallbackFunction)

TimerHandle_t xTimerCreate(const char * const pcTimerName, const 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). 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 );
*       }
* } (continues on next page)
```
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, not used by the kernel.
      ( 100 * x ), // The timer period in ticks.
      pdTRUE, // The timers will auto-reload themselves when they expire.
      ( void * ) x, // Assign each timer a unique id equal to its array index.
      vTimerCallback // Each timer calls the same callback when it expires.
    );
    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( ; ; );
}

Return If the timer is successfully created then a handle to the newly created timer is returned. If the timer cannot be created (because either there is insufficient FreeRTOS heap remaining to allocate the timer structures, or the timer period was set to 0) then NULL is returned.

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);”.

```
TimerHandle_t xTimerCreateStatic(const char * const pcTimerName, TickType_t xTimerPeriodInTicks, const 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). 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 )++;
 * 
 * (continues on next page)
```
If this callback has executed the required number of times, stop the timer.

```c
if (puxVariableToIncrement == 5)
{
    // This is called from a timer callback so must not block.
    xTimerStop( xExpiredTimer, staticDONT_BLOCK );
}
```

```c
void main( void )
{
    // Create the software time. xTimerCreateStatic() has an extra parameter
    // than the normal xTimerCreate() API function. The parameter is a
    // pointer
    // to the StaticTimer_t structure that will hold the software timer
    // structure. If the parameter is passed as NULL then the structure...
    // will be
    // allocated dynamically, just as if xTimerCreate() had been called.
    xTimer = xTimerCreateStatic("T1", // Text name for the task.
    xTimerPeriod, // The period of the...
    timer in ticks.
    pdTRUE, // This is an auto-reload
    timer.
    ( void * ) &uxVariableToIncrement, // A
    variable incremented by the software timer's callback function
    prvTimerCallback, // The function to...
    execute when the timer expires.
    &xTimerBuffer ); // The buffer that will...
    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
    // already
    // been set into the active state.
    vTaskStartScheduler();
    // Should not reach here.
    for( ;; );
}
```

**Return** If the timer is created then a handle to the created timer is returned. If pxTimerBuffer was NULL then NULL is returned.

**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. The 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 );”.
• 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.

void *pvTimerGetTimerID( const 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:

Return: The ID assigned to the timer being queried.

Parameters:
• xTimer: The timer being queried.

See the xTimerCreate() API function example usage scenario.

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:

Parameters:
• xTimer: The timer being updated.
• pvNewID: The ID to assign to the timer.

See the xTimerCreate() API function example usage scenario.

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 )
* {

(continues on next page)
if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply and...
  {  // xTimer is active, do something.
  }  
else  
  {  // xTimer is not active, do something else.
  }
  }

Return: pdFALSE will be returned if the timer is dormant. A value other than pdFALSE will be returned if the timer is active.

Parameters:
• xTimer: The timer being queried.

TaskHandle_t xTimerGetTimerDaemonTaskHandle ( void )
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 )
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:

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...  
}

void vAnISR( void )
{  
  BaseType_t xInterfaceToService, xHigherPriorityTaskWoken;  
  // An ISR that receives data packets from multiple interfaces  
  // Query the hardware to determine which interface needs processing.

(continues on next page)
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
// service is passed in the second parameter. The first parameter is
// not used in this case.

xHigherPriorityTaskWoken = pdFALSE;
xTimerPendFunctionCallFromISR( vProcessInterface, NULL, ( uint32_t )
  xInterfaceToService, &xHigherPriorityTaskWoken );

// 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 );

}

Return pdPASS is returned if the message was successfully sent to the timer daemon task, otherwise pdFALSE is returned.

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.

 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’).

Return pdPASS is returned if the message was successfully sent to the timer daemon task, otherwise pdFALSE is returned.

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.

const char *pcTimerGetName(TimerHandle_t xTimer)

const char * const pcTimerGetName( TimerHandle_t xTimer );
Ret <br /><br />urns the name that was assigned to a timer when the timer was created. <br />Return The name assigned to the timer specified by the xTimer parameter. <br />Parameters <br />• xTimer: The handle of the timer being queried. <br />void vTimersetName( TimerHandle_t xTimer, const char *pcName ) <br />void vTimersetName( TimerHandle_t xTimer, const char *pcName ); <br />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. <br />Parameters <br />• xTimer: The handle of the timer being updated. <br />• 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. <br />UBaseType_t uxTimerGetReloadMode( TimerHandle_t xTimer ) <br />UBaseType_t uxTimerGetReloadMode( TimerHandle_t xTimer ); <br />Queries a timer to determine if it is 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. <br />Return If the timer is an auto-reload timer then pdTRUE is returned, otherwise pdFALSE is returned. <br />Parameters <br />• xTimer: The handle of the timer being queried. <br />TickType_t xTimerGetPeriod( TimerHandle_t xTimer ) <br />TickType_t xTimerGetPeriod( TimerHandle_t xTimer ); <br />Returns the period of a timer. <br />Return The period of the timer in ticks. <br />Parameters <br />• xTimer: The handle of the timer being queried. <br />TickType_t xTimerGetExpiryTime( TimerHandle_t xTimer ) <br />TickType_t xTimerGetExpiryTime( TimerHandle_t xTimer ); <br />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. <br />Return 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. <br />Parameters <br />• xTimer: The handle of the timer being queried. <br />void vApplicationGetTimerTaskMemory( StaticTask_t **ppxTimerTaskTCBBuffer, StackType_t **ppxTimerTaskStackBuffer, uint32_t *pulTimerTaskStackSize ) <br />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 <br />Parameters <br />• ppxTimerTaskTCBBuffer: A handle to a statically allocated TCB buffer <br />• ppxTimerTaskStackBuffer: A handle to a statically allocated Stack buffer for this idle task <br />• pulTimerTaskStackSize: A pointer to the number of elements that will fit in the allocated stack buffer <br />Macros <br />tmrCOMMAND_EXECUTE_CALLBACK_FROM_ISR
Chapter 2. API Reference

```
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 )

BaseType_t xTimerStart( TimerHandle_t xTimer, TickType_t xTicksToWait );
```

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:

```
Return pdFAIL will be returned if the start 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 configTIMER_TASK_PRIORITY configuration constant.
```

```
Parameters

• xTimer: The handle of the timer being started/restarted.
• 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 xTimerStart() was called. xTicksToWait is ignored if xTimerStart() is called before the scheduler is started.
```

See the xTimerCreate() API function example usage scenario.

```
xTimerStop( xTimer, xTicksToWait )

BaseType_t 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 configTIMER_QUEUE_LENGTH configuration constant.

xTimerStop() stops a timer that was previously started using either of the xTimerStart(), xTimerReset(), xTimerStartFromISR(), xTimerResetFromISR(), xTimerChangePeriod() or xTimerChangePeriodFromISR() API functions.

Stopping a timer ensures the timer is not in the active state.

The configUSE_TIMERS configuration constant must be set to 1 for xTimerStop() to be available.

Example usage:

Return pdFAIL will be returned if the stop 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 configTIMER_TASK_PRIORITY configuration constant.

Parameters

- xTimer: The handle of the timer being stopped.
- 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 xTimerStop() was called. xTicksToWait is ignored if xTimerStop() is called before the scheduler is started.

See the xTimerCreate() API function example usage scenario.

xTimerChangePeriod(xTimer, xNewPeriod, 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.

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
* // 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.
* void vAFunction( TimerHandle_t xTimer )
* {
*   if( xTimerIsTimerActive( xTimer ) != pdFALSE ) // or more simply
*     // 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 )
*       return;
*     else
*       return;
*   }
* } (continues on next page)
```
The command was successfully sent.

else

--ticks

// to pass. Take appropriate action here.

Return 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 configTIMER_TASK_PRIORITY configuration constant.

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.

### 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:

Return 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 system. The timer service/daemon task priority is set by the configTIMER_TASK_PRIORITY configuration constant.

Parameters

• xTimer: The handle of the timer being deleted.
• 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.

See the xTimerChangePeriod() API function example usage scenario.

### 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 \( m \) ticks after xTimerReset() was called, where \( m \) 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 is pressed, an LCD back-light is switched on. If 5 seconds... 
 * // without a key being pressed, then the LCD back-light is switched off. In 
 * // this case, the timer is a one-shot timer. 
 * 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_
 * text name, not used by the kernel.
 * ( 5000 / portTICK_PERIOD_MS), // The...
 * //timer period in ticks.
```

(continues on next page)
pdFALSE, // The timer is not used by the callback so can take any value.
 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( ;; );

Return 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 configTIMER_TASK_PRIORITY configuration constant.

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.

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:

* // 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
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 );
}

void vKeyPressEventInterruptHandler( void )
{
    BaseType_t xHigherPriorityTaskWoken = pdFALSE;

    // Ensure the LCD back-light is on, then restart 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( 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).
    }
}

Return 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.

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 xTimerStartFromISR() sets this value to pdTRUE then a context switch should be per-
formed before the interrupt exits.

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:

```c
/* // This scenario assumes xTimer has already been created and started. When
/* // an interrupt occurs, the timer should be simply stopped.
/* * // The interrupt service routine that stops the timer.
* 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).
* }
* */
* */
*/
```

Return 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.

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.

xTimerChangePeriodFromISR (xTimer, xNewPeriod, pxHigherPriorityTaskWoken)

BaseType_t xTimerChangePeriodFromISR( TimerHandle_t xTimer, TickType_t xNewPeriod, BaseType_t *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.
   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 compiling 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).
                */
           }
         }
/*
Return  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 config-TIMER_TASK_PRIORITY configuration constant.

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.

`xTimerResetFromISR` *(xTimer, pxHigherPriorityTaskWoken)*

```c
    BaseType_t xTimerResetFromISR( TimerHandle_t xTimer, BaseType_t *pxHigherPriorityTaskWoken );
```
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). */ /*         } */ /* } */
```

Return

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.

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.

### Type Definitions

define struct tmrTimerControl * `TimerHandle_t`
define void (* `TimerCallbackFunction_t`) ( `TimerHandle_t` `xTimer`)

define 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 group 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 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 )
{
    // The event group was not created because there was insufficient
    // FreeRTOS heap available.
}
else
{
    // The event group was created.
}
```
Return 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 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
// 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 );
```

Return If the event group was created then a handle to the event group is returned. If pxEventGroupBuffer was NULL then NULL is returned.

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.

EventBits_t xEventGroupWaitBits( EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToWaitFor, const BaseType_t xClearOnExit, const BaseType_t xWaitForAllBits, const 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:

```c
#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...

// Don't wait for both bits, either bit will...

xTicksToWait); // Wait a maximum of 100ms for either bit to...

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.
}

Return  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 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.

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 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.

**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
#include <freertos/event_groups.h>

#define BIT_0 ( 1 << 0 )
#define BIT_4 ( 1 << 4 )

void aFunction( EventGroupHandle_t xEventGroup )
```

(continues on next page)
Clear bit 0 and bit 4 in \(x\)EventGroup.

\[
\text{uxBits} = \text{xEventGroupClearBits}(\text{xEventGroup}, \text{BIT}_0 | \text{BIT}_4) ; // \text{The bits being cleared.}
\]

\[
\text{if}( ( \text{uxBits} \& ( \text{BIT}_0 | \text{BIT}_4 ) ) == ( \text{BIT}_0 | \text{BIT}_4 ) )
\]

Both bit 0 and bit 4 were set before xEventGroupClearBits() was called. Both will now be clear (not set).

\[
\text{else if}( ( \text{uxBits} \& \text{BIT}_0 ) != 0 )
\]

Bit 0 was set before xEventGroupClearBits() was called. It will now be clear.

\[
\text{else if}( ( \text{uxBits} \& \text{BIT}_4 ) != 0 )
\]

Bit 4 was set before xEventGroupClearBits() was called. It will now be clear.

\[
\text{else}
\]

Neither bit 0 nor bit 4 were set in the first place.

\[
\}
\]

Return  The value of the event group before the specified bits were cleared.

Parameters
- \(x\)EventGroup: The event group in which the bits are to be cleared.
- \(ux\)BitsToClear: A bitwise value that indicates the bit or bits to clear in the event group. For example, to clear bit 3 only, set \(ux\)BitsToClear to 0x08. To clear bit 3 and bit 0 set \(ux\)BitsToClear to 0x09.

\[\text{EventBits\_t xEventGroupSetBits(EventGroupHandle\_t xEventGroup, const EventBits\_t uxBits\_toSet)}\]

Set bits within an event group. This function cannot be called from an interrupt. \(x\)EventGroupSetBits-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:

```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, // The event group being updated.
                               BIT_0 | BIT_4 ); // The bits being set.

    // Both bit 0 and bit 4 remained set when the function returned.
    if( ( uxBits & ( BIT_0 | BIT_4 ) ) == ( BIT_0 | BIT_4 ) )
    {
    }
    else if( ( uxBits & BIT_0 ) != 0 )
    {
    }
    // Neither bit 0 nor bit 4 were set in the first place.
} 
```
// 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.
}

Return 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.

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.

EventBits_t xEventGroupSync( EventGroupHandle_t xEventGroup, const EventBits_t uxBitsToSet, const EventBits_t uxBitsToWait, 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;

    // Use an event group to synchronise three tasks. It is assumed this event // group has already been created elsewhere.
    xEventGroupSync( xEventBits, TASK_0_BIT, TASK_1_BIT, TASK_2_BIT, 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( ;; )
  {
    // 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.
  }
}

Return 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.

**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.

`EventBits_t xEventGroupGetBitsFromISR (EventGroupHandle_t xEventGroup)`

A version of `xEventGroupGetBits()` that can be called from an ISR.

**Return** The event group bits at the time `xEventGroupGetBitsFromISR()` was called.

**Parameters**

- **xEventGroup**: The event group being queried.

`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.

**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.
    }
}
```

**Return** 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.
**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.

**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.

**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 )
{
    BaseType_t xHigherPriorityTaskWoken, xResult;
    // xHigherPriorityTaskWoken must be initialised to pdFALSE.
    xHigherPriorityTaskWoken = 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 );
    }
}
```

**Return**

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.

**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 result 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 interrupted) then `pxHigherPriorityTaskWoken` will be set to pdTRUE by `xEventGroupSetBitsFromISR()`, 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.

**xEventGroupGetBits** *(xEventGroup)*

Returns the current value of the bits in an event group. This function cannot be used from an interrupt.

**Return**

The event group bits at the time `xEventGroupGetBits()` was called.
Parameters

• \texttt{xEventGroup}: The event group being queried.

Type Definitions

typedef struct EventGroupDef_t* \texttt{EventGroupHandle_t}

typedef TickType_t \texttt{EventBits_t}

Stream Buffer API

Header File

• \texttt{components/freertos/FreeRTOS-Kernel/include.freertos/stream_buffer.h}

Functions

\texttt{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 \texttt{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 \texttt{xStreamBufferReceive()}) inside a critical section and set the receive block time to 0.

Use \texttt{xStreamBufferSend()} to write to a stream buffer from a task. Use \texttt{xStreamBufferSendFromISR()} to write to a stream buffer from an interrupt service routine (ISR).

Example use:

```c

void vAFuntion( 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, 0, 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, 0, strlen( pcStringToSend ), 0 );

    if( xBytesSent != strlen( pcStringToSend ) )
    {
        // The entire string could not be added to the stream buffer because
```
(continues on next page)
there was not enough free space in the buffer, but xBytesSent bytes were sent. Could try again to send the remaining bytes.

Return 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.

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 another 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.

Interrupt safe version of the API function that sends a stream of bytes to 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
// 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 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.

```c
void taskYIELD_FROM_ISR( xHigherPriorityTaskWoken );
```

Return The number of bytes actually written to the stream buffer, which will be less than xDataLengthBytes if the stream buffer didn’t have enough free space for all the bytes to be written.

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. *pxHigherPriorityTaskWoken should be set to pdFALSE before it is passed into the function. See the example code below for an example.

```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 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 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, ucRxData, sizeof( ucRxData ), xBlockTime );
    if ( xReceivedBytes == sizeof( ucRxData ) ) {
        // Process the data.
    } else {
        // The receive timeout occurred.
    }
}
```
xReceivedBytes = xStreamBufferReceive( xStreamBuffer, 
    ( void * ) ucRxData, 
    sizeof( ucRxData ), 
    xBlockTime );

if( xReceivedBytes > 0 )
{
    // A ucRxData contains another xReceivedBytes bytes of data, which can
    // be processed here....
}
}

Return The number of bytes actually read from the stream buffer, which will be less than xBufferLengthBytes if the call to xStreamBufferReceive() timed out before xBufferLengthBytes were available.

Parameters
- xStreamBuffer: The handle of the stream buffer from which bytes are to be received.
- pvRxData: A pointer to the buffer into which the received bytes will be 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.
- xTicksToWait: The maximum amount of time the task should remain in the Blocked state to wait for data to become available if the stream buffer is empty. xStreamBufferReceive() will return immediately 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. A task does not use any CPU time when it is in the Blocked state.

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:

```
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
```

(continues on next page)
 Returning The number of bytes read from the stream buffer, if any.

 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.

```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.

 Return If the stream buffer is full then pdTRUE is returned. Otherwise pdFALSE is returned.

 Parameters

- **xStreamBuffer**: The handle of the stream buffer being queried.

```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.

 Return If the stream buffer is empty then pdTRUE is returned. Otherwise pdFALSE is returned.

 Parameters

- **xStreamBuffer**: The handle of the stream buffer being queried.

```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.

 Return 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.

 Parameters

- **xStreamBuffer**: The handle of the stream buffer being reset.
**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.

**Return**  The number of bytes that can be written to the stream buffer before the stream buffer would be full.

**Parameters**

- **xStreamBuffer**: The handle of the stream buffer being queried.

**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.

**Return**  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.

**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().

**Return**  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.

**Parameters**

- **xStreamBuffer**: The handle of the stream buffer being updated.
- **xTriggerLevel**: The new trigger level for the stream buffer.

**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.

**Return**  If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

**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.

**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.

**Return** If a task was removed from the Blocked state then `pdTRUE` is returned. Otherwise `pdFALSE` is returned.

**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.

**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.
    }
  }
  ```

  **Return** 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.

  **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.
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.

**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
// Used to dimension the array used to hold the streams. 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 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.
}
```

**Return** 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.

**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 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.

Type Definitions

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.
    }
    else
    {
        // The message buffer was created successfully and can now be used.
    }
}
```

Return 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.

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.

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:
/* 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.
}

Return 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.

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 architecture 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).
- 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.

xMessageBufferSend(xMessageBuffer, pvTxData, xDataLengthBytes, xTicksToWait)

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:
void vAFunction( 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.
    }
}

Return 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.

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.

**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 ) )
    {
        // 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 );
}
```

Return  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.

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).
- 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

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example below for an example.

**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....
    }
}
```

**Return** 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 xBufferLengthBytes then the message will be left in the message buffer and zero is returned.

**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.
- **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.

**xMessageBufferReceiveFromISR** (xMessageBuffer, pvRxData, xBufferLengthBytes, 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 xMessageBufferReceiveFromISR() 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 );
}
```

Return  The length, in bytes, of the message read from the message buffer, if any.

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 unlocked 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.

`vMessageBufferDelete(xMessageBuffer)`

Deletes a message buffer that was previously created using a call to `xMessageBufferCreate()` or `xMessageBufferCreateStatic()`. 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.

**Return**
If the message buffer referenced by `xMessageBuffer` is full then `pdTRUE` is returned. Otherwise `pdFALSE` is returned.

**Parameters**
- `xMessageBuffer`: The handle of the message buffer being queried.

`xMessageBufferIsEmpty(xMessageBuffer)`

Tests to see if a message buffer is empty (does not contain any messages).

**Return**
If the message buffer referenced by `xMessageBuffer` is empty then `pdTRUE` is returned. Otherwise `pdFALSE` is returned.

**Parameters**
- `xMessageBuffer`: The handle of the message buffer being queried.

`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.

**Return**
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 a message to be available, then `pdFAIL` is returned.

**Parameters**
- `xMessageBuffer`: The handle of the message buffer being reset.

`xMessageBufferSpaceAvailable(xMessageBuffer)`

Returns the number of bytes of free space in the message buffer.

**Return**
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 `xMessageBufferSpaceAvailable()` returns 10, then the size of the largest message that can be written to the message buffer is 6 bytes.

**Parameters**
- `xMessageBuffer`: The handle of the message buffer being queried.

`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.

**Return**
The length (in bytes) of the next message in the message buffer, or 0 if the message buffer is empty.

**Parameters**
- `xMessageBuffer`: The handle of the message buffer being queried.
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.

Return If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

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.

xMessageBufferReceiveCompletedFromISR (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.

Return If a task was removed from the Blocked state then pdTRUE is returned. Otherwise pdFALSE is returned.

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.

Type Definitions
typedef void *MessageBufferHandle_t

Type by which message buffers are referenced. For example, a call to xMessageBufferCreate() returns a MessageBufferHandle_t variable that can then be used as a parameter to xMessageBufferSend(), xMessageBufferReceive(), etc.

2.7.11 FreeRTOS Supplemental Features

ESP-IDF uses a modified version of FreeRTOS v10.4.3 that contains significant changes for SMP compatibility (see ESP-IDF FreeRTOS SMP Changes). However, in addition to ESP-IDF FreeRTOS, various features are also provided by ESP-IDF to supplement the features offered by FreeRTOS.

This document describes these supplemental features added to ESP-IDF. This document is split into the following sections:
Overview

ESP-IDF FreeRTOS is modified version of based on the Xtensa port of FreeRTOS v10.4.3 with significant modifications for SMP compatibility (see ESP-IDF FreeRTOS SMP Changes). However, various new features specific to ESP-IDF FreeRTOS have been added. The features are 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

The ESP-IDF FreeRTOS ring buffer is a strictly FIFO buffer 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 API 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) {

```

(continues on next page)
The following example demonstrates retrieving and returning an item from a No-Split ring buffer using `xRingbufferReceive()` and `vRingbufferReturnItem()`

```c
//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()`

```c
//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()`

```c
printf("Failed to send item\n");
```
// 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.

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**.

Fig. 30: Sending items to byte buffers

Fig. 31: SendAcquire/SendComplete items in No-Split ring buffers

Fig. 32: Wrap around in No-Split buffers
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.

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.

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.

### Ring Buffers with Queue Sets

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()}. 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);
```

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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.

```
#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);
```
Priority Inversion  Ideally, ring buffers can be used with multiple tasks in an SMP fashion where the highest priority task will always be serviced first. However due to the usage of binary semaphores in the ring buffer’s underlying implementation, priority inversion may occur under very specific circumstances.

The ring buffer governs sending by a binary semaphore which is given whenever space is freed on the ring buffer. The highest priority task waiting to send will repeatedly take the semaphore until sufficient free space becomes available or until it times out. Ideally this should prevent any lower priority tasks from being serviced as the semaphore should always be given to the highest priority task.

However, in between iterations of acquiring the semaphore, there is a gap in the critical section which may permit another task (on the other core or with an even higher priority) to free some space on the ring buffer and as a result give the semaphore. Therefore, the semaphore will be given before the highest priority task can re-acquire the semaphore. This will result in the semaphore being acquired by the second-highest priority task waiting to send, hence causing priority inversion.

This side effect will not affect ring buffer performance drastically given if the number of tasks using the ring buffer simultaneously is low, and the ring buffer is not operating near maximum capacity.

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 ends 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 API:

- 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
    \texttt{\textcolor{blue}{esp\_register\_freertos\_idle\_hook()}} or
    \texttt{\textcolor{blue}{esp\_register\_freertos\_idle\_hook\_for\_cpu()}}
  – Deregister using
    \texttt{\textcolor{blue}{esp\_deregister\_freertos\_idle\_hook()}} or
    \texttt{\textcolor{blue}{esp\_deregister\_freertos\_idle\_hook\_for\_cpu()}}

\textbf{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 \textit{SPI flash API documentation} for more details.

\section*{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:

\begin{itemize}
  \item set a task’s TLSPs by calling \texttt{vTaskSetThreadLocalStoragePointer()} after the task has been created.
  \item get a task’s TLSPs by calling \texttt{pvTaskGetThreadLocalStoragePointer()} during the task’s lifetime.
  \item free the memory pointed to by the TLSPs before the task is deleted.
\end{itemize}

However, there can be instances where users may want the freeing of TLSP memory to be automatic. Therefore, ESP-IDF FreeRTOS provides the additional feature of TLSP deletion callbacks. These user provided deletion callbacks are called automatically when a task is deleted, thus allows the TLSP memory to be cleaned up without needing to add the cleanup logic explicitly to the code of each task.

The TLSP deletion callbacks are set in a similar fashion to the TLSPs themselves.

\begin{itemize}
  \item \texttt{vTaskSetThreadLocalStoragePointerAndDelCallback()} sets both a particular TLSP and its associated callback.
  \item Calling the Vanilla FreeRTOS function \texttt{vTaskSetThreadLocalStoragePointer()} will simply set the TLSP’s associated Deletion Callback to \texttt{NULL} meaning that no callback will be called for that TLSP during task deletion.
\end{itemize}

When implementing TLSP callbacks, users should note the following:

\begin{itemize}
  \item The callback \textbf{must never attempt to block or yield} and critical sections should be kept as short as possible
  \item The callback is called shortly before a deleted task’s memory is freed. Thus, the callback can either be called from \texttt{vTaskDelete()} itself, or from the idle task.
\end{itemize}

\section*{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:

\begin{itemize}
  \item \texttt{ORIG\_INCLUDE\_PATH} - contains an absolute path to freertos root include folder. Thus instead of \texttt{#include \"freertos/FreeRTOS.h\"} you can refer to headers directly: \texttt{#include \"FreeRTOS.h\"}.
\end{itemize}

\section*{API Reference}

\subsection*{Ring Buffer API}

\section*{Header File}

\begin{itemize}
  \item \texttt{components/esp\_ringbuf/include/freertos/ringbuf.h}
\end{itemize}
### 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.
- **Return** A handle to the created ring buffer, or NULL in case of error.

**Parameters**

- **[in]** xBufferSize: Size of the buffer in bytes. Note that items require space for a header in no-split/allow-split buffers
- **[in]** xBufferType: Type of ring buffer, see documentation.

**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.

- **Return** A RingbufHandle_t handle to the created ring buffer, or NULL in case of error.

**Parameters**

- **[in]** xItemSize: Size of each item to be put into the ring buffer
- **[in]** xItemNum: Maximum number of items the buffer needs to hold simultaneously

**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.
- **Return** A handle to the created ring buffer

**Parameters**

- **[in]** xBufferSize: Size of the buffer in bytes.
- **[in]** xBufferType: Type of ring buffer, see documentation
- **[in]** pucRingbufferStorage: Pointer to the ring buffer’s storage area. Storage area must have the same size as specified by xBufferSize
- **[in]** pxStaticRingbuffer: Pointed to a struct of type StaticRingbuffer_t which will be used to hold the ring buffer’s data structure

** BaseType_t xRingbufferSend** *(RingbufHandle_t xRingbuffer, const void *pvItem, size_t xItemSize, TickType_t xTicksToWait)*

Insert an item into the ring 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.

- **Return**
  - **pdTRUE** if succeeded
  - **pdFALSE** on time-out or when the data is larger than the maximum permissible size of the buffer

**Parameters**

- **[in]** xRingbuffer: Ring buffer to insert the item into
- **[in]** pvItem: Pointer to data to insert. NULL is allowed if xItemSize is 0.
- **[in]** xItemSize: Size of data to insert.
- **[in]** xTicksToWait: Ticks to wait for room in the ring buffer

** 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.

- **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.
Return

• pdTRUE if succeeded
• pdFALSE when the ring buffer does not have space.

Parameters

• [in] xRingbuffer: Ring buffer to insert the item into
• [in] pvItem: Pointer to data to insert. NULL is allowed if xItemSize is 0.
• [in] xItemSize: Size of data to insert.
• [out] pxHigherPriorityTaskWoken: Value pointed to will be set to pdTRUE if the function woke up a higher priority task.

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.

Return

• pdTRUE if succeeded
• pdFALSE on time-out or when the data is larger than the maximum permissible size of the buffer

Parameters

• [in] xRingbuffer: Ring buffer to allocate the memory
• [out] ppvItem: Double pointer to memory acquired (set to NULL if no memory were retrieved)
• [in] xItemSize: Size of item to acquire.
• [in] xTicksToWait: Ticks to wait for room in the ring buffer.

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.

Return

• pdTRUE if succeeded
• pdFALSE if fail for some reason.

Parameters

• [in] xRingbuffer: Ring buffer to insert the item into
• [in] pvItem: Pointer to item in allocated memory to insert.

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.

Return

• Pointer to the retrieved item on success; *pxItemSize filled with the length of the item.
• NULL on timeout, *pxItemSize is untouched in that case.

Parameters

• [in] xRingbuffer: Ring buffer to retrieve the item from
• [out] pxItemSize: Pointer to a variable to which the size of the retrieved item will be written.
• [in] xTicksToWait: Ticks to wait for items in the ring buffer.

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.

**Return**
- 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.

**Parameters**
- [in] xRingbuffer: Ring buffer to retrieve the item from
- [out] pxItemSize: Pointer to a variable to which the size of the retrieved item will be written.

```c
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.

**Note** This function should only be called on allow-split buffers.

**Return**
- pdTRUE if an item (split or unsplit) was retrieved
- pdFALSE when no item was retrieved

**Parameters**
- [in] xRingbuffer: Ring buffer to retrieve the item from
- [out] ppvHeadItem: Double pointer to first part (set to NULL if no items were retrieved)
- [out] ppvTailItem: Double pointer to second part (set to NULL if item is not split)
- [out] pxHeadItemSize: Pointer to size of first part (unmodified if no items were retrieved)
- [out] pxTailItemSize: Pointer to size of second part (unmodified if item is not split)
- [in] xTicksToWait: Ticks to wait for items in the ring buffer.

```c
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.

**Note** This function should only be called on allow-split buffers.

**Return**
- pdTRUE if an item (split or unsplit) was retrieved
- pdFALSE when no item was retrieved

**Parameters**
- [in] xRingbuffer: Ring buffer to retrieve the item from
- [out] ppvHeadItem: Double pointer to first part (set to NULL if no items were retrieved)
- [out] ppvTailItem: Double pointer to second part (set to NULL if item is not split)
- [out] pxHeadItemSize: Pointer to size of first part (unmodified if no items were retrieved)
- [out] pxTailItemSize: Pointer to size of second part (unmodified if item is not split)

```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.

**Return**

- Pointer to the retrieved item on success; *pxItemSize filled with the length of the item.
- NULL on timeout, *pxItemSize is untouched in that case.

**Parameters**

- [in] `xRingbuffer`: Ring buffer to retrieve the item from
- [out] `pxItemSize`: Pointer to a variable to which the size of the retrieved item will be written.
- [in] `xTicksToWait`: Ticks to wait for items in the ring buffer.
- [in] `xMaxSize`: Maximum number of bytes to return.

```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

**Return**

- 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.

**Parameters**

- [in] `xRingbuffer`: Ring buffer to retrieve the item from
- [out] `pxItemSize`: Pointer to a variable to which the size of the retrieved item will be written.
- [in] `xMaxSize`: Maximum number of bytes to return.

```c
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**

- [in] `xRingbuffer`: Ring buffer the item was retrieved from
- [in] `pvItem`: Item that was received earlier

```c
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**

- [in] `xRingbuffer`: Ring buffer the item was retrieved from
- [in] `pvItem`: Item that was received earlier
- [out] `pxHigherPriorityTaskWoken`: Value pointed to will be set to pdTRUE if the function woke up a higher priority task.

```c
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 be the user.

**Parameters**

- [in] `xRingbuffer`: Ring buffer to delete

```c
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.

Return Maximum size, in bytes, of an item that can be placed in a ring buffer.

Parameters
• [in] xRingbuffer: Ring buffer to query

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.

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

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().

Return Current free size, in bytes, available for an entry

Parameters
• [in] xRingbuffer: Ring buffer to query

BaseType_t xRingbufferAddToQueueSetRead(RingbufHandle_t xRingbuffer, QueueSetHandle_t xQueueSet)
Add the ring buffer’s read semaphore to a queue set.

The ring buffer’s read semaphore indicates that data has been written to the ring buffer. This function adds the ring buffer’s read semaphore to a queue set.

Return
• pdTRUE on success, pdFALSE otherwise

Parameters
• [in] xRingbuffer: Ring buffer to add to the queue set
• [in] xQueueSet: Queue set to add the ring buffer’s read semaphore to

BaseType_t xRingbufferCanRead(RingbufHandle_t xRingbuffer, QueueSetMemberHandle_t xMember)
Check if the selected queue set member is the ring buffer’s read semaphore.

This API checks if queue set member returned from xQueueSelectFromSet() is the read semaphore of this ring buffer. If so, this indicates the ring buffer has items waiting to be retrieved.

Return
• pdTRUE when semaphore belongs to ring buffer
• pdFALSE otherwise.

Parameters
• [in] xRingbuffer: Ring buffer which should be checked
• [in] xMember: Member returned from xQueueSelectFromSet

BaseType_t xRingbufferRemoveFromQueueSetRead(RingbufHandle_t xRingbuffer, QueueSetHandle_t xQueueSet)
Remove the ring buffer’s read semaphore from a queue set.

This specifically removes a ring buffer’s read semaphore from a queue set. The read semaphore is used to indicate when data has been written to the ring buffer.

Return
• pdTRUE on success
• pdFALSE otherwise

Parameters
• [in] xRingbuffer: Ring buffer to remove from the queue set
• [in] xQueueSet: Queue set to remove the ring buffer’s read semaphore from

void vRingbufferGetInfo(RingbufHandle_t xRingbuffer, BaseType_t *uxFree, BaseType_t *uxRead, BaseType_t *uxWrite, BaseType_t *uxAcquire, BaseType_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**
- **[in]** `xRingbuffer`: Ring buffer to remove from the queue set
- **[out]** `uxFree`: Pointer use to store free pointer position
- **[out]** `uxRead`: Pointer use to store read pointer position
- **[out]** `uxWrite`: Pointer use to store write pointer position
- **[out]** `uxAcquire`: Pointer use to store acquire pointer position
- **[out]** `uxItemsWaiting`: 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 = 0`
  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.

- `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.

- `RINGBUF_TYPE_MAX`

**Hooks API**
Chapter 2. API Reference

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.

Return

- 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

Parameters

- [in] new_idle_cb: Callback to be called
- [in] cpuid: id of the core

`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.

Return

- 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

Parameters

- [in] new_idle_cb: Callback to be called

`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.

Return

- 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

Parameters

- [in] new_tick_cb: Callback to be called
- [in] cpuid: id of the core

`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.

Return

- 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

Parameters

- [in] new_tick_cb: Callback to be called

`void esp_deregister_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

- [in] old_idle_cb: Callback to be unregistered
- [in] cpuid: id of the core
Chapter 2. API Reference

```c
void esp_deregister_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**
- `[in]` `old_idle_cb`: Callback to be unregistered

```c
void esp_deregister_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**
- `[in]` `old_tick_cb`: Callback to be unregistered
- `[in]` `cpuid`: id of the core

```c
void esp_deregister_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**
- `[in]` `old_tick_cb`: Callback to be unregistered

**Type Definitions**
```
typedef bool (*esp_freertos_idle_cb_t)(void)
typedef void (*esp_freertos_tick_cb_t)(void)
```

### 2.7.12 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-S3 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-S3 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 SPIRAM to the ESP32-S3 — external RAM can be integrated into the ESP32-S3’s memory map using the flash cache, and accessed similarly to DRAM.

DRAM uses capability MALLOCCAP_8BIT (accessible in single byte reads and writes). When calling malloc(), the ESP-IDF malloc() implementation internally calls heap_caps_malloc(size, MALLOCCAP_8BIT) in order to allocate DRAM that is byte-addressable. To test the free DRAM heap size at runtime, call \texttt{heap_caps_get_free_size(MALLOCCAP_8BIT)}.

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:** 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-S3 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:

<table>
<thead>
<tr>
<th>Address</th>
<th>Size</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>3FFAE6E0</td>
<td>0x1920</td>
<td>DRAM</td>
</tr>
<tr>
<td>3FFB2EC8</td>
<td>0x2D138</td>
<td>DRAM</td>
</tr>
<tr>
<td>3FFE0440</td>
<td>0x3AE0</td>
<td>D/IRAM</td>
</tr>
<tr>
<td>3FFE4350</td>
<td>0x1BCB0</td>
<td>D/IRAM</td>
</tr>
<tr>
<td>4008944C</td>
<td>0x16BB4</td>
<td>IRAM</td>
</tr>
</tbody>
</table>

Finding available heap See Heap Information.

Special Capabilities

**DMA-Capable Memory** Use the MALLOCCAP_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 MALLOCCAP_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-S3.

Memory allocated with MALLOCCAP_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.

API Reference - Heap Allocation

Header File

- components/heap/include/esp_heap_caps.h

Functions

- 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
  
  Return  ESP_OK if callback was registered.

  Parameters
  
  - callback: caller defined callback to be invoked

- 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.

  In IDF, malloc(p) is equivalent to heap_caps_malloc(p, MALLOC_CAP_8BIT).

  Return  A pointer to the memory allocated on success, NULL on failure

  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

- 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.

- 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.

  Return  Pointer to a new buffer of size ‘size’ with capabilities ‘caps’, or NULL if allocation failed.

  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.

- 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.

  Return  A pointer to the memory allocated on success, NULL on failure

  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

```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

**Parameters**

- **ptr**: Pointer to the memory allocated

```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.

**Return**: A pointer to the memory allocated on success, NULL on failure

**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

```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 malloc(), for capability-aware memory.

**In IDF, calloc(p) is equivalent to heap_caps_calloc(p, MALLOC_CAP_8BIT).**

**Return**: A pointer to the memory allocated on success, NULL on failure

**Parameters**

- **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

```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.

**Return**: total size in bytes

**Parameters**

- **caps**: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

```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.

**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.

**Return**: Amount of free bytes in the regions

**Parameters**

- **caps**: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

```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 the result may be less than the global all-time minimum available heap of this kind, as “low watermarks” are tracked per-region. Individual regions’ heaps may have reached their “low watermarks” at different points in time. However, this result still gives a “worst case” indication for all-time minimum free heap.

**Return**: Amount of free bytes in the regions
Parameters
• caps: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

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 heap_caps_malloc(s, caps) will succeed.

Return Size of the largest free block in bytes.

Parameters
• caps: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory

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 MALLOC_CAP_INVALID.

Return True if all heaps are valid, False if at least one heap is corrupt.

Parameters
• print_errors: Print specific errors if heap corruption is found.

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.

Return True if all heaps are valid, False if at least one heap is corrupt.

Parameters
• caps: Bitwise OR of MALLOC_CAP_* flags indicating the type of memory
• print_errors: Print specific errors if heap corruption is found.

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 overhead 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.

Return  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.

Parameters
• addr: Address in memory. Check for corruption in region containing this address.
• print_errors: Print specific errors if heap corruption is found.

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.

Return  A pointer to the memory allocated on success, NULL on failure

Parameters
• size: Size, in bytes, of the amount of memory to allocate
• num: Number of variable parameters

void *heap_caps_realloc_prefer (void *ptr, size_t size, size_t num, ...)
Reallocate a chunk of memory as preference in decreasing order.

Return  Pointer to a new buffer of size ‘size’, or NULL if allocation failed.

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

void *heap_capscalloc_prefer (size_t n, size_t size, size_t num, ...)
Allocate a chunk of memory as preference in decreasing order.

Return  A pointer to the memory allocated on success, NULL on failure

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

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.

**Return** Size of the memory allocated at this block.

**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.

**Macros**

**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.

**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**

**MALLOC_CAP_RTCRAM**
Memory must be in RTC fast memory.

**MALLOC_CAP_INVALID**
Memory can’t 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

Parameters

• size: in bytes of failed allocation
• caps: capabilities requested of failed allocation
• function_name: function which generated the failure

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. 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.

Heap Tracing & Debugging

The following features are documented on the Heap Memory Debugging page:

• Heap Information (free space, etc.)
• Heap Corruption Detection
• Heap Tracing (memory leak detection, monitoring, etc.)

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.
Return 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().

Parameters
- start: Start address of new region.
- end: End address of new region.

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.

Return
- 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

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.

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() or multi_heap_calloc() 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 - 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_heapAligned_alloc (multi_heap_handle_t heap, size_t size, size_t alignment)
allocate a chunk of memory with specific alignment

Return pointer to the memory allocated, NULL on failure

Parameters
- heap: Handle to a registered heap.
- size: size in bytes of memory chunk
• alignment: how the memory must be aligned

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.

Return  Pointer to new memory, or NULL if allocation fails.

Parameters
• heap: Handle to a registered heap.
• size: Size of desired buffer.

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.

Return  New buffer of ‘size’ containing contents of ‘p’, or NULL if reallocation failed.

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.

size_t multi_heap_get_allocated_size (multi_heap_handle_t heap, void *p)
Return the size that a particular pointer was allocated with.

Return  Size of the memory allocated at this block. May be more than the original size argument, due to padding and minimum block sizes.

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.

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.

Return  Handle of a new heap ready for use, or NULL if the heap region was too small to be initialised.

Parameters
• start: Start address of the memory to use for a new heap.
• size: Size (in bytes) of the new heap.
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, de-
dined 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_PRINT in multi_heap_platform.h.

Return true if heap is valid, false otherwise.

Parameters
  • heap: Handle to a registered heap.
  • print_errors: If true, errors will be printed to stderr.

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().

Return Number of free bytes.

Parameters
  • heap: Handle to a registered heap.

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.

Return Number of free bytes.

Parameters
  • heap: Handle to a registered heap.

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.
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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.

2.7.13 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 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)
{
  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
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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 malloc() (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 0xFEFEFEFEF, 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_TRACELeaks) );
    do_something_you_suspect_is_leaking();
    ESP_ERROR_CHECK( heap_trace_stop() );
    heap_trace_dump();
    ...
}
```

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:0x400d27c1
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...
    →0x400d2776:0x400d27c1
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_TRACE_LEAKS** 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.
- **CPU x** is the CPU (0 or 1) running when the allocation was made.
- **ccount 0x...** is the C_COUNT (CPU cycle count) register value when the allocation was mode. 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_DESTINATION** 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:

```plaintext
target remote :3333
mon reset halt
flushregs
tb heap_trace_start
commands
mon esp sysview start file:///tmp/heap.svdat
end
tb heap_trace_stop
commands
mon esp sysview stop
end
```

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:
   ```shell
   xtensa-esp32s3-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:
   ```shell
   $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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→--sysview_heap_log.c:47
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→--sysview_heap_log.c:48
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→--sysview_heap_log.c:31 (discriminator 9)
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)

[0.002782950] HEAP: Freed bytes @ 0x3ffb40b8 from task "main" on core 0 by:
/home/user/projects/esp/esp-idf/components/freertos/tasks.c:4590
/home/user/projects/esp/esp-idf/components/freertos/tasks.c:4590
```
(continues on next page)
Processing completed.
Processed 1019 events

---------- HEAP TRACE REPORT ----------
Processed 14 heap events.
[0.002244575] HEAP: Allocated 1 bytes @ 0x3ffaffd8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.102667075] HEAP: Allocated 6 bytes @ 0x3ffafff0 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.302667500] HEAP: Allocated 8 bytes @ 0x3fffb40b8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.102436025] HEAP: Allocated 2 bytes @ 0x3ffaffe0 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.302451475] HEAP: Allocated 8 bytes @ 0x3fffb40b8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:31 (discriminator 9)
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.202667075] HEAP: Allocated 8 bytes @ 0x3fffb40b8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.1022436200] HEAP: Allocated 3 bytes @ 0x3ffaffe8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.002798700] HEAP: Freed bytes @ 0x3fffb50bc from task "main" on core 0 by:
/home/user/projects/esp/esp-idf/components/freertos/tasks.c:4590
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:31 (discriminator 9)
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.202436000] HEAP: Allocated 4 bytes @ 0x3ffaffe8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp/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/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.202667075] HEAP: Freed bytes @ 0x3ffafff0 from task "free" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:31 (discriminator 9)
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.302436000] HEAP: Allocated 4 bytes @ 0x3ffaffe8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:47
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.302451475] HEAP: Allocated 8 bytes @ 0x3fffb40b8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/esp-idf/components/freertos/port.c:355 (discriminator 1)
[0.302667500] HEAP: Allocated 8 bytes @ 0x3fffb40b8 from task "alloc" on core 0 by:
/home/user/projects/esp/esp-idf/examples/system/sysview_tracing_heap_log/main/
→sysview_heap_log.c:48
/home/user/projects/esp/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 MemoryLeaks

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 stdin - 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);`

**Return**

- 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.

**Parameters**

- `record_buffer`: Provide a buffer to use for heap trace data. Must remain valid any time heap tracing is enabled, meaning it must be allocated from internal memory not in PSRAM.
- `num_records`: Size of the heap trace buffer, as number of record structures.

```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.

**Return**

- ESP_ERR_INVALID_STATE Heap tracing is currently in progress.
- ESP_OK Heap tracing initialised successfully.

```c
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.

**Return**

- 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.

**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.)

```c
esp_err_t heap_trace_stop (void)
```

Stop heap tracing.

**Return**

- 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.

```c
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).

**Return**

- 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.

```c
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.

```c
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.

**Return**
- 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.

**Parameters**
- `index`: Index (zero-based) of the record to return.
- `[out] record`: Record where the heap trace record will be copied.

```c
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.

**Structures**

```c
struct heap_trace_record_t
```

Trace record data type. Stores information about an allocated region of memory.

**Public Members**

```c
uint32_t ccount
```

CCOUNT of the CPU when the allocation was made. LSB (bit value 1) is the CPU number (0 or 1).

```c
void *address
```

Address which was allocated.

```c
size_t size
```

Size of the allocation.

```c
void *allocated_by[CONFIG_HEAP_TRACING_STACK_DEPTH]
```

Call stack of the caller which allocated the memory.

```c
void *freed_by[CONFIG_HEAP_TRACING_STACK_DEPTH]
```

Call stack of the caller which freed the memory (all zero if not freed.)

**Macros**

```c
CONFIG_HEAP_TRACING_STACK_DEPTH
```

**Enumerations**

```c
enum heap_trace_mode_t
```

Values:

- `HEAP_TRACE_ALL`
- `HEAP_TRACE_LEAKS`

2.7.14 High Resolution Timer

**Overview**

Although FreeRTOS provides software timers, these timers have a few limitations:
• Maximum resolution is equal to RTOS tick period
• Timer callbacks are dispatched from a low-priority task

Hardware timers are free from both of the limitations, but often they are less convenient to use. For example, application components may need timer events to fire at certain times in the future, but the hardware timer only contains one “compare” value used for interrupt generation. This means that some facility needs to be built on top of the hardware timer to manage the list of pending events can dispatch the callbacks for these events as corresponding hardware interrupts happen.

An interrupt level of the handler depends on the `CONFIG_ESP_TIMER_INTERRUPT_LEVEL` option. It allows to set this: 1, 2 or 3 level (by default 1). Raising the level, the interrupt handler can reduce the timer processing delay.

`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, where the implementation depends on the target. SYSTIMER is used for ESP32-S3.

Timer callbacks can be dispatched by two methods:

- **ESP_TIMER_TASK**
- **ESP_TIMER_ISR**. Available only if `CONFIG_ESP_TIMER_SUPPORTS_ISR_DISPATCH_METHOD` is enabled (by default disabled).

**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 priority higher than `esp_timer` are running, callback dispatching will be delayed until `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 less than 20us, the callback will be dispatched only after approximately 20us.

Periodic `esp_timer` also imposes a 50us restriction on the minimal timer period. Periodic software timers with period of less than 50us 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 small period is required.

**Using esp_timer APIs**

Single timer is represented by `esp_timer_handle_t` type. 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 which are processed by ESP_TIMER_ISR method should not call the context switch call - portYIELD_FROM_ISR(), instead of this you should 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 the 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 overflow of some queues. This only applies to periodic timers, 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 consumption of the system when it is in light sleep. The duration of light sleep is also determined by esp_timers. Timers with skip_unhandled_events option will not wake up the system.

**Handling callbacks**

esp_timer is designed to achieve a high-resolution low latency timer and the ability to handle delayed events. If the timer is late then the callback will be called as soon as possible, it will not be lost. In the worst case, when the timer has not been processed for more than one period (for periodic timers), in this case 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 was 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 usage of esp_timer APIs: system/esp_timer.

**API Reference**

**Header File**
Chapter 2. API Reference

- components/esp_timer/include/esp_timer.h

Functions

```c
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.

**Return**

- ESP_OK on success

```c
esp_err_t esp_timer_init (void)
```

Initialize esp_timer library.

**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.

**Return**

- ESP_OK on success
  - ESP_ERR_NO_MEM if allocation has failed
  - ESP_ERR_INVALID_STATE if already initialized
  - other errors from interrupt allocator

```c
esp_err_t esp_timer_deinit (void)
```

De-initialize esp_timer library.

**Note** Normally this function should not be called from applications

**Return**

- ESP_OK on success
  - ESP_ERR_INVALID_STATE if not yet initialized

```c
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.

**Return**

- 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

**Parameters**

- create_args: Pointer to a structure with timer creation arguments. Not saved by the library, can be allocated on the stack.
- [out] out_handle: Output, pointer to esp_timer_handle_t variable which will hold the created timer handle.

```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.

**Return**

- ESP_OK on success
  - ESP_ERR_INVALID_ARG if the handle is invalid
  - ESP_ERR_INVALID_STATE if the timer is already running

**Parameters**

- timer: timer handle created using esp_timer_create
- timeout_us: timer timeout, in microseconds relative to the current moment
**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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the handle is invalid
- ESP_ERR_INVALID_STATE if the timer is already running

**Parameters**
- **timer**: timer handle created using esp_timer_create
- **period**: timer period, in microseconds

**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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if the timer is not running

**Parameters**
- **timer**: timer handle created using esp_timer_create

**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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_STATE if the timer is running

**Parameters**
- **timer**: timer handle allocated using esp_timer_create

**int64_t** `esp_timer_get_time` *(void)*

Get time in microseconds since boot.

**Return**
- 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.

**Return**
- 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.

**Return**
- 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.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the arguments are invalid

**Parameters**
- **timer**: timer handle allocated using esp_timer_create
- **period**: memory to store the timer period value in microseconds
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.

Return
- ESP_OK on success
- ESP_ERR_INVALID_ARG if the arguments are invalid
- ESP_ERR_NOT_SUPPORTED if the timer type is periodic

Parameters
- timer: timer handle allocated using esp_timer_create
- expiry: memory to store the timeout value in microseconds

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

Return
- ESP_OK on success
- ESP_ERR_NO_MEM if cannot allocate temporary buffer for the output

Parameters
- stream: stream (such as stdout) to dump the information to

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.

Return
- 1 if timer is still active
- 0 if timer is not active.

Parameters
- timer: timer handle created using esp_timer_create

Structures

struct esp_timer_create_args_t

Timer configuration passed to esp_timer_create.

Public Members

est_timer_cb_t callback

Function to call when timer expires.

void *arg

Argument to pass to the callback.
**Chapter 2. API Reference**

```c
esp_timer_dispatch_t dispatch_method
Call the callback from task or from ISR.
```

```c
const char *name
Timer name, used in esp_timer_dump function.
```

```c
bool skip_unhandled_events
Skip unhandled events for periodic timers.
```

### Type Definitions

```c
typedef struct esp_timer *esp_timer_handle_t
Opaque type representing a single esp_timer.
```

```c
typedef void (*esp_timer_cb_t)(void *arg)
Timer callback function type.
```

#### Parameters
- `arg`: pointer to opaque user-specific data

### Enumerations

```c
enum esp_timer_dispatch_t
Method for dispatching timer callback.
```

#### Values:

- `ESP_TIMER_TASK`
  Callback is called from timer task.

- `ESP_TIMER_MAX`
  Count of the methods for dispatching timer callback.

## 2.7.15 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-S3, 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-Level 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:
  - 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.

```assembly
/* 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.

**Return**

- ESP_ERR_INVALID_ARG if `cpu_id` is invalid
- ESP_ERR_INVALID_STATE if the FreeRTOS scheduler is not running
- ESP_OK otherwise

**Parameters**

- [in] `cpu_id`: CPU where the given function should be executed (0 or 1)
- [in] `func`: Pointer to a function of type `void func(void* arg)` to be executed
- [in] `arg`: Arbitrary argument of type `void*` to be passed into the function

`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.

**Return**

- ESP_ERR_INVALID_ARG if `cpu_id` is invalid
- ESP_ERR_INVALID_STATE if the FreeRTOS scheduler is not running
- ESP_OK otherwise

**Parameters**

- [in] `cpu_id`: CPU where the given function should be executed (0 or 1)
- [in] `func`: Pointer to a function of type `void func(void* arg)` to be executed
- [in] `arg`: Arbitrary argument of type `void*` to be passed into the function

Type Definitions

```c
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_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**

- [in] `func`: Pointer to a function of type `void func(void* arg)` to be executed
Chapter 2. API Reference

• [in] arg: Arbitrary argument of type void* to be passed into the function

void esp_ipc_isr_asm_call_blocking (esp_ipc_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
• [in] func: Pointer to a function of type void func(void* arg) to be executed
• [in] arg: 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.

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() and esp_ipc_isr_stall_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 releasing the CPU stall feature.

• 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().
2.7.16 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

Macros

ESP_EXECUTE_EXPRESSION_WITH_STACK (lock, stack, stack_size, expression)

Type Definitions

typedef void (*shared_stack_function)(void)

2.7.17 Interrupt allocation

Overview

The ESP32-S3 has two cores, with 32 interrupts. 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 interrupt 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-S3 but outside the Xtensa cores themselves. Most ESP32-S3 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 (erases 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.

**Return** ESP_ERR_INVALID_ARG if cpu or intno is invalid ESP_OK otherwise

**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.

**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.

**Return** ESP_ERR_INVALID_ARG if cpu or intno is invalid ESP_OK otherwise

**Parameters**

- **intno**: The number of the interrupt (0-31)
- **cpu**: CPU on which the interrupt should be marked as shared (0 or 1)

**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.

**Return** 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

**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.
- **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.
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.

Return ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_ERR_NOT_FOUND if no free interrupt found with the specified flags ESP_OK otherwise.

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 ORred 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.

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.

Return ESP_ERR_INVALID_ARG the handle is NULL ESP_FAIL failed to release this handle ESP_OK otherwise.

Parameters

- **handle**: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

int esp_intr_get_cpu(intr_handle_t handle)

Get CPU number an interrupt is tied to.

Return The core number where the interrupt is allocated

Parameters

- **handle**: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

int esp_intr_get_intno(intr_handle_t handle)

Get the allocated interrupt for a certain handle.

Return The interrupt number

Parameters

- **handle**: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

esp_err_t esp_intr_disable(intr_handle_t handle)

Disable the interrupt associated with the handle.

Note
1. 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.

2. 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.

Return ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

Parameters
- handle: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

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.

Return ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

Parameters
- handle: The handle, as obtained by esp_intr_alloc or esp_intr_alloc_intrstatus

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.

Return ESP_ERR_INVALID_ARG if the combination of arguments is invalid. ESP_OK otherwise

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.

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 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.
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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.

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_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

```c
typedef void(*intr_handler_t)(void *arg)
```

Function prototype for interrupt handler function

```c
typedef struct intr_handle_data_t intr_handle_data_t
```

Interrupt handler associated data structure

```c
typedef intr_handle_data_t *intr_handle_t
```

Handle to an interrupt handler

### 2.7.18 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 `CONFIG_LOG_DEFAULT_LEVEL`.
- **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 logging macros to produce output, e.g:

```c
ESP_LOGW(TAG, "%s 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 makefile:

```makefile
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 cannot 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.

Return The current log level for the given tag

Parameters

- **tag**: Tag of the log to query current level. Must be a non-NULL zero terminated string.

```c
vprintf_like_t esp_log_set_vlogprintf(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.

Note Please note that function callback here must be re-entrant as it can be invoked in parallel from multiple thread context.

Return func old Function used for output.

Parameters

- **func**: new Function used for output. Must have same signature as vprintf.

```c
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 starts running, it switches to FreeRTOS tick count.

For now, we ignore millisecond counter overflow.

Return timestamp, in milliseconds

```c
char *esp_log_system_timestamp(void)
```

Function which returns timestamp to be used in log output.

This function is used in expansion of ESP_LOGx macros 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.

Return timestamp, in “HH:MM:SS.sss”

```c
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.

Return timestamp, in milliseconds

```c
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.
Chapter 2. API Reference

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
sink.
See esp_log_write()

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:

```
W (195) log_example: 0x3ffb4280 45 53 50 33 32 20 69 73 20 67 72 65 61 74 ,
  → 2c 20 |ESP32 is great, |
W (195) log_example: 0x3ffb4290 77 6f 72 6b 69 6e 77 69 67 20 61 6c 6f 6e 67 20 ,
  → 77 69 |working along wi |
W (205) log_example: 0x3ffb42a0 74 68 20 74 68 65 20 49 44 46 2e 00 ,
  → | 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)
Log a buffer of hex bytes at Info level.
See 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)
Log a buffer of characters at Info level. Buffer should contain only printable characters.
See 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 allocator and syscalls have been initialized. Log at ESP_LOG_ERROR level.

See printf, ESP_LOGE, ESP_DRAM_LOGE 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 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 ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_EARLY_LOGI** (tag, format,...)

Macro to output logs in startup code at ESP_LOG_INFO level.

See ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_EARLY_LOGD** (tag, format,...)

Macro to output logs in startup code at ESP_LOG_DEBUG level.

See ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_EARLY_LOGV** (tag, format,...)

Macro to output logs in startup code at ESP_LOG_VERBOSE level.

See ESP_EARLY_LOGE, ESP_LOGE, printf

**ESP_LOG_EARLY_ENABLED** (log_level)

Runtime macro to output logs at a specified level.

See printf

**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. Also check the level with LOG_LOCAL_LEVEL.

See 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", orESP_DRAM_LOGE(TAG, "format" , "..."), where TAG is a char* that points to a str in the DRAM.
Note Unlike normal logging macros, it’s possible to use this macro when interrupts are disabled or inside an ISR.

See 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.

Note Placing log strings in DRAM reduces available DRAM, so only use when absolutely essential.

See esp_rom_printf, ESP_LOGE

ESP_DRAM_LOGW (tag, format, ...) macro to output logs when the cache is disabled at ESP_LOG_WARN level.

See 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 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 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 ESP_DRAM_LOGV, ESP_LOGV, esp_rom_printf

Type Definitions
typedef int (*vprintf_like_t)(const char *, va_list)

Enumerations
eenum esp_log_level_t

Log level.

Values:

ESP_LOG_NONE

No log output

ESP_LOG_ERROR

Critical errors, software module cannot recover on its own

ESP_LOG_WARN

Error conditions from which recovery measures have been taken

ESP_LOG_INFO

Information messages which describe normal flow of events

ESP_LOG_DEBUG

Extra debug information which is not necessary for normal use (values, pointers, sizes, etc).

ESP_LOG_VERBOSE

Bigger chunks of debugging information, or frequent messages which can potentially flood the output.

2.7.19 Miscellaneous System APIs

Software reset

To perform software reset of the chip, esp_restart() function is provided. When the function is called, execution of the program will stop, both CPUs will be reset, application will be loaded by the bootloader and started again.
Additionally, `esp_register_shutdown_handler()` function is provided to register a routine which needs to be called prior to restart (when done by `esp_restart()`). This is similar to the functionality of `atexit` POSIX function.

**Reset reason**

ESP-IDF application 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 was available during program execution.

Note that ESP-IDF supports multiple heaps with different capabilities. Functions mentioned in this section return the size of heap memory which can be allocated using `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 network interfaces that supported (e.g. Wi-Fi, Bluetooth, Ethernet).

To fetch MAC address for a specific interface (e.g. Wi-Fi, Bluetooth, Ethernet), call the function `esp_read_mac()` function.

In ESP-IDF these addresses are calculated from a single *Base MAC address*. By default, the Espressif base MAC address is used. This MAC is pre-programmed into ESP32-S3 eFuse from the factory.

<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><em>Local MAC</em> 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><em>Local MAC</em> (derived from Bluetooth MAC)</td>
</tr>
</tbody>
</table>

**Note:** The default configuration is 4 universally administered MAC addresses, and this is recommended when using Espressif-provided MAC addresses.

**Note:** ESP32-S3 has no integrated Ethernet MAC, but it’s still possible to calculate an Ethernet MAC address. This MAC address can only be used with an external interface such as an SPI-Ethernet device, see Ethernet.

**Custom Base MAC** The default Base MAC is pre-programmed by Espressif in eFuse BLK1. To set a custom Base MAC instead, call the function `esp_base_mac_addr_set()` before initializing any network interfaces or calling the `esp_read_mac()` function. The customized MAC address can be stored in any supported storage device (e.g. Flash, NVS, etc).
Chapter 2. API Reference

The custom base MAC addresses should be allocated such that derived MAC addresses will not overlap. Configure the option `CONFIG_ESP32S3_UNIVERSAL_MAC_ADDRESSES` to set the number of valid universal MAC addresses that can be derived from the custom base MAC, according to the table above.

**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. It’s recommended to use the Base MAC approach documented here instead, to avoid the possibility of the original MAC address briefly appearing on the network before it is changed.

### Custom MAC address in eFuse

When reading custom MAC addresses from eFuse, ESP-IDF provides a helper function `esp_efuse_mac_get_custom()`. This loads the MAC address from eFuse BLK3. This 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>
</tr>
</thead>
<tbody>
<tr>
<td>MAC address</td>
<td>48</td>
<td>200:248</td>
</tr>
</tbody>
</table>

**Note:** The eFuse BLK3 uses RS-coding during a burn operation it means that all eFuse fields in this block must be burnt at the same time.

Once MAC address has been obtained using `esp_efuse_mac_get_custom()`, call `esp_base_mac_addr_set()` to set this MAC address as base MAC address.

### Local vs Universal MAC addresses

ESP32-S3 comes pre-programmed with enough valid Espressif universally administered MAC addresses for all internal interfaces. The specific calculations to derive an interface’s MAC address from the base MAC address is shown in the table above.

When using a custom MAC address scheme, it’s possible that not all interfaces can be assigned 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 local and universally administered MAC addresses.

Function `esp_derive_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 (meaning: 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.

### 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 IDF version which was 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 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:

```c
#include "esp_idf_version.h"

#if ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)
    // enable functionality present in IDF v4.0
#endif
```

### App version

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 field version has string type and max length 32 chars.

To set version in your project manually you need to set PROJECT_VER variable in your project CMakeLists.txt/Makefile:

- In application CMakeLists.txt put `set(PROJECT_VER "0.1.0.1")` before including project.cmake.

If CONFIG_APP_PROJECT_VER_FROM_CONFIG option is set, the value of CONFIG_APP_PROJECT_VER will be used. Otherwise, if PROJECT_VER variable is not set in the project then it will be retrieved from either `${PROJECT_PATH}/version.txt` file (if present) else using git command `git describe`. If neither is available then PROJECT_VER will be set to “I”. Application can make use of this by calling `esp_ota_get_app_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.

  **Return**
  - 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

  **Parameters**
  - handle: function to execute on restart

- **esp_err_t esp_unregister_shutdown_handler (shutdown_handler_t 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 hasn’t 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.
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**esp_reset_reason_t esp_reset_reason (void)**
Get reason of last reset.

- **Return**: 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.
- **Return**: 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.
- **Return**: Available internal heap size, in bytes.

**uint32_t esp_get_minimum_free_heap_size (void)**
Get the minimum heap that has ever been available.

- **Return**: 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**:
  - **ESP_RST_UNKNOWN**: Reset reason can not be determined.
  - **ESP_RST_POWERON**: Reset due to power-on event.
  - **ESP_RST_EXT**: Reset by external pin (not applicable for ESP32)
  - **ESP_RST_SW**: Software reset via esp_restart.
  - **ESP_RST_PANIC**: Software reset due to exception/panic.
  - **ESP_RST_INT_WDT**: Reset (software or hardware) due to interrupt watchdog.
  - **ESP_RST_TASK_WDT**: Reset due to task watchdog.
  - **ESP_RST_WDT**: Reset due to other watchdogs.
  - **ESP_RST_DEEPSLEEP**: Reset after exiting deep sleep mode.
  - **ESP_RST_BROWNOUT**: Brownout reset (software or hardware)
ESP_RST_SDIO
Reset over SDIO.

Header File

- components/esp_common/include/esp_idf_version.h

Functions

\textbf{const char* \texttt{esp_get_idf_version} (void)}

Return full IDF version string, same as ‘git describe’ output.

\textbf{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.

\textbf{Return} constant string from IDF_VER

Macros

\textbf{ESP_IDF_VERSION_MAJOR}

Major version number (X.x.x)

\textbf{ESP_IDF_VERSION_MINOR}

Minor version number (x.X.x)

\textbf{ESP_IDF_VERSION_PATCH}

Patch version number (x.x.X)

\textbf{ESP_IDF_VERSION_VAL} (major, minor, patch)

Macro to convert IDF version number into an integer

To be used in comparisons, such as \texttt{ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)}

\textbf{ESP_IDF_VERSION}

Current IDF version, as an integer

To be used in comparisons, such as \texttt{ESP_IDF_VERSION >= ESP_IDF_VERSION_VAL(4, 0, 0)}

Header File

- components/esp_hw_support/include/esp_mac.h

Functions

\textbf{esp_err_t \texttt{esp_base_mac_addr_set} (const uint8_t* \textit{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.

\textbf{Note} Base MAC must be a unicast MAC (least significant bit of first byte must be zero).

\textbf{Note} If not using a valid OUI, set the locally administered” bit (bit value 0x02 in the first byte) to avoid collisions.

\textbf{Return} ESP_OK on success ESP_ERR_INVALID_ARG If \textit{mac} is NULL or is not a unicast MAC

\textbf{Parameters}

- \texttt{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)

\textbf{esp_err_t \texttt{esp_base_mac_addr_get} (uint8_t* \textit{mac})}

Return base MAC address which is set using \texttt{esp_base_mac_addr_set}.

\textbf{Note} If no custom Base MAC has been set, this returns the pre-programmed Espressif base MAC address.
Return ESP_OK on success ESP_ERR_INVALID_ARG mac is NULL ESP_ERR_INVALID_MAC base MAC address has not been set

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)

`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.

Return ESP_OK on success ESP_ERR_INVALID_ARG mac is NULL ESP_ERR_INVALID_MAC CUS-

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)

`esp_err_t esp_efuse_mac_get_default (uint8_t *mac)`

Return base MAC address which is factory-programmed by Espressif in EFUSE.

Return ESP_OK on success ESP_ERR_INVALID_ARG mac is NULL

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)

`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.

Return ESP_OK on success

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)
- *type*: Type of MAC address to return

`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.

Return ESP_OK on success

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)
- *universal_mac*: Source universal MAC address, length: 6 bytes.

Macros

MAC2STR (a)
MACSTR

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Enumerations

```c
enum esp_mac_type_t
{
    ESP_MAC_WIFI_STA,
    ESP_MAC_WIFI_SOFTAP,
    ESP_MAC_BT,
    ESP_MAC_ETH,
    ESP_MAC_IEEE802154
};
```

2.7.20 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 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.
**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>The restriction. Will be selected.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_UNDEFINED</td>
<td>Non-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><strong>CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE</strong> option is set it will be selected only once. In bootloader the state immediately changes to ESP_OTA_IMG_PENDING_VERIFY.</td>
</tr>
<tr>
<td>ESP_OTA_IMG_PENDING_VERIFY</td>
<td><strong>CONFIG_BOOTLOADER_APP_ROLLBACK_ENABLE</strong> option is set it will not be selected, and the state will change to ESP_OTA_IMG_ABORTED.</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()`.
- 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_roll_back_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);
} ...
```

Restrictions:

• The number of bits in the `secure_version` field is limited to 16 bits. This means that only 16 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.

• 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`.

**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`
OTA Tool (otatool.py)

The component \texttt{app\_update} provides a tool \texttt{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 \texttt{(read\_otadata)}
- erase otadata partition, effectively resetting device to factory app \texttt{(erase\_otadata)}
- switch OTA partitions \texttt{(switch\_ota\_partition)}
- erasing OTA partition \texttt{(erase\_ota\_partition)}
- write to OTA partition \texttt{(write\_ota\_partition)}
- read contents of OTA partition \texttt{(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 \texttt{otatool} module is imported.

```python
import sys
import os

idf_path = os.environ["IDF_PATH"] # get value of IDF_PATH from environment
otatool_dir = os.path.join(idf_path, "components", "app\_update") # otatool.py... lives in $IDF_PATH/components/app\_update

sys.path.append(otatool_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 \texttt{OtatoolTarget} object:

```python
# Create a partool.py target device connected on serial port /dev/ttyUSB1
target = OtatoolTarget("/dev/ttyUSB1")
```

The created object can now be used to perform operations on the target device:

```python
# Erase otadata, 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 \texttt{otatool.py} has the following structure:

```
otatool.py [command-args] [subcommand] [subcommand-args]
```

- \texttt{command-args} - these are arguments that are needed \texttt{for} executing the main...
- \texttt{command} (parttool.py), mostly pertaining to the target device
- \texttt{subcommand} - this is the operation to be performed
- \texttt{subcommand-args} - these are arguments that are specific to the chosen operation
Chapter 2. API Reference

```
# Erase otadata, 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:

```
# 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
- Lower-Level SPI Flash/Partition 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

```c
const esp_app_desc_t *esp_ota_get_app_description (void)
    Return esp_app_desc structure. This structure includes app version.
    Return description for running app.

Return  Pointer to esp_app_desc structure.
```

```c
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.
    Return  Number of bytes written to dst (including null terminator)
```

Parameters

- dst: Destination buffer
- size: Size of the buffer

```c
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.
```

Submit Document Feedback
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).

Return

- 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.

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.

```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.

Return

- 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

Parameters

- handle: Handle obtained from esp_ota_begin
- data: Data buffer to write
- size: Size of data buffer in bytes.

```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.

Return

- 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

**Parameters**
- **handle**: Handle obtained from esp_ota_begin
- **data**: Data buffer to write
- **size**: Size of data buffer in bytes
- **offset**: Offset in flash partition

```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).

**Return**
- 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.

**Parameters**
- **handle**: Handle obtained from esp_ota_begin().

```c
esp_err_t esp_ota_abort(esp_ota_handle_t handle)
```

Abort OTA update, free the handle and memory associated with it.

**Return**
- ESP_OK: Handle and its associated memory is freed successfully.
- ESP_ERR_NOT_FOUND: OTA handle was not found.

**Parameters**
- **handle**: obtained from esp_ota_begin().

```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.

**Return**
- 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.

**Parameters**
- **partition**: Pointer to info for partition containing app image to boot.

```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.
**Return** 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.

**Return** 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.

**Return** 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.

**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.

```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.

**Return**
- 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.

**Parameters**
- `[in] partition`: Pointer to app partition. (only app partition)
- `[out] app_desc`: Structure of info about app.

```c
uint8_t esp_ota_get_app_partition_count (void)
```
Returns number of OTA partitions provided in partition table.

**Return**
- 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.

**Return**
- ESP_OK: if successful.

```c
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.
Return

- ESP_FAIL: if not successful.
- ESP_ERR_OTA_ROLLBACK_FAILED: The rollback is not possible due to flash does not have any apps.

```c
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).

Return partition.

```c
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.

Return

- 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 otadata or state was not found for given partition.

Parameters

- [in] partition: Pointer to partition.
- [out] ota_state: state of partition (if this partition has a record in otadata).

```c
esp_err_t esp_ota_erase_last_boot_app_partition(void)
```

Erase previous boot app partition and corresponding otadata select for this partition.

When current app is marked to as valid then you can erase previous app partition.

Return

- ESP_OK: Successful, otherwise ESP_ERR.

```c
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 otadata 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).

Return

- True: Returns true if the slots have at least one app (except the running app).
- False: The rollback is not possible.

```c
esp_err_t esp_ota_revoke_secure_boot_public_key(esp_ota_secure_boot_public_key_index_t index)
```

Revokes the old signature digest. To be called in the application after the rollback logic.

Relevant for Secure boot v2 on ESP32-S2, ESP32-S3, ESP32-C3, ESP32-H2 where upto 3 key digests can be stored (Key #N-1, Key #N, Key #N+1). When key #N-1 used to sign an app is invalidated, an OTA update is to be sent with an app signed with key #N-1 & Key #N. After successfully booting the OTA app should call this function to revoke Key #N-1.

Return

- ESP_OK: If revocation is successful.
- ESP_ERR_INVALID_ARG: If the index of the public key to be revoked is incorrect.
- ESP_FAIL: If secure boot v2 has not been enabled.

Parameters

- index: - The index of the signature block to be revoked

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)
Chapter 2. API Reference

ESP_ERR_OTA_BASE
Base error code for ota_ops api

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().

Enumerations

typedef enum esp_ota_secure_boot_public_key_index_t
Secure Boot V2 public key indexes.

Values:

SECURE_BOOT_PUBLIC_KEY_INDEX_0
Points to the 0th index of the Secure Boot v2 public key

SECURE_BOOT_PUBLIC_KEY_INDEX_1
Points to the 1st index of the Secure Boot v2 public key

SECURE_BOOT_PUBLIC_KEY_INDEX_2
Points to the 2nd index of the Secure Boot v2 public key

Debugging OTA Failure

2.7.21 Performance Monitor

The Performance Monitor component provides APIs to use ESP32-S3 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.
Fig. 37: How to Debug When OTA Fails (click to enlarge)
High level API Reference

Header Files

- perfmon/include/perfmon.h

API Reference

Header File

- components/perfmon/include/xtensa_perfmon_access.h

Functions

```c
esp_err_t xtensa_perfmon_init (int id, uint16_t select, uint16_t mask, int kernelcnt, int tracelevel)
```

Init Performance Monitor.

Initialize performance monitor register with define values

Return

- ESP_OK on success
- ESP_ERR_INVALID_ARG if one of the arguments is not correct

Parameters

- [in] id: performance counter number
- [in] select: select value from PMCTRLx register
- [in] mask: mask value from PMCTRLx register
- [in] kernelcnt: kernelcnt value from PMCTRLx register
- [in] tracelevel: tracelevel value from PMCTRLx register

```c
esp_err_t xtensa_perfmon_reset (int id)
```

Reset PM counter.

Reset PM counter. Writes 0 to the PMx register.

Return

- ESP_OK on success
- ESP_ERR_INVALID_ARG if id out of range

Parameters

- [in] id: performance counter number

```c
void xtensa_perfmon_start (void)
```

Start PM counters.

Start all PM counters synchronously. Write 1 to the PGM register

```c
void xtensa_perfmon_stop (void)
```

Stop PM counters.

Stop all PM counters synchronously. Write 0 to the PGM register

```c
uint32_t xtensa_perfmon_value (int id)
```

Read PM counter.

Read value of defined PM counter.

Return

- Performance counter value

Parameters

- [in] id: performance counter number

```c
esp_err_t xtensa_perfmon_overflow (int id)
```

Read PM overflow state.

Read overflow value of defined PM counter.

Return

- ESP_OK if there is no overflow (overflow = 0)
• ESP_FAIL if overflow occur (overflow = 1)

Parameters
• [in] id: performance counter number

void xtensa_perfmon_dump (void)
Dump PM values.
Dump all PM register to the console.

Header File
• components/perfmon/include/xtensa_perfmon_apis.h

Functions
esp_err_t xtensa_perfmon_exec (const xtensa_perfmon_config_t *config)
Execute PM.
Execute performance counter for dedicated function with defined parameters

Return
• ESP_OK if no errors
• ESP_ERR_INVALID_ARG if one of the required parameters not defined
• ESP_FAIL - counter overflow

Parameters
• [in] config: pointer to the configuration structure

void xtensa_perfmon_view_cb (void *params, uint32_t select, uint32_t mask, uint32_t value)
Callback to dump perfmon result to a FILE* stream specified in perfmon_config_t::callback_params. If call-
back_params is set to NULL, will print to stdout

Parameters
• [in] params: 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.
• [in] select: select value for current counter
• [in] mask: mask value for current counter
• [in] value: 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

### 2.7.22 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_esp32s3_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_ESP32S3_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-S3 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-S3, 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-S3, 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-S3 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_ESP32S3_DEFAULT_CPU_FREQ_MHZ`.
Max CPU Frequency Set | Lock Acquisition | CPU and APB Frequencies
---|---|---
240 | ESP_PM_CPU_FREQ_MAX acquired | CPU: 240 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()  
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 skipUnhandledEvents 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.

The following peripherals work normally even when the APB frequency is changing:

- **UART**: if REF_TICK is used as a clock source. See useRefTick member of uart_config_t.
- **LEDC**: if REF_TICK is used as a clock source. See ledc_timer_config() function.
- **RMT**: if REF_TICK or XTAL is used as a clock source. See flags member of rmt_config_t and macro RMT_CHANNEL_FLAGS_AWARE_DFS.
• **GPTimer**: if APB is used as the clock source. See `clk_src` member of `gptimer_config_t`.

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
- I2C
- I2S (If the APPLL 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()`.
- **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()`.
- **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.

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 (note, the new GPTimer will hold the `ESP_PM_APB_FREQ_MAX` lock while the timer is working, if the clock source is set to APB)
- MCPWM

**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.

**Return**

- 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

**Parameters**

- `config`: pointer to implementation-specific configuration structure (e.g. `esp_pm_config_esp32`)

`esp_err_t esp_pm_get_configuration(void *config)`

Get implementation-specific power management configuration.

**Return**

- ESP_OK on success
- ESP_ERR_INVALID_ARG if the pointer is null

**Parameters**

- `config`: pointer to implementation-specific configuration structure (e.g. `esp_pm_config_esp32`)

`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.

**Return**
- 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

**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]** **out_handle**: 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.

```c
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.

**Return**
- 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

**Parameters**
- **handle**: handle obtained from esp_pm_lock_create function

```c
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.

**Return**
- 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

**Parameters**
- **handle**: handle obtained from esp_pm_lock_create function

```c
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.

**Return**
- 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

**Parameters**

- **handle**: handle obtained from esp_pm_lock_create function

**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.

**Return**

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if CONFIG_PM_ENABLE is not enabled in sdkconfig

**Parameters**

- **stream**: stream to print information to; use stdout or stderr to print to the console; use fmemo-
  - pen/open_memstream to print to a string buffer.

**Type Definitions**

```c
typedef struct esp_pm_lock *esp_pm_lock_handle_t

Opaque handle to the power management lock.
```

**Enumerations**

```c
enum esp_pm_lock_type_t

Power management constraints.
```

**Values:**

- **ESP_PM_CPU_FREQ_MAX**
  
  Require CPU frequency to be at the maximum value set via esp_pmConfigure. Argument is unused and
  should be set to 0.

- **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.

- **ESP_PM_NO_LIGHT_SLEEP**
  
  Prevent the system from going into light sleep. Argument is unused and should be set to 0.

**Header File**

- components/esp_pm/include/esp32s3/pm.h

**Structures**

```c
struct esp_pm_config_esp32s3_t

Power management config for ESP32.
```

Pass a pointer to this structure as an argument to esp_pmConfigure 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
```
2.7.23 Random Number Generation

ESP32-S3 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-S3 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, 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.

Secondary Entropy

ESP32-S3 RNG contains a secondary entropy source, based on sampling an asynchronous 8MHz internal oscillator (see the Technical Reference Manual for details). This entropy source is always enabled in ESP-IDF and continuously mixed into the RNG state by hardware. In testing, this secondary entropy source was sufficient to pass the Dieharder random number test suite without the main entropy source enabled (test input was created by concatenating short samples from a continuously resetting ESP32-S3). However, it is currently only guaranteed that true random numbers will be produced when the main entropy source is also enabled as described above.

API Reference

Header File

- components/esp_hw_support/include/esp_random.h
Functions

```c
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).

**Return** Random value between 0 and UINT32_MAX

```c
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

```c
void bootloader_random_enable (void)
```

Enable an entropy source for RNG if RF 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 used from app code early during operation, if true random numbers are required before RF is initialised. Consult ESP-IDF Programming Guide “Random Number Generation” section for details.

```c
void bootloader_random_disable (void)
```

Disable entropy source for RNG.

- Disables internal entropy source. Must be called after bootloader_random_enable() and before RF features, ADC, or I2S (ESP32 only) are initialized.
- Consult the ESP-IDF Programming Guide “Random Number Generation” section for details.

```c
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.

### 2.7.24 Sleep Modes

#### Overview

ESP32-S3 is capable of light sleep and deep sleep power saving modes.

In light sleep mode, digital peripherals, most of the RAM, and CPUs are clock-gated, and supply voltage is reduced. Upon exit from light sleep, peripherals and CPUs resume operation, their internal state is preserved.

In deep sleep mode, CPUs, most of the RAM, and all the digital peripherals which are clocked from APB_CLK are powered off. The only parts of the chip which can still be powered on are:

- RTC controller
- RTC peripherals
- ULP coprocessor
- RTC fast memory
- RTC slow memory

Wakeup from deep and light sleep modes can be done using several sources. These sources can be combined, in this case the chip will wake up when any one of the sources is 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 or deep sleep mode.

Additionally, the application can force specific powerdown modes for the RTC peripherals and RTC memories using `esp_sleep_pd_config()` API.

Once wakeup sources are configured, 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 RTC controller will either power down or power off the CPUs and digital peripherals.

If WiFi connection needs to be maintained, enable WiFi modem sleep, and enable automatic light sleep feature (see `Power Management APIs`). This will allow the system to wake up from sleep automatically when required by WiFi driver, thereby maintaining connection to the AP.

#### WiFi/BT and sleep modes

In deep sleep and light sleep modes, wireless peripherals are powered down. Before entering deep sleep or light sleep modes, applications must disable WiFi and BT using appropriate calls (`esp_bluedroid_disable()`, `esp_bt_controller_disable()`, `esp_wifi_stop()`). WiFi and BT connections will not be maintained in deep sleep or light sleep, even if these functions are not called.

#### Wakeup sources

**Timer** 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-S3 Technical Reference Manual > ULP Coprocessor [PDF].

This wakeup mode doesn’t require RTC peripherals or RTC memories to be powered on during sleep.

`esp_sleep_enable_timer_wakeup()` function can be used to enable deep sleep wakeup using a timer.
**Touch pad**  RTC IO module contains logic to trigger wakeup when a touch sensor interrupt occurs. You need to configure the touch pad interrupt before the chip starts deep sleep.

`esp_sleep_enable_touchpad_wakeup()` function can be used to enable this wakeup source.

**External wakeup (ext0)**  RTC IO module contains logic to trigger wakeup when one of RTC GPIOs is set to a predefined logic level. RTC IO is part of RTC peripherals power domain, so RTC peripherals will be kept powered on during sleep if this wakeup source is requested.

Because RTC IO module is enabled in this mode, 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_sleep_start()`.

`esp_sleep_enable_ext0_wakeup()` function can be used to enable this wakeup source.

**Warning:** After wake up from sleep, IO pad used for wakeup will be configured as RTC IO. Before using this pad as digital GPIO, reconfigure it using `rtc_gpio_deinit(gpio_num)` function.

**External wakeup (ext1)**  RTC controller contains logic to trigger wakeup using multiple RTC GPIOs. One of the 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. To use internal pullup or pulldown resistors, request 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);
gpio_pullup_dis(gpio_num);
gpio_pulldown_en(gpio_num);
```

**Warning:** After wake up from sleep, IO pad(s) used for wakeup will be configured as RTC IO. Before using these pads as digital GPIOs, reconfigure them using `rtc_gpio_deinit(gpio_num)` function.

`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 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.

`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_SPI 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_SPI 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()`:

```
esp_sleep_pd_config(ESP_PD_DOMAIN_VDDSDIO, ESP_PD_OPTION_ON);
```

UART wakeup (light sleep only) When ESP32-S3 receives UART input from external devices, it is often required to wake up the chip when input data is available. 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-S3 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.

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.

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 go into 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 go into 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-S3 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, preventing extra current draw, call `rtc_gpio_isolate()` function.

For example, on ESP32-WROVER module, GPIO12 is pulled up externally. GPIO12 also has an internal pull-down 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 this extra current:

```
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 touch pad, it is possible to identify touch pad which has caused wakeup using `esp_sleep_get_touchpad_wakeup_status()` functions.

For ext1 wake sources, it is possible to identify pin which has caused wakeup using `esp_sleep_get_ext1_wakeup_status()` functions.

Disable sleep wakeup source

Previously configured wakeup source 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`.

Application Example

Implementation of basic functionality of deep sleep is shown in `protocols/sntp` example, where ESP module is periodically waken up to retrieve time from NTP server.

More extensive example in `system/deep_sleep` illustrates 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_sleep_start` function.

**Return**

- `ESP_OK` on success
- `ESP_ERR_INVALID_STATE` if trigger was not active

**Parameters**

- `source`: number of source to disable of type `esp_sleep_source_t`

```c
esp_err_t esp_sleep_enable_ulp_wakeup(void)
```

Enable wakeup by ULP coprocessor.

**Note** In revisions 0 and 1 of the 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.
Return

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if additional current by touch (CONFIG_ESP32_RTC_EXT_CRYST_ADDIT_CURRENT) is enabled.
- ESP_ERR_INVALID_STATE if ULP co-processor is not enabled or if wakeup triggers conflict

```
esp_err_t esp_sleep_enable_timer_wakeup(uint64_t time_in_us)
```

Enable wakeup by timer.

Return

- ESP_OK on success
- ESP_ERR_INVALID_ARG if value is out of range (TBD)

Parameters

- `time_in_us`: time before wakeup, in microseconds

```
esp_err_t esp_sleep_enable_touchpad_wakeup(void)
```

Enable wakeup by touch sensor.

Note In revisions 0 and 1 of the ESP32, touch wakeup source can not 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.

Return

- ESP_OK on success
- ESP_ERR_NOT_SUPPORTED if additional current by touch (CONFIG_ESP32_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;

Return 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.

Return True if this GPIO number will be accepted as a sleep wakeup source.

Parameters

- `gpio_num`: Number of the GPIO to test for wakeup source capability

```
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_sleep_start, immediately before entering sleep mode.

Note In revisions 0 and 1 of the ESP32, ext0 wakeup source can not be used together with touch or ULP wakeup sources.

Return

- 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

Parameters

- `gpio_num`: GPIO number used as wakeup source. Only GPIOs which are have RTC functionality can be used: 0,2,4,12-15,25-27,32-39.
- `level`: input level which will trigger wakeup (0=low, 1=high)
\textbf{esp_err_t \textit{esp_sleep_enable_ext1_wakeup}(uint64_t \textit{mask}, esp_sleep_ext1_wakeup_mode_t \textit{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.

\textbf{Note} This function does not modify pin configuration. The pins are configured in esp_sleep_start, immediately before entering sleep mode.

\textbf{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.

\textbf{Return}  
- ESP_OK on success  
- ESP_ERR_INVALID_ARG if any of the selected GPIOs is not an RTC GPIO, or mode is invalid

\textbf{Parameters}  
- \textit{mask}: bit mask of GPIO numbers which will cause wakeup. Only GPIOs which have RTC functionality can be used in this bit map: 0,2,4,12-15,25-27,32-39.  
- \textit{mode}: select logic function used to determine wakeup condition:  
  - 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

\textbf{esp_err_t \textit{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.

\textbf{Note} In revisions 0 and 1 of the ESP32, GPIO wakeup source can not be used together with touch or ULP wakeup sources.

\textbf{Return}  
- ESP_OK on success  
- ESP_ERR_INVALID_STATE if wakeup triggers conflict

\textbf{esp_err_t \textit{esp_sleep_enable_uart_wakeup}(int \textit{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.

\textbf{Note} ESP32 does not support wakeup from UART2.

\textbf{Return}  
- ESP_OK on success  
- ESP_ERR_INVALID_ARG if wakeup from given UART is not supported

\textbf{Parameters}  
- \textit{uart_num}: UART port to wake up from

\textbf{esp_err_t \textit{esp_sleep_enable_wifi_wakeup}(void)}

Enable wakeup by WiFi MAC.

\textbf{Return}  
- ESP_OK on success

\textbf{esp_err_t \textit{esp_sleep_disable_wifi_wakeup}(void)}

Disable wakeup by WiFi MAC.

\textbf{Return}  
- 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.

Return bit mask, if GPIOn 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.

Return

• ESP_OK on success
• ESP_ERR_INVALID_ARG if either of the arguments is out of range

Parameters

• domain: power domain to configure
• option: power down option (ESP_PD_OPTION_OFF, ESP_PD_OPTION_ON, or ESP_PD_OPTION_AUTO)

void esp_deep_sleep_start (void)

Enter deep sleep with the configured wakeup options.

This function does not return.

esp_err_t esp_light_sleep_start (void)

Enter light sleep with the configured wakeup options.

Return

• ESP_OK on success (returned after wakeup)
• ESP_ERR_INVALID_STATE if WiFi or BT is not stopped

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.

esp_deep_sleep does not shut down WiFi, BT, and higher level protocol connections gracefully. Make sure relevant WiFi and BT stack functions are called to close any connections and deinitialize the peripherals. These include:

• esp_bluedroid_disable
• esp_bt_controller_disable
• esp_wifi_stop

This function does not return.

Note The device will wake up immediately if the deep-sleep time is set to 0

Parameters

• time_in_us: deep-sleep time, unit: microsecond

esp_sleep_wakeup_cause_t esp_sleep_get_wakeup_cause (void)

Get the wakeup source which caused wakeup from sleep.

Return 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.

```c
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().

```c
esp_deep_sleep_wake_stub_fn_t esp_get_deep_sleep_wake_stub(void)
```

Get current wake from deep sleep stub.

Return: Return current wake from deep sleep stub, or NULL if no stub is installed.

```c
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.

```c
void esp_deep_sleep_disable_rom_logging(void)
```

Disable logging from the ROM code after deep sleep.

Using LSB of RTC_STORE4.

```c
esp_err_t esp_sleep_cpu_pd_low_init(bool enable)
```

CPU Power down low-level initialize.

Return:

- ESP_OK on success
- ESP_ERR_NO_MEM not enough retention memory

Parameters:

- `enable`: enable or disable CPU power down during light sleep

```c
void esp_sleep_config_gpio_isolate(void)
```

Configure to isolate all GPIO pins in sleep state.

```c
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

**Type Definitions**

```c
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**

```c
enum esp_sleep_ext1_wakeup_mode_t
```

Logic function used for EXT1 wakeup mode.

Values:

- `ESP_EXT1_WAKEUP_ALL_LOW` = 0
  - Wake the chip when all selected GPIOs go low.

- `ESP_EXT1_WAKEUP_ANY_HIGH` = 1
  - Wake the chip when any of the selected GPIOs go high.

```c
enum esp_sleep_pd_domain_t
```

Power domains which can be powered down in sleep mode.

Values:
Chapter 2. API Reference

ESP_PD_DOMAIN_RTC_PERIPH
RTC IO, sensors and ULP co-processor.

ESP_PD_DOMAIN_RTC_SLOW_MEM
RTC slow memory.

ESP_PD_DOMAIN_RTC_FAST_MEM
RTC fast memory.

ESP_PD_DOMAIN_XTAL
XTAL oscillator.

ESP_PD_DOMAIN_CPU
CPU core.

ESP_PD_DOMAIN_RTC8M
Internal 8M oscillator.

ESP_PD_DOMAIN_VDDSDIO
VDD_SDIO.

ESP_PD_DOMAIN_MAX
Number of domains.

enum esp_sleep_pd_option_t
Power down options.

Values:

ESP_PD_OPTION_OFF
Power down the power domain in sleep mode.

ESP_PD_OPTION_ON
Keep power domain enabled during sleep mode.

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:

ESP_SLEEP_WAKEUP_UNDEFINED
In case of deep sleep, reset was not caused by exit from deep sleep.

ESP_SLEEP_WAKEUP_ALL
Not a wakeup cause, used to disable all wakeup sources with esp_sleep_disable_wakeup_source.

ESP_SLEEP_WAKEUP_EXT0
Wakeup caused by external signal using RTC_IO.

ESP_SLEEP_WAKEUP_EXT1
Wakeup caused by external signal using RTC_CNTL.

ESP_SLEEP_WAKEUP_TIMER
Wakeup caused by timer.

ESP_SLEEP_WAKEUP_TOUCHPAD
Wakeup caused by touchpad.

ESP_SLEEP_WAKEUP_ULP
Wakeup caused by ULP program.

ESP_SLEEP_WAKEUP_GPIO
Wakeup caused by GPIO (light sleep only).

ESP_SLEEP_WAKEUP_UART
Wakeup caused by UART (light sleep only).
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ESP_SLEEP_WAKEUP_WIFI
Wakeup caused by WIFI (light sleep only)

ESP_SLEEP_WAKEUP_COCPU
Wakeup caused by COCPU int.

ESP_SLEEP_WAKEUP_COCPU_TRAP_TRIG
Wakeup caused by COCPU crash.

ESP_SLEEP_WAKEUP_BT
Wakeup caused by BT (light sleep only)

2.7.25 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.

Interrupt watchdog  The interrupt watchdog makes sure the FreeRTOS task switching interrupt isn’t blocked for a long time. This is bad because no other tasks, including potentially important ones like the WiFi task and the idle task, can’t get any CPU runtime. A blocked task switching interrupt can happen because a program runs into an infinite loop with interrupts disabled or hangs in an interrupt.

The default action of the interrupt watchdog is to invoke the panic handler, causing a register dump and an opportunity for the programmer to find out, using either OpenOCD or gdbstub, what bit of code is stuck with interrupts disabled. Depending on the configuration of the panic handler, it can also blindly reset the CPU, which may be preferred in a production environment.

The interrupt watchdog is built around the hardware watchdog in timer group 1. If this watchdog for some reason cannot execute the NMI handler that invokes the panic handler (e.g. because IRAM is overwritten by garbage), it will hard-reset the SOC. If the panic handler executes, it will display the panic reason as “Interrupt wdt timeout on CPU0” or “Interrupt wdt timeout on CPU1” (as applicable).

Configuration  The interrupt watchdog is enabled by default via the CONFIG_ESP_INT_WDT configuration flag. The timeout is configured by setting CONFIG_ESP_INT_WDT_TIMEOUT_MS. 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 INT WDT timeout should always be longer than the period between FreeRTOS ticks (see CONFIG_FREERTOS_HZ).

Tuning  If you find the Interrupt watchdog timeout is triggering 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, with non-critical computation happening outside the critical section. Interrupt handlers should also perform the minimum possible amount of computation, consider pushing data into a queue from the ISR and processing it in a task instead. 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  The Task Watchdog Timer (TWDT) is responsible for detecting instances of tasks running for a prolonged period of time without yielding. This is a symptom of CPU starvation and is usually caused by a higher priority task looping without yielding to a lower-priority task thus starving the lower priority task from CPU time. This can be an indicator of poorly written code that spinloops on a peripheral, or a task that is stuck in an infinite loop.
By default the TWDT will watch the Idle task, however any task can subscribe to be watched by the TWDT. Each watched task must ‘reset’ the TWDT periodically to indicate that they have been allocated CPU time. If a task does not reset within the TWDT timeout period, a warning will be printed with information about which tasks failed to reset the TWDT in time and which tasks are currently running.

It is also possible to redefine the function `esp_task_wdt_isr_user_handler` in the user code, in order to receive the timeout event and handle it differently.

The TWDT is built around the Hardware Watchdog Timer in Timer Group 0. The TWDT can be initialized by calling `esp_task_wdt_init()` which will configure the hardware timer. A task can then subscribe to the TWDT using `esp_task_wdt_add()` in order to be watched. Each subscribed task must periodically call `esp_task_wdt_reset()` to reset the TWDT. Failure by any subscribed tasks to periodically call `esp_task_wdt_reset()` indicates that one or more tasks have been starved of CPU time or are stuck in a loop somewhere.

A watched task can be unsubscribed from the TWDT using `esp_task_wdt_delete()`. A task that has been unsubscribed should no longer call `esp_task_wdt_reset()`. Once all tasks have unsubscribed from the TWDT, the TWDT can be deinitialized by calling `esp_task_wdt_deinit()`.

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 monopolise 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:** It might cause severe watchdog timeout issue when erasing large flash areas. Here are two methods to avoid this issue:

- 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 at startup. They are all enabled by default:

- `CONFIG_ESP_TASK_WDT` - 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_add()` at any time.
- `CONFIG_ESP_TASK_WDT_CHECK_IDLE_TASK_CPU1` - CPU1 Idle task is subscribed to the TWDT during startup.

**JTAG and 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-S3 is connected to OpenOCD via JTAG.

**XTAL32K Watchdog Timer (XTWDT)** The XTAL32K watchdog makes sure the (optional) external 32 KHz crystal or oscillator is functioning correctly.

When `XTAL32K_CLK` works as the clock source of `RTC_SLOW_CLK` and stops oscillating, the XTAL32K watchdog timer will detect this and generate an interrupt. It also provides functionality for automatically switching over to the internal, but less accurate oscillator as the `RTC_SLOW_CLK` source.

Since the switch to the backup clock is done in hardware it can also happen during deep sleep. This means that even if `XTAL32K_CLK` stops functioning while the chip is in deep sleep, waiting for a timer to expire, it will still be able to wake-up as planned.
If the XTAL32K_CLK starts functioning normally again, you can call esp_xt_wdt_restore_clk to switch back to this clock source and re-enable the watchdog timer.

**Configuration** When the external 32KHz crystal or oscillator is selected (CONFIG_ESP32S3_RTC_CLK_SRC) the XTAL32K watchdog can be enabled via the CONFIG_ESP_XT_WDT configuration flag. The timeout is configured by setting CONFIG_ESP_XT_WDT_TIMEOUT. The automatic backup clock functionality is enabled via the ref:CONFIG_ESP_XT_WDT_BACKUP_CLK_ENABLE configuration.

**Interrupt Watchdog API Reference**

**Header File**

- esp_system/include/esp_int_wdt.h

**Functions**

```c
void esp_int_wdt_init (void)
```

Initialize the non-CPU-specific parts of interrupt watchdog. This is called in the init code if the interrupt watchdog is enabled in menuconfig.

**Task Watchdog API Reference**

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**

```c
esp_err_t esp_task_wdt_init (uint32_t timeout, bool panic)
```

Initialize the Task Watchdog Timer (TWDT)

This function configures and initializes the TWDT. If the TWDT is already initialized when this function is called, this function will update the TWDT’s timeout period and panic configurations instead. After initializing the TWDT, any task can elect to be watched by the TWDT by subscribing to it using esp_task_wdt_add().

**Return**

- ESP_OK: Initialization was successful
- ESP_ERR_NO_MEM: Initialization failed due to lack of memory

**Note** esp_task_wdt_init() must only be called after the scheduler started

**Parameters**

- [in] timeout: Timeout period of TWDT in seconds
- [in] panic: Flag that controls whether the panic handler will be executed when the TWDT times out

```c
esp_err_t esp_task_wdt_deinit (void)
```

Deinitialize the Task Watchdog Timer (TWDT)

This function will deinitialize the TWDT. Calling this function whilst tasks are still subscribed to the TWDT, or when the TWDT is already deinitialized, will result in an error code being returned.

**Return**

- ESP_OK: TWDT successfully deinitialized
- ESP_ERR_INVALID_STATE: Error, tasks are still subscribed to the TWDT
- ESP_ERR_NOT_FOUND: Error, TWDT has already been deinitialized
esp_err_t esp_task_wdt_add (TaskHandle_t 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. If the task being subscribed is one of the Idle Tasks, this function will automatically enable esp_task_wdt_reset() to called from the Idle Hook of the Idle Task. Calling this function whilst the TWDT is uninitialized or attempting to subscribe an already subscribed task will result in an error code being returned.

Return

- ESP_OK: Successfully subscribed the task to the TWDT
- ESP_ERR_INVALID_ARG: Error, the task is already subscribed
- ESP_ERR_NO_MEM: Error, could not subscribe the task due to lack of memory
- ESP_ERR_INVALID_STATE: Error, the TWDT has not been initialized yet

Parameters

- [in] handle: Handle of the task. Input NULL to subscribe the current running task to the TWDT

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. If the IDLE tasks have been subscribed to the TWDT, they will automatically call this function from their idle hooks. Calling this function from a task that has not subscribed to the TWDT, or when the TWDT is uninitialized will result in an error code being returned.

Return

- ESP_OK: Successfully reset the TWDT on behalf of the currently running task
- ESP_ERR_NOT_FOUND: Error, the current running task has not subscribed to the TWDT
- ESP_ERR_INVALID_STATE: Error, the TWDT has not been initialized yet

esp_err_t esp_task_wdt_delete (TaskHandle_t 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(). If the task is an IDLE task, this function will automatically disable the calling of esp_task_wdt_reset() from the Idle Hook. Calling this function whilst the TWDT is uninitialized or attempting to unsubscribe an already unsubscribed task from the TWDT will result in an error code being returned.

Return

- ESP_OK: Successfully unsubscribed the task from the TWDT
- ESP_ERR_NOT_FOUND: Error, the task is already unsubscribed
- ESP_ERR_INVALID_STATE: Error, the TWDT has not been initialized yet

Parameters

- [in] handle: Handle of the task. Input NULL to unsubscribe the current running task.

esp_err_t esp_task_wdt_status (TaskHandle_t 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.

Return

- ESP_OK: The task is currently subscribed to the TWDT
- ESP_ERR_NOT_FOUND: The task is currently not subscribed to the TWDT
- ESP_ERR_INVALID_STATE: The TWDT is not initialized, therefore no tasks can be subscribed

Parameters

- [in] handle: Handle of the task. Input NULL to query the current running task.

2.7.26 System Time
Overview

System time can be kept using either one time source or two time sources simultaneously. The choice depends on the application purpose and accuracy requirements for system time.

There are the following two time sources:

- **RTC timer**: Allows keeping the system time during any resets and sleep modes, only the power-up reset leads to resetting the RTC timer. The frequency deviation depends on an RTC Clock Source and affects accuracy only in sleep modes, in which case the time will be measured at 6.6667 us resolution.

- **High-resolution timer**: Not available during any reset and sleep modes. The reason for using this timer is to achieve greater accuracy. It 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 us resolution.

The settings for the system time source are as follows:

- RTC and high-resolution timer (default)
- RTC
- High-resolution timer
- None

It is recommended to stick to the default setting which provides maximum accuracy. If you want to choose a different timer, configure `CONFIG_ESP32S3_TIME_SYSCALL` in project configuration.

RTC Clock Source

The RTC timer has the following clock sources:

- **Internal 150kHz RC oscillator** (default): Features the lowest deep sleep current consumption and no dependence on any external components. However, as frequency stability is affected by temperature fluctuations, time may drift in both Deep and Light sleep modes.

- **External 32kHz crystal**: Requires a 32kHz crystal to be connected to the 32K_XP and 32K_XN pins. Provides better frequency stability at the expense of slightly higher (by 1 uA) Deep sleep current consumption.

- **External 32kHz oscillator at 32K_XN pin**: Allows using 32kHz 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 is signal amplitude. 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.

- **Internal 8.5MHz oscillator, divided by 256 (~33kHz)**: Provides better frequency stability than the internal 150kHz RC oscillator at the expense of higher (by 5 uA) 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_ESP32S3_RTC_CLK_SRC` in project configuration.

More details on wiring requirements for the External 32kHz crystal and External 32kHz oscillator at 32K_XN pin sources can be found in Section Crystal Oscillator of ESP32-S3 Hardware Design Guidelines <https://www.espressif.com/sites/default/files/documentation/esp32-s3_hardware_design_guidelines_en.pdf#page=11>.

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
```

(continues on next page)
difftime
gmtime
elocaltime
mtime
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 method:

```c
time_t now;
char strftime_buf[64];
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
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.

A function to use inside the lwIP SNTP library depends on a sync mode for system time. Use the function `sntp_set_sync_mode()` to set 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()`.

The lwIP SNTP library has API functions for setting a callback function for a certain event. You might need the following functions:

- `sntp_set_time_sync_notification_cb()` - use it for setting a callback function that will notify of the time synchronization process
- `sntp_get_sync_status()` and `sntp_set_sync_status()` - use it to get/set time synchronization status

To start synchronization via SNTP, just call the following three functions:

```c
sntp_setoperatingmode(SNTP_OPMODE_POLL);
sntp_setservername(0, "pool.ntp.org");
sntp_init();
```
An application with this initialization code will periodically synchronize the time. The time synchronization period is determined by `CONFIG_LWIP_SNTP_UPDATE_DELAY` (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 `protocols/sntp` directory.

### Timezones

To set local timezone, use the following POSIX functions:

1. Call `setenv()` to set the `TZ` environment variable to the correct value depending 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 time zone.

Once these steps are completed, call the standard C library function `localtime()`, and it will return correct local time taking into account the time zone offset and daylight saving time.

### 64-bit `time_t`

ESP-IDF uses 32-bit `time_t` type by default. To address Y2K38 issue, you may need to use 64-bit `time_t` type when building the application.

Currently this requires building the cross-compiler toolchain from scratch. See the instructions for building the toolchain in `Standard Toolchain Setup for Linux and macOS`. To enable 64-bit `time_t` support in the toolchain, you need to remove the `--enable-newlib-long-time_t` option from the `crosstool-NG/samples/xtensa-esp32-elf/crosstool.config` file before building the toolchain.

If you need to make the program compatible with both 32-bit and 64-bit `time_t`, you may use the following methods:

- In C or C++ source files, `__USE_LONG_TIME_T` preprocessor macro will be defined if 32-bit `time_t` is used. You need to include `<sys/types.h>` to make this macro available.
- In CMake files, `TIME_T_SIZE` IDF build property will be set to the size of `time_t`, in bytes. You may call `idf_build_get_property(var TIME_T_SIZE)` to get the value of this property into a CMake variable `var`. See `build system API reference` for more information about `idf_build_get_property`.

Note that the size of `time_t` type also affects the sizes of other types, for example `struct timeval`, `struct stat`, `struct utimbuf`.

### 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 synchronization.

**Parameters**

- `tv`: Time received from SNTP server.
void **nntp_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.

void **nntp_get_sync_mode**(void)

Get set sync mode.

**Return** SNTP_SYNC_MODE_IMMED: Update time immediately. SNTP_SYNC_MODE_SMOOTH: Smooth time updating.

**nntp_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.

**Return** SNTP_SYNC_STATUS_RESET: Reset status. SNTP_SYNC_STATUS_COMPLETED: Time is synchronized. SNTP_SYNC_STATUS_IN_PROGRESS: Smooth time sync in progress.

void **nntp_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 **nntp_set_time_sync_notification_cb**(sntp_sync_time_cb_t callback)

Set a callback function for time synchronization notification.

**Parameters**

- **callback**: a callback function

void **nntp_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, otherwise 15 seconds will be set.

uint32_t **nntp_get_sync_interval**(void)

Get the sync interval of SNTP operation.

**Return** the sync interval

**sntp_restart**(void)

Restart SNTP.

**Return** True - Restart False - SNTP was not initialized yet

**Type Definitions**

typedef void (*sntp_sync_time_cb_t)(struct timeval *tv)

SNTP callback function for notifying about time sync event.

**Parameters**

- **tv**: Time received from SNTP server.
## Enumerations

### enum sntp_sync_mode_t

SNTP time update mode.

**Values:**

- **SNTP_SYNC_MODE_IMMED**: Update system time immediately when receiving a response from the SNTP server.
- **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.

### enum sntp_sync_status_t

SNTP sync status.

**Values:**

- **SNTP_SYNC_STATUS_RESET**
- **SNTP_SYNC_STATUS_COMPLETED**
- **SNTP_SYNC_STATUS_IN_PROGRESS**

### 2.7.27 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

### Functions

#### int esp_rom_printf (const char *fmt, ...)

Print formatted string to console device.

**Note** float and long long data are not supported!

**Return** int: Total number of characters written on success; A negative number on failure.

**Parameters**

- *fmt*: Format string
- *...*: Additional arguments, depending on the format string

#### 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_putc (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 esp_rom_install_uart_printf (void)

Install UART1 as the default console channel, equivalent to esp_rom_install_channel_putc(1, esp_rom_uart_putchar)

#### soc_reset_reason_t esp_rom_get_reset_reason (int cpu_no)

Get reset reason of CPU.
Return  Reset reason code (see in soc/reset_reasons.h)

Parameters
• cpu_no: CPU number

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:
1. Route peripheral interrupt source to CPU. e.g. esp_rom_route_intr_matrix(0, ETS_WIFI_MAC_INTR_SOURCE, ETS_WMAC_INUM)
2. Set interrupt handler for CPU
3. Enable CPU interrupt
4. 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

uint32_t esp_rom_get_cpu_ticks_per_us (void)

Get the real CPU ticks per us.

Return  CPU ticks per us

Code examples for this API section are provided in the system directory of ESP-IDF examples.

2.8 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 build system guide.
• 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 ESP-IDF interface.

ESP-IDF consists of components written specifically for ESP-IDF as well as third-party libraries. In some cases, an ESP-IDF-specific wrapper is added to the third-party library, providing an interface that is either simpler or better integrated with the rest of ESP-IDF facilities. In other cases, the original API of the third-party library is presented to the application developers.

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

2.8.1 Error handling

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

2.8.2 Configuration structures

Important: Correct initialization of configuration structures is an important part in making the application compatible with future versions of ESP-IDF.
Most initialization or configuration functions in ESP-IDF take as an argument a pointer to a configuration structure. 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);
```

Initialization 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 */
};
```

C++ language doesn’t support the designated initializers syntax until C++20, however GCC compiler partially supports it as an extension. When using ESP-IDF APIs in C++ code, you may consider using 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. 
   Any field can still be modified: */
config.server_port = 8081;
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.

### 2.8.3 Private APIs

Certain header files in ESP-IDF contain APIs intended to be used only in ESP-IDF source code, and not 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.
2.8.4 Components in example projects

ESP-IDF examples contain a variety of projects demonstrating 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. Take time to read the code and understand if it applicable to your use case.

2.8.5 API Stability

ESP-IDF uses Semantic Versioning as explained in the [versions page](#). 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 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 in 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 renaming mechanism 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 issue reports about any unintended breaking changes that don’t fall into the categories below.

- [Private APIs](#).
- [Components in example projects](#).
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• Features clearly marked as “beta”, “preview”, or “experimental”.
• Changes made to mitigate security issues or to replace insecure default behaviors with a secure ones.
• Features which 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 which depend on non-functional chip hardware features.
• Unexpected or undefined behavior (for example, due to missing validation of argument ranges) that is not documented explicitly may be fixed/changed.
• Location of Kconfig options in menuconfig.
• Location and names of example projects.

2.9 Project Configuration

2.9.1 Introduction

ESP-IDF uses kconfiglib which is a Python-based extension to the Kconfig system which provides a compile-time project configuration mechanism. Kconfig is based around options of several types: integer, string, boolean. Kconfig files specify dependencies between options, default values of the options, the way the options are grouped together, etc.

For the complete list of available features please see Kconfig and kconfiglib extensions.

2.9.2 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 inside sdkconfig file in the project root directory. Based on sdkconfig, application build targets will generate sdkconfig.h file in the build directory, and will make sdkconfig options available to the project build system and source files.

2.9.3 Using sdkconfig.defaults

In some cases, such as when sdkconfig file is under revision control, the fact that sdkconfig file gets changed by the build system may be inconvenient. The build system offers a way to avoid this, in the form of sdkconfig.defaults file. This file is never touched by the build system, and can be created manually or automatically. It can contain all the options which matter for 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 configurations. Otherwise, the file can be generated automatically by running the idf.py savedefconfig command.

Once sdkconfig.defaults is created, sdkconfig can be deleted and added to the ignore list of the revision control system (e.g. .gitignore file for git). Project build targets will automatically create sdkconfig file, populated with the settings from sdkconfig.defaults file, and the rest of the settings will be set to their default values. Note that the build process will not override settings that are already in sdkconfig by ones from sdkconfig.defaults. For more information, see Custom sdkconfig defaults.

2.9.4 Kconfig Formatting Rules

The following attributes of Kconfig files are standardized:

• Within any menu, option names should have a consistent prefix. The prefix length is currently set to at least 3 characters.
• The indentation style is 4 characters created by spaces. All sub-items belonging to a parent item are indented by one level deeper. For example, menu is indented by 0 characters, the config inside of the menu by 4 characters, the help of the config by 8 characters and the text of the help by 12 characters.
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- No trailing spaces are allowed at the end of the lines.
- The maximum length of options is set to 40 characters.
- The maximum length of lines is set to 120 characters.

Format checker

tools/check_kconfigs.py is provided for checking the Kconfig formatting 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 recommendations how to fix issues (if there are any). Please note that the checker cannot correct all rules and the responsibility of the developer is to check and make final corrections in order to pass the tests. For example, indentations will be corrected if there isn’t some misleading previous formatting but it cannot come up with a common prefix for options inside a menu.

### 2.9.5 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. confgen.py is used by the tool chain to pre-process sdkconfig files before anything else, for example menuconfig, would read them. As the consequence, the settings for old options will be kept and not ignored.
2. confgen.py 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. confgen.py post-processes sdkconfig files and generates all build outputs (sdkconfig.h, sdkconfig.cmake, auto.conf) by adding a list of compatibility statements, i.e. value of the old option is set the value of the new option (after modification). This is done in order to not break customer codes where old option might still be used.
4. Deprecated options and their replacements are automatically generated by confgen.py.

### 2.9.6 Configuration Options Reference

Subsequent sections contain the list of available ESP-IDF options, automatically generated from Kconfig files. Note that depending on the options selected, some options listed here may not be visible by default in the interface of menuconfig.

By convention, all option names are upper case 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 sdkconfig and sdkconfig.h files will have CONFIG_ENABLE_FOO defined. In this reference, option names are also prefixed with CONFIG_, same as in the source code.

**Build type**

Contains:

- `CONFIG_APP_BUILD_TYPE`
- `CONFIG_APP_REPRODUCIBLE_BUILD`

**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. Note that since IROM and DRAM
sizes are very limited, it is not possible to build any complex application this way. However for kinds of
testing and debugging, this option may provide faster iterations, since the application does not need to
be written into flash. Note that at the moment, 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
```

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/

Recommended sdkconfig defaults for building loadable ELF files is as follows. CONFIG_APP_BUILD_TYPE_ELF_RAM is required, other options help reduce application memory footprint.

```
CONFIG_APP_BUILD_TYPE_ELF_RAM=y
CONFIG_VFS_SUPPORT_TERMIOS=y
CONFIG_NEWLIB_NANO_FORMAT=y
CONFIG_ESP_SYSTEM_PANIC_PRINT_HALT=y
CONFIG_ESP_DEBUG_STUBS_ENABLE=y
CONFIG_ESP_ERR_TO_NAME_LOOKUP=y
```

Available options:

- Default (binary application + 2nd stage bootloader) (APP_BUILD_TYPE_APP_2NDBOOT)
- ELF file, loadable into RAM (EXPERIMENTAL) (APP_BUILD_TYPE_ELF_RAM)

**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)

**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*

Project version

**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.
Chapter 2. API Reference

Range:
- from 8 to 64

Default value:
- 16

Bootloader config

Contains:
- CONFIG_BOOTLOADER_LOG_LEVEL
- CONFIG_BOOTLOADER_COMPILER_OPTIMIZATION
- CONFIG_BOOTLOADER_APP.Rollback_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_SKIP_VALIDATE_ON_POWER_ON
- CONFIG_BOOTLOADER_SKIP_VALIDATE_IN_DEEP_SLEEP
- CONFIG_BOOTLOADER_WDT_ENABLE
- CONFIG_BOOTLOADER_VDDSDIO_BOOST

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) (BOOTLOADER_COMPILER_OPTIMIZATION_SIZE)
- Debug (-Og) (BOOTLOADER_COMPILER_OPTIMIZATION_DEBUG)
- Optimize for performance (-O2) (BOOTLOADER_COMPILER_OPTIMIZATION_PERF)
- Debug without optimization (-O0) (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 (BOOTLOADER_LOG_LEVEL_NONE)
- Error (BOOTLOADER_LOG_LEVEL_ERROR)
- Warning (BOOTLOADER_LOG_LEVEL_WARN)
- Info (BOOTLOADER_LOG_LEVEL_INFO)
- Debug (BOOTLOADER_LOG_LEVEL_DEBUG)
- Verbose (BOOTLOADER_LOG_LEVEL_VERBOSE)
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 (BOOTLOADER_VDDSDIO_BOOST_1_8V)
  - 1.9V (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.

*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 (BOOTLOADER_FACTORY_RESET_PIN_LOW)
  - Reset on GPIO high (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_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_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 ESP32_RTC_CLK_SRC (INTERNAL_RC or EXTERNAL_CRYSTAL).

**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 dis-
abling 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_OOTA_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`

**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 16 if `CONFIG_BOOTLOADER_APP_ANTI_ROLLBACK`

Default value:

• 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.

**Range:**
- from 0 to 0x10 if CONFIG_BOOTLOADER_CUSTOM_RESERVE_RTC

**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_FLASH_CHECK_ENC_EN_IN_APP
- CONFIG_SECURE_BOOT_ENABLE_AGGRESSIVE_KEY_REVOKE
- CONFIG_SECURE_FLASH_ENC_ENABLED
- CONFIG_SECURE_BOOT
- Potentially insecure options
- CONFIG_SECURE_SIGNED_APPS_NO_SECURE_BOOT
- CONFIG_SECURE_BOOT_VERIFICATION_KEY
- 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*


*Available options:*
- ECDSA (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 (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.

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*

Available options:

- **Enable Secure Boot version 1 (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 (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_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. Secure Boot V2: This RSA public key is compiled into the signature block at the end of the bootloader/app.

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

**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) 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 (256-bit key) (SECURE_FLASH_ENCRYPTION_AES128)
- AES-256 (512-bit key) (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.

Refer to the Flash Encryption section of the ESP-IDF Programmer’s Guide for details.

**Available options:**
- Development (NOT SECURE) (SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT)
- Release (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_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_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 || 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 espfuse.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 ensure 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

CONFIG_SECURE_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 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 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 SECURE_FLASH_ENCRYPTION_MODE_DEVELOPMENT

**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)) (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)) (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 simple flash read, write and erase operations, plus a command to return a summary of currently enabled security features.
  
  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)) (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 production use cases.

**Boot ROM Behavior**

Contains:

- `CONFIG_BOOT_ROM_LOG_SCHEME`

**CONFIG_BOOT_ROM_LOG_SCHEME**

Permanently change Boot ROM output

*Found in: Boot ROM Behavior*

Controls the Boot ROM log behavior. The rom log behavior can only be changed for once, specific eFuse bit(s) will be burned at app boot stage.

**Available options:**

- Always Log (BOOT_ROM_LOG_ALWAYS_ON)
  Always print ROM logs, this is the default behavior.
- Permanently disable logging (BOOT_ROM_LOG_ALWAYS_OFF)
  Don’t print ROM logs.
- Log on GPIO High (BOOT_ROM_LOG_ON_GPIO_HIGH)
  Print ROM logs when GPIO level is high during start up. The GPIO number is chip dependent, e.g. on ESP32-S2, the control GPIO is GPIO46.
- Log on GPIO Low (BOOT_ROM_LOG_ON_GPIO_LOW)
  Print ROM logs when GPIO level is low during start up. The GPIO number is chip dependent, e.g. on ESP32-S2, the control GPIO is GPIO46.

**Serial flasher config**

Contains:

- `CONFIG_ESPTOOLPY_AFTER`
- `CONFIG_ESPTOOLPY_BEFORE`
- `CONFIG_ESPTOOLPY_FLASHSIZE_DETECT`
- `CONFIG_ESPTOOLPY_NO_STUB`
- `CONFIG_ESPTOOLPY_OCT_FLASH`
- `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)

**CONFIG_ESPTOOLPY_OCT_FLASH**

Enable Octal Flash

*Found in: Serial flasher config*

Default value:
• No (disabled)

**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 (ESPTOOLPY_FLASHMODE_QIO)
• QOUT (ESPTOOLPY_FLASHMODE_QOUT)
• DIO (ESPTOOLPY_FLASHMODE_DIO)
• DOUT (ESPTOOLPY_FLASHMODE_DOUT)
• OPI (ESPTOOLPY_FLASHMODE_OPI)

**CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE**

Flash Sampling Mode

*Found in: Serial flasher config*

**Available options:**
• STR Mode (ESPTOOLPY_FLASH_SAMPLE_MODE_STR)
• DTR Mode (ESPTOOLPY_FLASH_SAMPLE_MODE_DTR)

**CONFIG_ESPTOOLPY_FLASHFREQ**

Flash SPI speed

*Found in: Serial flasher config*

The SPI flash frequency to be used.

**Available options:**
• 120 MHz (ESPTOOLPY_FLASHFREQ_120M)
• 80 MHz (ESPTOOLPY_FLASHFREQ_80M)
• 40 MHz (ESPTOOLPY_FLASHFREQ_40M)
• 26 MHz (ESPTOOLPY_FLASHFREQ_26M)
• 20 MHz (ESPTOOLPY_FLASHFREQ_20M)

**CONFIG_ESPTOOLPY_FLASHSIZE**

Flash size

*Found in: Serial flasher config*

SPI flash size, in megabytes

**Available options:**
• 1 MB (ESPTOOLPY_FLASHSIZE_1MB)
• 2 MB (ESPTOOLPY_FLASHSIZE_2MB)
• 4 MB (ESPTOOLPY_FLASHSIZE_4MB)
Chapter 2. API Reference

- 8 MB (ESPTOOLPY_FLASHSIZE_8MB)
- 16 MB (ESPTOOLPY_FLASHSIZE_16MB)
- 32 MB (ESPTOOLPY_FLASHSIZE_32MB)
- 64 MB (ESPTOOLPY_FLASHSIZE_64MB)
- 128 MB (ESPTOOLPY_FLASHSIZE_128MB)

**CONFIG_ESPTOOLPY_FLASHSIZE_DETECT**

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.

**Default value:**
- Yes (enabled)

**CONFIG_ESPTOOLPY BEFORE**

Before flashing

*Found in: Serial flasher config*

Configure whether esptool.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 (ESPTOOLPY BEFORE RESET)
- No reset (ESPTOOLPY BEFORE NORESET)

**CONFIG_ESPTOOLPY AFTER**

After flashing

*Found in: Serial flasher config*

Configure whether esptool.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 (ESPTOOLPY AFTER RESET)
- Stay in bootloader (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 (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 (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 (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 (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 (PARTITION_TABLE SINGLE_APP_ENCRYPTED_NVSI)
  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_nvsi.csv

- Single factory app (large), no OTA, encrypted NVS (PARTITION_TABLE SINGLE_APP_LARGE_ENC_NVSI)
  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_nvsi.csv

- Factory app, two OTA definitions, encrypted NVS (PARTITION_TABLE TWO OTA ENCRYPTED_NVSI)
  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_nvsi.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 ESP32_COMPATIBLE_PRE_V3_1_BOOTLOADERS

**Compiler options**

Contains:

- `CONFIG_COMPILER_OPTIMIZATION_ASSERTION_LEVEL`
- `CONFIG_COMPILER_OPTIMIZATION_CHECKS_SILENT`
- `CONFIG_COMPILER_DISABLE_GCC8_WARNINGS`
- `CONFIG_COMPILER_DUMPRTL_FILES`
- `CONFIG_COMPILER_WARN_WRITE_STRINGS`
- `CONFIG_COMPILER_CXX_EXCEPTIONS`
- `CONFIG_COMPILER_CXX_RTTI`
- `CONFIG_COMPILER_OPTIMIZATION`
- `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 BOOTLOADER_COMPILER_OPTIMIZATION setting.

Available options:
• Debug (-Og) (COMPILER_OPTIMIZATION_DEFAULT)
• Optimize for size (-Os) (COMPILER_OPTIMIZATION_SIZE)
• Optimize for performance (-O2) (COMPILER_OPTIMIZATION_PERF)
• Debug without optimization (-O0) (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 (COMPILER_OPTIMIZATION_ASSERTIONS_ENABLE)
  Enable assertions. Assertion content and line number will be printed on failure.
• Silent (saves code size) (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) (COMPILER_OPTIMIZATION_ASSERTIONS_DISABLE)
  If assertions are disabled, -DNDEBUG is added to CPPFLAGS.

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_EXIT_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 -f-file-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 (COMPILER_STACK_CHECK_MODE_NONE)
• Normal (COMPILER_STACK_CHECK_MODE_NORM)
• Strong (COMPILER_STACK_CHECK_MODE_STRONG)
• Overall (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_GCC8_WARNINGS

Disable new warnings introduced in GCC 6 - 8

Found in: Compiler options

Enable this option if using GCC 6 or newer, and wanting to disable warnings which don’t appear with GCC 5.

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-Calibration
• Application Level Tracing
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• Bluetooth
• CoAP Configuration
• 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 System Settings
• ESP-ASIO
• ESP-MQTT Configurations
• ESP-TLS
• ESP32S3-Specific
• 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
• IPC (Inter-Processor Call)
• LCD and Touch Panel
• Log output
• LWIP
• mbedTLS
• mDNS
• Modbus configuration
• Newlib
• NVS
• OpenSSL
• OpenThread
• PHY
• Power Management
• PThreads
• SPI Flash driver
• SPIFFS Configuration
• Supplicant
• TCP Transport
• TinyUSB Stack
• Ultra Low Power (ULP) Co-processor
• Unity unit testing library
• USB-OTG
• Virtual file system
• Wear Levelling
• Wi-Fi
• Wi-Fi Provisioning Manager

Application Level Tracing  Contains:

• CONFIG_APPTRACE_DESTINATION
• FreeRTOS SystemView Tracing
• CONFIG_APPTRACE_GCOV_ENABLE
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- `CONFIG_APPTRACE_BUF_SIZE`
- `CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX`
- `CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH`
- `CONFIG_APPTRACE_ONPANIC_HOST_FLUSH_TMO`

**CONFIG_APPTRACE_DESTINATION**

Data Destination

*Found in: Component config > Application Level Tracing*

Select destination for application trace: JTAG or none (to disable).

**Available options:**
- JTAG (APTRACE_DEST_JTAG)
- None (APTRACE_DEST_NONE)

**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 (scheduler, ISRs etc). If this parameter is 0 then events will be discarded when main HW buffer is full.

**FreeRTOS SystemView Tracing** Contains:

- `CONFIG_APPTRACE_SV_ENABLE`

**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_TS_SOURCE**

Timer to use as timestamp source

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

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) (APTRACE_SV_TS_SOURCE_CCOUNT)
- General Purpose Timer (Timer Group) (APTRACE_SV_TS_SOURCE_GPTIMER)
- esp_timer high resolution timer (APTRACE_SV_TS_SOURCE_ESP_TIMER)

**CONFIG_APPTRACE_SV_MAX_TASKS**

Maximum supported tasks

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

Enables “ISR Enter” event.

**CONFIG_APPTRACE_SV_EVT_ISR_EXIT_ENABLE**

ISR Exit Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

Enables “ISR to Scheduler” event.

CONFIG_APPTRACE_SV_EVT_TASK_START_EXEC_ENABLE

Task Start Execution Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

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 > CONFIG_APPTRACE_SV_ENABLE*

Enables “Task Create” event.

CONFIG_APPTRACE_SV_EVT_TASK_TERMINATE_ENABLE

Task Terminate Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

Enables “Task Terminate” event.
CONFIG_APPTRACE_SV_EVT_IDLE_ENABLE

System Idle Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

Enables “System Idle” event.

CONFIG_APPTRACE_SV_EVT_TIMER_ENTER_ENABLE

Timer Enter Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

Enables “Timer Enter” event.

CONFIG_APPTRACE_SV_EVT_TIMER_EXIT_ENABLE

Timer Exit Event

*Found in: Component config > Application Level Tracing > FreeRTOS SystemView Tracing > CONFIG_APPTRACE_SV_ENABLE*

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.

ESP-ASIO Contains:

- **CONFIG_ASIO_SSL_SUPPORT**

CONFIG_ASIO_SSL_SUPPORT

Enable SSL/TLS support of ASIO

*Found in: Component config > ESP-ASIO*

Enable support for basic SSL/TLS features, available for mbedTLS/OpenSSL as well as wolfSSL TLS library.

**Default value:**

- No (disabled)

CONFIG_ASIO_SSL_LIBRARY_CHOICE

Choose SSL/TLS library for ESP-TLS (See help for more Info)

*Found in: Component config > ESP-ASIO > CONFIG_ASIO_SSL_SUPPORT*

The ASIO support multiple backend TLS libraries. Currently the mbedTLS with a thin ESP-OpenSSL port layer (default choice) 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:**

- esp-openssl (ASIO_USE_ESP_OPENSSL)
• wolfSSL (License info in wolfSSL directory README) (ASIO_USE_ESP_WOLFSSL)

**CONFIG_ASIO_SSL_BIO_SIZE**

Size of BIO object

*Found in: Component config > ESP-ASIO > CONFIG_ASIO_SSL_SUPPORT*

Size in bytes of SSL-BIO implementation. Reducing the BIO size saves more RAM, but may slow down input output operations due to fragmentation.

**Default value:**

• 1024 if CONFIG_ASIO_SSL_SUPPORT

**Bluetooth** Contains:

• Bluedroid Options
• CONFIG_BT_ENABLED
• NimBLE Options

**CONFIG_BT_ENABLED**

Bluetooth

*Found in: Component config > Bluetooth*

Select this option to enable Bluetooth and show the submenu with Bluetooth configuration choices.

**Bluetooth controller** Contains:

• CONFIG_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP
• CONFIG_BT_CTRL_BLE_ADFT_TX_POWER_LEVEL
• CONFIG_BT_CTRL_BLE_MAX_ACT
• CONFIG_BT_CTRL_BLE_SCAN_DUPL
• CONFIG_BT_CTRL_BLE_STATIC_ACL_TX_BUF_NB
• CONFIG_BT_CTRL_HW_CCA_VAL
• CONFIG_BT_CTRL_COEX_PHY_CODED_TX_RX_TLIM
• CONFIG_BT_CTRL_CE_LENGTH_TYPE
• CONFIG_BT_CTRL_RX_ANTENNA_INDEX
• CONFIG_BT_CTRL_TX_ANTENNA_INDEX
• CONFIG_BT_CTRL_AGRC_RECT вместоRECT
• CONFIG_BT_CTRL_HCI_MODE_CHOICE
• CONFIG_BT_CTRL_HW_CCA
• MODEM SLEEP Options
• CONFIG_BT_CTRL_PINNED_TO_CORE_CHOICE
• CONFIG_BT_CTRL_ADV_DUP_FILT_MAX

**CONFIG_BT_CTRL_BLE_MAX_ACT**

BLE Max Instances

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

BLE maximum instances of bluetooth controller.

**Range:**

• from 1 to 10 if CONFIG_BT_ENABLED

**Default value:**

• 10 if CONFIG_BT_ENABLED
**CONFIG_BT_CTRL_BLE_STATIC_ACL_TX_BUF_NB**

BLE static ACL TX buffer numbers

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

BLE ACL buffer have two methods to be allocated. One is persistent allocating (allocate when controller initialise, never free until controller de-initialise) another is dynamically allocating (allocate before TX and free after TX).

**Range:**
- from 0 to 12 if `CONFIG_BT_ENABLED`

**Default value:**
- 0 if `CONFIG_BT_ENABLED`

**CONFIG_BT_CTRL_PINNED_TO_CORE_CHOICE**

The cpu core which bluetooth controller run

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

Specify the cpu core to run bluetooth controller. Can not specify no-affinity.

**Available options:**
- Core 0 (PRO CPU) (BT_CTRL_PINNED_TO_CORE_0)
- Core 1 (APP CPU) (BT_CTRL_PINNED_TO_CORE_1)

**CONFIG_BT_CTRL_HCI_MODE_CHOICE**

HCI mode

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

Specify HCI mode as VHCI or UART(H4)

**Available options:**
- VHCI (BT_CTRL_HCI_MODE_VHCI)
  - Normal option. Mostly, choose this VHCI when bluetooth host run on ESP32S3, too.
- UART(H4) (BT_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.

**CONFIG_BT_CTRL_ADV_DUP_FILT_MAX**

The maximum number of 5.0 extend duplicate scan filter

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

The maximum number of suplicate scan filter

**Range:**
- from 1 to 500 if `CONFIG_BT_ENABLED`

**Default value:**
- 30 if `CONFIG_BT_ENABLED`

**CONFIG_BT_CTRL_HW_CCA**

HW CCA check enable

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

It enables HW CCA feature in controller

**Default value:**
- No (disabled) if `CONFIG_BT_ENABLED`
CONFIG_BT_CTRL_HW_CCA_VAL

CCA threshold value

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

It is the threshold value of HW CCA, if the value is 30, it means CCA threshold is -30 dBm.

**Range:**
- from 20 to 60 if `CONFIG_BT_ENABLED`

**Default value:**
- 20 if `CONFIG_BT_ENABLED`

CONFIG_BT_CTRL_CE_LENGTH_TYPE

Connection event length determination method

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

Specify connection event length determination

**Available options:**
- ORIGINAL (BT_CTRL_CE_LENGTH_TYPE_ORIG)
- Use CE parameter for HCI command (BT_CTRL_CE_LENGTH_TYPE_CE)
- Use Espressif self-defined method (BT_CTRL_CE_LENGTH_TYPE_SD)

CONFIG_BT_CTRL_TX_ANTENNA_INDEX

default Tx antenna used

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

Specify default Tx antenna used for bluetooth

**Available options:**
- Antenna 0 (BT_CTRL_TX_ANTENNA_INDEX_0)
- Antenna 1 (BT_CTRL_TX_ANTENNA_INDEX_1)

CONFIG_BT_CTRL_RX_ANTENNA_INDEX

default Rx antenna used

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

Specify default Rx antenna used for bluetooth

**Available options:**
- Antenna 0 (BT_CTRL_RX_ANTENNA_INDEX_0)
- Antenna 1 (BT_CTRL_RX_ANTENNA_INDEX_1)

CONFIG_BT_CTRL_DFT_TX_POWER_LEVEL

BLE default Tx power level

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

Specify default Tx power level

**Available options:**
- -27dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N27)
- -24dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N24)
- -21dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N21)
- -18dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N18)
- -15dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N15)
- -12dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N12)
Chapter 2. API Reference

-9dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N9)
-6dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N6)
-3dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N3)
0dBm (BT_CTRL_DFT_TX_POWER_LEVEL_N0)
+3dBm (BT_CTRL_DFT_TX_POWER_LEVEL_P3)
+6dBm (BT_CTRL_DFT_TX_POWER_LEVEL_P6)
+9dBm (BT_CTRL_DFT_TX_POWER_LEVEL_P9)
+12dBm (BT_CTRL_DFT_TX_POWER_LEVEL_P12)
+15dBm (BT_CTRL_DFT_TX_POWER_LEVEL_P15)
+18dBm (BT_CTRL_DFT_TX_POWER_LEVEL_P18)

CONFIG_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP

BLE adv report flow control supported

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

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_BT_ENABLED

CONFIG_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_NUM

BLE adv report flow control number

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP

The number of unprocessed advertising report that bluetooth host can save. If you set BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_NUM to a small value, this may cause adv packets lost. If you set BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_NUM to a large value, bluetooth host 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 BT_CTRL_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_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED

Default value:
- 100 if CONFIG_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED

CONFIG_BT_CTRL_BLE_ADV_REPORT_DISCARD_THRESHOLD

BLE adv lost event threshold value

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BT_CTRL_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 BT_CTRL_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_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP && CONFIG_BT_ENABLED

Default value:
• 20 if \( \text{CONFIG_BT_CTRL_BLE_ADV_REPORT_FLOW_CTRL_SUPP} \) && \( \text{CONFIG_BT_ENABLED} \)

**CONFIG_BT_CTRL_BLE_SCAN_DUPL**

BLE Scan Duplicate Options

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller*

This select enables parameters setting of BLE scan duplicate.

**Default value:**
- Yes (enabled) if \( \text{CONFIG_BT_ENABLED} \)

**CONFIG_BT_CTRL_SCAN_DUPL_TYPE**

Scan Duplicate Type

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BT_CTRL_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 (BT_CTRL_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 (BT_CTRL_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 (BT_CTRL_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_BT_CTRL_SCAN_DUPL_CACHE_SIZE**

Maximum number of devices in scan duplicate filter

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BT_CTRL_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 \( \text{CONFIG_BT_CTRL_BLE_SCAN_DUPL} \) && \( \text{CONFIG_BT_ENABLED} \)

**Default value:**
- 100 if \( \text{CONFIG_BT_CTRL_BLE_SCAN_DUPL} \) && \( \text{CONFIG_BT_ENABLED} \)

**CONFIG_BT_CTRL_BLE_MESH_SCAN_DUPL_EN**

Special duplicate scan mechanism for BLE Mesh scan

*Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BT_CTRL_BLE_SCAN_DUPL*

This enables the BLE scan duplicate for special BLE Mesh scan.
Default value:
- No (disabled) if `CONFIG_BT_CTRL_BLE_SCAN_DUPL` && `CONFIG_BT_ENABLED`

**CONFIG_BT_CTRL_MESH_DUPL_SCAN_CACHE_SIZE**

Maximum number of Mesh adv packets in scan duplicate filter

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > `CONFIG_BT_CTRL_BLE_SCAN_DUPL` > `CONFIG_BT_CTRL_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_BT_CTRL_BLE_MESH_SCAN_DUPL_EN` && `CONFIG_BT_ENABLED`

**Default value:**
- 100 if `CONFIG_BT_CTRL_BLE_MESH_SCAN_DUPL_EN` && `CONFIG_BT_ENABLED`

**CONFIG_BT_CTRL_COEX_PHY_CODED_TX_RX_TLIM**

Coexistence: limit on MAX Tx/Rx time for coded-PHY connection

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller

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 (BT_CTRL_COEX_PHY_CODED_TX_RX_TLIM_EN)
  Always enable the limitation on max tx/rx time for Coded-PHY connection
- Force Disable (BT_CTRL_COEX_PHY_CODED_TX_RX_TLIM_DIS)
  Disable the limitation on max tx/rx time for Coded-PHY connection

**MODEM SLEEP Options**

Contains:
- `CONFIG_BT_CTRL_MODEM_SLEEP`

**CONFIG_BT_CTRL_MODEM_SLEEP**

Bluetooth modem sleep

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > MODEM SLEEP Options

Enable/disable bluetooth controller low power mode. Modem sleep is not supported to be used with UART HCI.

**Default value:**
- No (disabled) if BT_CTRL_HCI_MODE_UART_H4 && `CONFIG_BT_ENABLED`

**CONFIG_BT_CTRL_MODEM_SLEEP_MODE_1**

Bluetooth Modem sleep Mode 1

*Found in:* Component config > Bluetooth > `CONFIG_BT_ENABLED` > Bluetooth controller > MODEM SLEEP Options > `CONFIG_BT_CTRL_MODEM_SLEEP`

Mode 1 is the currently supported sleep mode. In this mode, bluetooth controller sleeps between and BLE events. A low power clock is used to maintain bluetooth reference clock.

**Default value:**
- Yes (enabled) if `CONFIG_BT_CTRL_MODEM_SLEEP` && `CONFIG_BT_ENABLED`
CONFIG_BT_CTRL_LOWPOWER_CLOCK

Bluetooth low power clock

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > MODEM SLEEP Options > CONFIG_BT_CTRL_MODEM_SLEEP > CONFIG_BT_CTRL_MODEM_SLEEP_MODE_1

Select the low power clock source for bluetooth controller

Available options:
  • Main crystal (BT_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 relatively better performance than other bluetooth low power clock sources.
  • External 32kHz crystal (BT_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.
  • Internal 150kHz RC oscillator (BT_CTRL_LPCLK_SEL_RTC_SLOW)
    Internal 150kHz RC oscillator. The accuracy of this clock is a lot larger than 500ppm which is required in Bluetooth communication, so don’t select this option in scenarios such as BLE connection state.

CONFIG_BT_CTRL_AGCRECORRECT_EN

Enable HW AGC recorrect

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller

Enable uncoded phy AGC recorrect

Default value:
  • No (disabled) if CONFIG_BT_ENABLED

CONFIG_BT_CTRL_CODED_AGCRECORRECT_EN

Enable coded phy AGC recorrect

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED > Bluetooth controller > CONFIG_BT_CTRL_AGCRECORRECT_EN

Enable coded phy AGC recorrect

Default value:
  • No (disabled) if CONFIG_BT_CTRL_AGCRECORRECT_EN & & CONFIG_BT_ENABLED

CONFIG_BT_HOST

Bluetooth Host

Found in: Component config > Bluetooth > CONFIG_BT_ENABLED

This helps to choose Bluetooth host stack

Available options:
  • Bluedroid - Dual-mode (BT_BLUEDROID_ENABLED)
    This option is recommended for classic Bluetooth or for dual-mode usecases
  • NimBLE - BLE only (BT_NIMBLE_ENABLED)
    This option is recommended for BLE only usecases to save on memory
• Controller Only (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).

**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_BLE_ENABLED`
- `BT DEBUG LOG LEVEL`
- `CONFIG_BT_ACL_CONNECTIONS`
- `CONFIG_BT_ALLOCATION_FROM_SPIRAM_FIRST`
- `CONFIG_BT_STACK_NO_LOG`
- `CONFIG_BT_BLE_42_FEATURES_SUPPORTED`
- `CONFIG_BT_BLE_50_FEATURES_SUPPORTED`
- `CONFIG_BT_MULTI_CONNECTION_ENABLE`
- `CONFIG_BT_MAX_DEVICE_NAME_LEN`
- `CONFIG_BT_BLE_ACT_SCAN_REP_ADV_SCAN`
- `CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE`
- `CONFIG_BT_BLE_ESTAB_LINK_CONN_TOUT`
- `CONFIG_BT_BLE_RPA_SUPPORTED`
- `CONFIG_BT_BLE_DYNAMIC_ENV_MEMORY`

**CONFIG_BT_BTU_TASK_STACK_SIZE**

Bluetooth event (callback to application) task stack size

*Found in: Component config > Bluetooth > Bluedroid Options*

This select btp task stack size

**Default value:**
- 3072 if `BT_BLUEDROID_ENABLED` && `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) (BT_BLUEDROID_PINNED_TO_CORE_0)
- Core 1 (APP CPU) (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 `BT_BLUEDROID_ENABLED` && `BT_BLUEDROID_ENABLED`
**CONFIG_BT_BLUEANDROID_MEM_DEBUG**

Bluedroid memory debug

*Found in: Component config > Bluetooth > Bluedroid Options*

Bluedroid memory debug

**Default value:**

- No (disabled) if BT_BLUEANDROID_ENABLED && BT_BLUEANDROID_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 BT_BLUEANDROID_ENABLED && BT_BLUEANDROID_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 && BT_BLUEANDROID_ENABLED

---

**CONFIG_BT_GATTS_PPPC_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 && BT_BLUEANDROID_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 && BT_BLUEANDROID_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` && `BT_BLUEDROID_ENABLED` && `BT_BLUEDROID_ENABLED`

**Default value:**
- 8 if `CONFIG_BT_GATTS_ENABLE` && `BT_BLUEDROID_ENABLED` && `BT_BLUEDROID_ENABLED`

CONFIG_BT_GATTSEND_SERVICE_CHANGE_MODE
GATT 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 (BT_GATTSEND_SERVICE_CHANGE_MANUAL)
  Manually send service change indication through API
  `esp_ble_gatts_send_service_change_indication()`
- GATTs automatically send service change indication (BT_GATTSEND_SERVICE_CHANGE_AUTO)
  Let Bluedroid handle the service change indication internally

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` && `BT_BLUEDROID_ENABLED`

CONFIG_BT_GATTC_CACHE_NVSS_FLASH
Save gattc cache data to nvs flash

*Found in: Component config > Bluetooth > Bluedroid Options > CONFIG_BT_BLE_ENABLED > CONFIG_BT_GATTC_ENABLE*

This select can save gattc cache data to nvs flash

**Default value:**
- No (disabled) if `CONFIG_BT_GATTC_ENABLE` && `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
**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` && `BT_BLUEDROID_ENABLED`

**CONFIG_BT_SMP_SLAVE_CON_PARAMS_UPD_ENABLE**

Slave enable connection parameters updateduring 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` && `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 `BT_BLUEDROID_ENABLED` && `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_BLUFI_TRACE_LEVEL`
- `CONFIG_BT_LOG_BNEP_TRACE_LEVEL`
- `CONFIG_BT_LOG_BTC_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 > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for HCI layer

**Available options:**
- NONE (BT_LOG_HCI_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_HCI_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_HCI_TRACE_LEVEL_WARNING)
- API (BT_LOG_HCI_TRACE_LEVEL_API)
- EVENT (BT_LOG_HCI_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_HCI_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_HCI_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_BTM_TRACE_LEVEL**

BTM layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for BTM layer

**Available options:**
- NONE (BT_LOG_BTM_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_BTM_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_BTM_TRACE_LEVEL_WARNING)
- API (BT_LOG_BTM_TRACE_LEVEL_API)
- EVENT (BT_LOG_BTM_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_BTM_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_BTM_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_L2CAP_TRACE_LEVEL**

L2CAP layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for L2CAP layer

**Available options:**
- NONE (BT_LOG_L2CAP_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_L2CAP_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_L2CAP_TRACE_LEVEL_WARNING)
- API (BT_LOG_L2CAP_TRACE_LEVEL_API)
- EVENT (BT_LOG_L2CAP_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_L2CAP_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_L2CAP_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_RFCOMM_TRACE_LEVEL**

RFCOMM layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for RFCOMM layer

**Available options:**
- NONE (BT_LOG_RFCOMM_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_RFCOMM_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_RFCOMM_TRACE_LEVEL_WARNING)
- API (BT_LOG_RFCOMM_TRACE_LEVEL_API)
Chapter 2. API Reference

- EVENT (BT_LOG_RFCOMM_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_RFCOMM_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_SDP_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_SDP_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_SDP_TRACE_LEVEL_WARNING)
- API (BT_LOG_SDP_TRACE_LEVEL_API)
- EVENT (BT_LOG_SDP_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_SDP_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_GAP_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_GAP_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_GAP_TRACE_LEVEL_WARNING)
- API (BT_LOG_GAP_TRACE_LEVEL_API)
- EVENT (BT_LOG_GAP_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_GAP_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_BNEP_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_BNEP_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_BNEP_TRACE_LEVEL_WARNING)
- API (BT_LOG_BNEP_TRACE_LEVEL_API)
- EVENT (BT_LOG_BNEP_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_BNEP_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_PAN_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_PAN_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_PAN_TRACE_LEVEL_WARNING)
- API (BT_LOG_PAN_TRACE_LEVEL_API)
- EVENT (BT_LOG_PAN_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_PAN_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_A2D_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_A2D_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_A2D_TRACE_LEVEL_WARNING)
- API (BT_LOG_A2D_TRACE_LEVEL_API)
- EVENT (BT_LOG_A2D_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_A2D_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_AVDT_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_AVDT_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_AVDT_TRACE_LEVEL_WARNING)
- API (BT_LOG_AVDT_TRACE_LEVEL_API)
- EVENT (BT_LOG_AVDT_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_AVDT_TRACE_LEVEL_DEBUG)
- VERBOSE (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:

- NONE (BT_LOG_AVCT_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_AVCT_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_AVCT_TRACE_LEVEL_WARNING)
- API (BT_LOG_AVCT_TRACE_LEVEL_API)
- EVENT (BT_LOG_AVCT_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_AVCT_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_AVCT_TRACE_LEVEL_VERBOSE)
**CONFIG_BT_LOG_AVRC_TRACE_LEVEL**

AVRC layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for AVRC layer

**Available options:**

- NONE (BT_LOG_AVRC_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_AVRC_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_AVRC_TRACE_LEVEL_WARNING)
- API (BT_LOG_AVRC_TRACE_LEVEL_API)
- EVENT (BT_LOG_AVRC_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_AVRC_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_AVRC_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_MCA_TRACE_LEVEL**

MCA layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for MCA layer

**Available options:**

- NONE (BT_LOG_MCA_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_MCA_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_MCA_TRACE_LEVEL_WARNING)
- API (BT_LOG_MCA_TRACE_LEVEL_API)
- EVENT (BT_LOG_MCA_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_MCA_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_MCA_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_HID_TRACE_LEVEL**

HID layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for HID layer

**Available options:**

- NONE (BT_LOG_HID_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_HID_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_HID_TRACE_LEVEL_WARNING)
- API (BT_LOG_HID_TRACE_LEVEL_API)
- EVENT (BT_LOG_HID_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_HID_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_HID_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_LOG_APPL_TRACE_LEVEL**

APPL layer

*Found in: Component config > Bluetooth > Bluez > Bluez Options > BT DEBUG LOG LEVEL*

Define BT trace level for APPL layer

**Available options:**

- NONE (BT_LOG_APPL_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_APPL_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_APPL_TRACE_LEVEL_WARNING)
- API (BT_LOG_APPL_TRACE_LEVEL_API)
• EVENT (BT_LOG_APPL_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_APPL_TRACE_LEVEL_DEBUG)
• VERBOSE (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 (BT_LOG_GATT_TRACE_LEVEL_NONE)
• ERROR (BT_LOG_GATT_TRACE_LEVEL_ERROR)
• WARNING (BT_LOG_GATT_TRACE_LEVEL_WARNING)
• API (BT_LOG_GATT_TRACE_LEVEL_API)
• EVENT (BT_LOG_GATT_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_GATT_TRACE_LEVEL_DEBUG)
• VERBOSE (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 (BT_LOG_SMP_TRACE_LEVEL_NONE)
• ERROR (BT_LOG_SMP_TRACE_LEVEL_ERROR)
• WARNING (BT_LOG_SMP_TRACE_LEVEL_WARNING)
• API (BT_LOG_SMP_TRACE_LEVEL_API)
• EVENT (BT_LOG_SMP_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_SMP_TRACE_LEVEL_DEBUG)
• VERBOSE (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 (BT_LOG_BTIF_TRACE_LEVEL_NONE)
• ERROR (BT_LOG_BTIF_TRACE_LEVEL_ERROR)
• WARNING (BT_LOG_BTIF_TRACE_LEVEL_WARNING)
• API (BT_LOG_BTIF_TRACE_LEVEL_API)
• EVENT (BT_LOG_BTIF_TRACE_LEVEL_EVENT)
• DEBUG (BT_LOG_BTIF_TRACE_LEVEL_DEBUG)
• VERbose (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 (BT_LOG_BTC_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_BTC_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_BTC_TRACE_LEVEL_WARNING)
- API (BT_LOG_BTC_TRACE_LEVEL_API)
- EVENT (BT_LOG_BTC_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_BTC_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_OSI_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_OSI_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_OSI_TRACE_LEVEL_WARNING)
- API (BT_LOG_OSI_TRACE_LEVEL_API)
- EVENT (BT_LOG_OSI_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_OSI_TRACE_LEVEL_DEBUG)
- VERBOSE (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 (BT_LOG_BLUFI_TRACE_LEVEL_NONE)
- ERROR (BT_LOG_BLUFI_TRACE_LEVEL_ERROR)
- WARNING (BT_LOG_BLUFI_TRACE_LEVEL_WARNING)
- API (BT_LOG_BLUFI_TRACE_LEVEL_API)
- EVENT (BT_LOG_BLUFI_TRACE_LEVEL_EVENT)
- DEBUG (BT_LOG_BLUFI_TRACE_LEVEL_DEBUG)
- VERBOSE (BT_LOG_BLUFI_TRACE_LEVEL_VERBOSE)

**CONFIG_BT_ACL_CONNECTIONS**

BT/BLE MAX ACL CONNECTIONS(1~7)

*Found in: Component config > Bluetooth > Bluedroid Options*

Maximum BT/BLE connection count

**Range:**

- from 1 to 7 if BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED

**Default value:**

- 4 if BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED

**CONFIG_BT_MULTI_CONNECTION_ENABLE**

Enable BLE multi-conections

*Found in: Component config > Bluetooth > Bluedroid Options*

Enable this option if there are multiple connections
**Default value:**
• Yes (enabled) if BT_BLUEDROID_ENABLED && 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 BT_BLUEDROID_ENABLED && 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:*
• No (disabled) if BT_BLUEDROID_ENABLED && 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 BT_BLUEDROID_ENABLED && 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 BT_BLUEDROID_ENABLED && (BTDM_CTRL_MODE_BTDM || BTDM_CTRL_MODE_BLE_ONLY) && 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 BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED
Default value:
  • 30 if BT_BLUEDROID_ENABLED && 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 BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED

**Default value:**
  • 32 if BT_BLUEDROID_ENABLED && 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 ESP32C3 and esp32s3, 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:**
  • Yes (enabled) if BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED

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 BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED

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 BT_BLUEDROID_ENABLED && BT_BLUEDROID_ENABLED
NimBLE Options  Contains:

- CONFIG_BT_NIMBLE_ACL_BUF_COUNT
- CONFIG_BT_NIMBLE_ACL_BUF_SIZE
- CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_NAME
- CONFIG_BT_NIMBLE_HS_STOP_TIMEOUT_MS
- CONFIG_BT_NIMBLE_ROLE_BROADCASTER
- CONFIG_BT_NIMBLE_ROLE_CENTRAL
- CONFIG_BT_NIMBLE_MESH
- CONFIG_BT_NIMBLE_ROLE_OBSERVER
- CONFIG_BT_NIMBLE_ROLE_PERIPHERAL
- CONFIG_BT_NIMBLE_BLUFI_ENABLE
- CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT
- CONFIG_BT_NIMBLE_USE_ESP_TIMER
- CONFIG_BT_NIMBLE_EXT_ADV
- CONFIG_BT_NIMBLE_DEBUG
- CONFIG_BT_NIMBLE_HOST_BASED_PRIVACY
- CONFIG_BT_NIMBLE_HS_FLOW_CTRL
- CONFIG_BT_NIMBLE_SVC_GAP_APPEARANCE
- CONFIG_BT_NIMBLE_HCI_EVT_BUF_SIZE
- CONFIG_BT_NIMBLE_HCI_EVT_HI_BUF_COUNT
- CONFIG_BT_NIMBLE_HCI_EVT_LO_BUF_COUNT
- CONFIG_BT_NIMBLE_GAP_DEVICE_NAME_MAX_LEN
- CONFIG_BT_NIMBLE_MAX_BONDS
- CONFIG_BT_NIMBLE_MAX_CCCDS
- CONFIG_BT_NIMBLE_MAX_CONNECTIONS
- CONFIG_BT_NIMBLE_L2CAP_COC_MAX_NUM
- CONFIG_BT_NIMBLE_MEM_ALLOC_MODE
- CONFIG_BT_NIMBLE_MSYS1_BLOCK_COUNT
- CONFIG_BT_NIMBLE_LOG_LEVEL
- CONFIG_BT_NIMBLE_TASK_STACK_SIZE
- CONFIG_BT_NIMBLE_CRYPTO_STACK_MBEDTLS
- CONFIG_BT_NIMBLE_NVSC_PERSIST
- CONFIG_BT_NIMBLE_ATT_PREFERRED_MTU
- CONFIG_BT_NIMBLE_RPA_TIMEOUT
- CONFIG_BT_NIMBLE_SM_LEGACY
- CONFIG_BT_NIMBLE_SM_SC
- CONFIG_BT_NIMBLE_PINNED_TO_CORE_CHOICE
- CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS

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 (BT_NIMBLE_MEM_ALLOC_MODE_INTERNAL)
- External SPIRAM (BT_NIMBLE_MEM_ALLOC_MODE_EXTERNAL)
- Default alloc mode (BT_NIMBLE_MEM_ALLOC_MODE_DEFAULT)
- Internal IRAM (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 (BT_NIMBLE_LOG_LEVEL_NONE)
- Error logs (BT_NIMBLE_LOG_LEVEL_ERROR)
- Warning logs (BT_NIMBLE_LOG_LEVEL_WARNING)
- Info logs (BT_NIMBLE_LOG_LEVEL_INFO)
- Debug logs (BT_NIMBLE_LOG_LEVEL_DEBUG)

**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.

**Range:**

- from 1 to 8 if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**Default value:**

- 3 if BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

Default value:
- 0 if BT_NIMBLE_ENABLED && 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) (BT_NIMBLE_PINNED_TO_CORE_0)
- Core 1 (APP CPU) (BT_NIMBLE_PINNED_TO_CORE_1)

**CONFIG_BT_NIMBLE_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 && BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED
- 4096 if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_ROLE_CENTRAL**

Enable BLE Central role

*Found in: Component config > Bluetooth > NimBLE Options*

*Default value:*
- Yes (enabled) if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_ROLE_PERIPHERAL**

Enable BLE Peripheral role

*Found in: Component config > Bluetooth > NimBLE Options*

*Default value:*
- Yes (enabled) if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_ROLE_BROADCASTER**

Enable BLE Broadcaster role

*Found in: Component config > Bluetooth > NimBLE Options*

*Default value:*
- Yes (enabled) if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED
CONFIG_BT_NIMBLE_ROLE_OBSERVER
Enable BLE Observer role

*Found in: Component config > Bluetooth > NimBLE Options*

**Default value:**
- Yes (enabled) if BT_NIMBLE_ENABLED && 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:**
- Yes (enabled) if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_SM_LEGACY
Security manager legacy pairing

*Found in: Component config > Bluetooth > NimBLE Options*

Enable security manager legacy pairing

**Default value:**
- Yes (enabled) if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_SM_SC
Security manager secure connections (4.2)

*Found in: Component config > Bluetooth > NimBLE Options*

Enable security manager secure connections

**Default value:**
- Yes (enabled) if BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_SM_SC_DEBUG_KEYS
Use predefined public-private key pair

*Found in: Component config > Bluetooth > NimBLE Options*

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_SM_SC && BT_NIMBLE_ENABLED
CONFIG_BT_NIMBLE_SVC_GAP_DEVICE_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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_GAP_DEVICE_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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

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 BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_ACL_BUF_COUNT

ACL Buffer count

Found in: Component config > Bluetooth > NimBLE Options

The number of ACL data buffers.

Default value:
- 20 if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

CONFIG_BT_NIMBLE_ACL_BUF_SIZE

ACL Buffer size

Found in: Component config > Bluetooth > NimBLE Options

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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_HCI_EVT_BUF_SIZE**

HCI Event Buffer size

*Found in: Component config > Bluetooth > NimBLE Options*

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 && BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

• 70 if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_HCI_EVT_HI_BUF_COUNT**

High Priority HCI Event Buffer count

*Found in: Component config > Bluetooth > NimBLE Options*

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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_HCI_EVT_LO_BUF_COUNT**

Low Priority HCI Event Buffer count

*Found in: Component config > Bluetooth > NimBLE Options*

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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_MSYS1_BLOCK_COUNT**

MSYS_1 Block Count

*Found in: Component config > Bluetooth > NimBLE Options*

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:*

• 12 if BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && 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 && 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 && 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 && 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 BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**Default value:**
- 900 if BT_NIMBLE_ENABLED && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_MESH**

Enable BLE mesh functionality

*Found in:* Component config > Bluetooth > NimBLE Options

Enable BLE Mesh functionality

**Default value:**
- No (disabled) if BT_NIMBLE_ENABLED && 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
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- \texttt{CONFIG_BT_NIMBLE_MESH_RELAY}
- \texttt{CONFIG_BT_NIMBLE_MESH_DEVICE_NAME}
- \texttt{CONFIG_BT_NIMBLE_MESH_NODE_COUNT}

\textbf{CONFIG_BT_NIMBLE_MESH_PROXY}

Enable mesh proxy functionality

\textit{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

\textbf{Default value:}
- No (disabled) if \texttt{CONFIG_BT_NIMBLE_MESH} && BT_NIMBLE_ENABLED

\textbf{CONFIG_BT_NIMBLE_MESH_PROV}

Enable BLE mesh provisioning

\textit{Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_MESH}

Enable mesh provisioning

\textbf{Default value:}
- Yes (enabled) if \texttt{CONFIG_BT_NIMBLE_MESH} && BT_NIMBLE_ENABLED

\textbf{CONFIG_BT_NIMBLE_MESH_PB_ADV}

Enable mesh provisioning over advertising bearer

\textit{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

\textbf{Default value:}
- Yes (enabled) if \texttt{CONFIG_BT_NIMBLE_MESH_PROV} && BT_NIMBLE_ENABLED

\textbf{CONFIG_BT_NIMBLE_MESH_PB_GATT}

Enable mesh provisioning over GATT bearer

\textit{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

\textbf{Default value:}
- Yes (enabled) if \texttt{CONFIG_BT_NIMBLE_MESH_PROV} && BT_NIMBLE_ENABLED

\textbf{CONFIG_BT_NIMBLE_MESH_GATT_PROXY}

Enable GATT Proxy functionality

\textit{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

\textbf{Default value:}
- Yes (enabled) if \texttt{CONFIG_BT_NIMBLE_MESH} && BT_NIMBLE_ENABLED
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**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` && `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` && `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` && `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` && `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` && `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` && `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 BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && 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 BT_NIMBLE_ENABLED && 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 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 BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT && BT_NIMBLE_ENABLED

**Default value:**
- 3 if BT_NIMBLE_ENABLED && CONFIG_BT_NIMBLE_ENABLE_CONN_REATTEMPT && BT_NIMBLE_ENABLED
**CONFIG_BT_NIMBLE_EXT_ADV**

Enable extended advertising.

*Found in: Component config > Bluetooth > NimBLE Options*

Enable this option to do extended advertising. Extended advertising will be supported from BLE 5.0 onwards.

**CONFIG_BT_NIMBLE_MAX_EXT_ADV_INSTANCES**

Maximum number of extended advertising instances.

*Found in: Component config > Bluetooth > NimBLE Options > 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.

*Range:*
  - from 0 to 4 if `CONFIG_BT_NIMBLE_EXT_ADV` && BT_NIMBLE_ENABLED

*Default value:*
  - 1 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && BT_NIMBLE_ENABLED
  - 0 if `CONFIG_BT_NIMBLE_EXT_ADV` && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_MAX_EXT_ADV_DATA_LEN**

Maximum length of the advertising data.

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_EXT_ADV*

Defines size of extended advertising data. Size should not increase 1650.

*Range:*
  - from 0 to 1650 if `CONFIG_BT_NIMBLE_EXT_ADV` && BT_NIMBLE_ENABLED

*Default value:*
  - 1650 if `CONFIG_BT_NIMBLE_EXT_ADV` && `CONFIG_BT_NIMBLE_EXT_ADV` && BT_NIMBLE_ENABLED
  - 0 if `CONFIG_BT_NIMBLE_EXT_ADV` && BT_NIMBLE_ENABLED

**CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV**

Enable periodic advertisement.

*Found in: Component config > Bluetooth > NimBLE Options > CONFIG_BT_NIMBLE_EXT_ADV*

Enable this option to start periodic advertisement.

*Default value:*
  - Yes (enabled) if `CONFIG_BT_NIMBLE_EXT_ADV` && 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_EXT_ADV > CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV*

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 1 to 8 if `CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV` && BT_NIMBLE_ENABLED

*Default value:*
  -
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- 1 if `CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV` && `CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV` && `BT_NIMBLE_ENABLED`
- 0 if `CONFIG_BT_NIMBLE_ENABLE_PERIODIC_ADV` && `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 `BT_NIMBLE_ENABLED` & & `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 `BT_NIMBLE_ENABLED`

### 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_SUBNET_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_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_DUPLICATE_SCAN

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 BT_BLUEDROID_ENABLED && 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 (BLE_MESH_MEM_ALLOC_MODE_INTERNAL)
- External SPIRAM (BLE_MESH_MEM_ALLOC_MODE_EXTERNAL)
- Default alloc mode (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 (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 (ESP32_SPIRAM_SUPPORT || 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 (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 (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:
- 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`

*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`

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**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`

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**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:**
- from 1 to 32767 if CONFIG_BLE_MESH_GATT_PROXY_SERVER && CONFIG_BLE_MESH

**Default value:**
- 4 if CONFIG_BLE_MESH_GATT_PROXY_SERVER && CONFIG_BLE_MESH
CONFIG_BLE_MESH_GATT_PROXY_CLIENT

BLE Mesh GATT Proxy Client

*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 `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_SETTINGS

Store BLE Mesh configuration persistently

*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 `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_STORE_TIMEOUT

Delay (in seconds) before storing anything persistently

*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 `CONFIG_BLE_MESH_SETTINGS` && `CONFIG_BLE_MESH`

**Default value:**
- 0 if `CONFIG_BLE_MESH_SETTINGS` && `CONFIG_BLE_MESH`

CONFIG_BLE_MESH_SEQ_STORE_RATE

How often the sequence number gets updated in storage

*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 `CONFIG_BLE_MESH_SETTINGS` && `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 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 operations 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`

*Default value:*
- 4 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*
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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:
- from 36 to 384 if CONFIG_BLE_MESH

Default value:
- 384 if CONFIG_BLE_MESH

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_LOW_POWER**

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_LOW_POWER*

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_LOW_POWER && 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_LOW_POWER

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 to send Friend Request at a certain period until it finds a proper Friend node.

Default value:
  • No (disabled) if CONFIG_BLE_MESH_LOW_POWER && 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_LOW_POWER > 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_LOW_POWER && CONFIG_BLE_MESH

Default value:
  • 15 if CONFIG_BLE_MESH_LPN_AUTO && CONFIG_BLE_MESH_LOW_POWER && 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 && CONFIG_BLE_MESH

Default value:
  • 6 if CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH

CONFIG_BLE_MESH_LPN_RSSI_FACTOR

RSSIFactor, 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 && CONFIG_BLE_MESH

Default value:
  • 0 if CONFIG_BLE_MESH_LOW_POWER && CONFIG_BLE_MESH
**CONFIG_BLE_MESH_LPN_RECV_WIN_FACTOR**

ReceiveWindowFactor, 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 && CONFIG_BLE_MESH`

**Default value:**
- 0 if `CONFIG_BLE_MESH_LOW_POWER && 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 && CONFIG_BLE_MESH`

**Default value:**
- 1 if `CONFIG_BLE_MESH_LOW_POWER && 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_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`

**CONFIG_BLE_MESH_FRIEND_LPN_COUNT**

Number of supported LPN nodes

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FRIEND`

Number of Low Power Nodes with which a Friend can have Friendships simultaneously. A Friend node can have friendship with multiple Low Power nodes at the same time, while a Low Power node can only establish friendship with only one Friend node at the same time.

*Range:*
  - from 1 to 1000 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

*Default value:*
  - 2 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_FRIEND_SEG_RX**

Number of incomplete segment lists per LPN

*Found in:* `Component config > CONFIG_BLE_MESH > CONFIG_BLE_MESH_FRIEND`

Number of incomplete segment lists tracked for each Friends’ LPN. In other words, this determines from how many elements can segmented messages destined for the Friend queue be received simultaneously.

*Range:*
  - from 1 to 1000 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

*Default value:*
  - 1 if `CONFIG_BLE_MESH_FRIEND && CONFIG_BLE_MESH`

**CONFIG_BLE_MESH_NO_LOG**

Disable BLE Mesh debug logs (minimize bin size)

*Found in:* `Component config > CONFIG_BLE_MESH`
Chapter 2. API Reference

Select this to save the BLE Mesh related rodata code size. Enabling this option will disable the output of BLE Mesh debug log.

**Default value:**
- No (disabled) if `CONFIG_BLE_MESH` && `CONFIG_BLE_MESH`

**BLE Mesh STACK DEBUG LOG LEVEL**  
Contains:
- `CONFIG_BLE_MESH_STACK_TRACE_LEVEL`

**CONFIG_BLE_MESH_STACK_TRACE_LEVEL**

BLE_MESH_STACK  
*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh STACK DEBUG LOG LEVEL*

Define BLE Mesh trace level for BLE Mesh stack.

**Available options:**
- NONE (BLE_MESH_TRACE_LEVEL_NONE)
- ERROR (BLE_MESH_TRACE_LEVEL_ERROR)
- WARNING (BLE_MESH_TRACE_LEVEL_WARNING)
- INFO (BLE_MESH_TRACE_LEVEL_INFO)
- DEBUG (BLE_MESH_TRACE_LEVEL_DEBUG)
- VERBOSE (BLE_MESH_TRACE_LEVEL_VERBOSE)

**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 (BLE_MESH_NET_BUF_TRACE_LEVEL_NONE)
- ERROR (BLE_MESH_NET_BUF_TRACE_LEVEL_ERROR)
- WARNING (BLE_MESH_NET_BUF_TRACE_LEVEL_WARNING)
- INFO (BLE_MESH_NET_BUF_TRACE_LEVEL_INFO)
- DEBUG (BLE_MESH_NET_BUF_TRACE_LEVEL_DEBUG)
- VERBOSE (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_LIGHTNESS_CLI
- CONFIG_BLE_MESH_LIGHT_XYL_CLI
- CONFIG_BLE_MESH_LIGHTING_SERVER
- CONFIG_BLE_MESH_SCENE_CLI
- CONFIG_BLE_MESH_SCHEDULER_CLI
- 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_SELF_TEST`

**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_TEST_AUTO_ENTER_NETWORK**

Unprovisioned device enters mesh network automatically

*Found in: Component config > CONFIG_BLE_MESH > BLE Mesh specific test option > CONFIG_BLE_MESH_SELF_TEST*

With this option enabled, an unprovisioned device can automatically enters mesh network using a specific test function without the pro-visioning 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 > CONFIG_BLE_MESH_SELF_TEST*

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.

CoAP Configuration Contains:

- `CONFIG_COAP_MBEDTLS_ENCRYPTION_MODE`
- `CONFIG_COAP_MBEDTLS_DEBUG`

CONFIG_COAP_MBEDTLS_ENCRYPTION_MODE

CoAP Encryption method

*Found in:* Component config > CoAP Configuration

If the CoAP information is to be encrypted, the encryption environment can be set up in one of two ways (default being Pre-Shared key mode):

- Encrypt using defined Pre-Shared Keys (PSK if uri includes coaps://)
- Encrypt using defined Public Key Infrastructure (PKI if uri includes coaps://)

**Available options:**

- Pre-Shared Keys (COAP_MBEDTLS_PSK)
- PKI Certificates (COAP_MBEDTLS_PKI)
**CONFIG_COAP_MBEDTLS_DEBUG**

Enable CoAP debugging

*Found in: Component config > CoAP Configuration*

Enable CoAP debugging functions at compile time for the example code.

If this option is enabled, call `coap_set_log_level()` at runtime in order to enable CoAP debug output via the ESP log mechanism.

**Default value:**
- No (disabled)

**CONFIG_COAP_MBEDTLS_DEBUG_LEVEL**

Set CoAP debugginglevel

*Found in: Component config > CoAP Configuration > CONFIG_COAP_MBEDTLS_DEBUG*

Set CoAP debugginglevel

**Available options:**
- Emergency (COAP_LOG_EMERG)
- Alert (COAP_LOG_ALERT)
- Critical (COAP_LOG_CRIT)
- Error (COAP_LOG_ERROR)
- Warning (COAP_LOG_WARNING)
- Notice (COAP_LOG_NOTICE)
- Info (COAP_LOG_INFO)
- Debug (COAP_LOG_DEBUG)
- mbedTLS (COAP_LOG_MBEDTLS)

**Driver configurations** Contains:
- ADC configuration
- GDMA Configuration
- GPTimer Configuration
- MCPWM configuration
- SPI configuration
- TWAI configuration
- UART configuration

**ADC configuration** Contains:

- CONFIG_ADC_DISABLE_DAC
- CONFIG_ADC_FORCE_XPD_FSM

**CONFIG_ADC_FORCE_XPD_FSM**

Use the FSM to control ADC power

*Found in: Component config > Driver configurations > ADC configuration*

ADC power can be controlled by the FSM instead of software. This allows the ADC to be shut off when it is not working leading to lower power consumption. However using the FSM control ADC power will increase the noise of ADC.

**Default value:**
- No (disabled)
**CONFIG_ADC_DISABLE_DAC**

Disable DAC when ADC2 is used on GPIO 25 and 26

*Found in: Component config > Driver configurations > 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)

**MCPWM configuration** Contains:

- **CONFIG_MCPWM_ISR_IN_IRAM**

**CONFIG_MCPWM_ISR_IN_IRAM**

Place MCPWM ISR function into IRAM

*Found in: Component config > Driver configurations > MCPWM configuration*

If this option is not selected, the MCPWM interrupt will be deferred when the Cache is in a disabled state (e.g. Flash write/erase operation).

Note that if this option is selected, all user registered ISR callbacks should never try to use cache as well. (with IRAM_ATTR)

**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.

During unit test, this is enabled to measure the ideal case of api.

**Default value:**
- No (disabled)

**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.
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)

**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_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)

**UART configuration** Contains:
- **CONFIG_UART_ISR_IN_IRAM**
Chapter 2. API Reference

**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)

**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 > Driver configurations > 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)

**CONFIG_GDMA_ISR_IRAM_SAFE**

GDMA ISR IRAM-Safe

*Found in: Component config > Driver configurations > 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)

**GPTimer Configuration**
Contains:
- `CONFIG_GPTIMER_ISR_IRAM_SAFE`
- `CONFIG_GPTIMER_CTRL_FUNC_IN_IRAM`
- `CONFIG_GPTIMER_SUPPRESS_DEPRECATE_WARN`

**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*

This will ensure the GPTimer 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_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)

**eFuse Bit Manager**

Contains:
- `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.

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).

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_ESP_TLS_SERVER_SESSION_TICKETS
• CONFIG_ESP_WOLFSSL_SMALL_CERT_VERIFY
• CONFIG_ESP_TLS_USE_DS_PERIPHERAL

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 (ESP_TLS_USING_MBEDTLS)
• wolfSSL (License info in wolfSSL directory README) (ESP_TLS_USING_WOLFSSL)

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)

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.
Default value:
- No (disabled)

**CONFIG_ESP_TLS_CLIENT_SESSION_TICKETS**

Enable client session tickets

*Found in: Component config > ESP-TLS*

Enable session ticket support as specified in RFC5077.

Default value:
- No (disabled)

**CONFIG_ESP_TLS_SERVER_SESSION_TICKETS**

Enable server session tickets

*Found in: Component config > ESP-TLS*

Enable session ticket support as specified in RFC5077

Default value:
- No (disabled) if `CONFIG_ESP_TLS_SERVER && ESP_TLS_USING_MBEDTLS && CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS`

**CONFIG_ESP_TLS_SERVER_SESSION_TICKET_TIMEOUT**

Server session ticket timeout in seconds

*Found in: Component config > ESP-TLS > 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_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.

Default value:
- No (disabled)

**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 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.

Default value:
- No (disabled) if ESP_TLS_USING_WOLFSSL

ESP32S3-Specific Contains:

- Cache config
- CONFIG_ESP32S3_DEFAULT_CPU_FREQ_MHZ
- CONFIG_ESP32S3_DEEP_SLEEP_WAKEUP_DELAY
- CONFIG_ESP32S3_BROWNOUT_DET
- CONFIG_ESP32S3_DEBUG_OCDWARE
- CONFIG_ESP32S3_NO_BLOBS
- CONFIG_ESP32S3_RTC_CLK_CAL_CYCLES
- CONFIG_ESP32S3_RTCDATA_IN_FAST_MEM
- CONFIG_ESP32S3_RTC_CLK_SRC
- CONFIG_ESP32S3_SPIRAM_SUPPORT
- CONFIG_ESP32S3_TIME_SYSCALL
- CONFIG_ESP32S3_USE_FIXED_STATIC_RAM_SIZE
- CONFIG_ESP32S3_TRAX

CONFIG_ESP32S3_DEFAULT_CPU_FREQ_MHZ

CPU frequency

Found in: Component config > ESP32S3-Specific

CPU frequency to be set on application startup.
Available options:

- 40 MHz (ESP32S3_DEFAULT_CPU_FREQ_40)
- 80 MHz (ESP32S3_DEFAULT_CPU_FREQ_80)
- 160 MHz (ESP32S3_DEFAULT_CPU_FREQ_160)
- 240 MHz (ESP32S3_DEFAULT_CPU_FREQ_240)

Cache config Contains:

- CONFIG_ESP32S3_DCACHE_ASSOCIATED_WAYS
- CONFIG_ESP32S3_DATA_CACHE_LINE_SIZE
- CONFIG_ESP32S3_DATA_CACHE_SIZE
- CONFIG_ESP32S3_ICACHE_ASSOCIATED_WAYS
- CONFIG_ESP32S3_INSTRUCTION_CACHE_LINE_SIZE
- CONFIG_ESP32S3_INSTRUCTION_CACHE_SIZE

CONFIG_ESP32S3_INSTRUCTION_CACHE_SIZE

Instruction cache size

Found in: Component config > ESP32S3-Specific > Cache config

Instruction cache size to be set on application startup. If you use 16KB instruction cache rather than
32KB instruction cache, then the other 16KB will be managed by heap allocator.

Available options:

- 16KB (ESP32S3_INSTRUCTION_CACHE_16KB)
- 32KB (ESP32S3_INSTRUCTION_CACHE_32KB)

CONFIG_ESP32S3_ICACHE_ASSOCIATED_WAYS

Instruction cache associated ways

Found in: Component config > ESP32S3-Specific > Cache config

Instruction cache associated ways to be set on application startup.

Available options:

- 4 ways (ESP32S3_INSTRUCTION_CACHE_4WAYS)
- 8 ways (ESP32S3_INSTRUCTION_CACHE_8WAYS)

CONFIG_ESP32S3_INSTRUCTION_CACHE_LINE_SIZE

Instruction cache line size

Found in: Component config > ESP32S3-Specific > Cache config

Instruction cache line size to be set on application startup.

Available options:

- 16 Bytes (ESP32S3_INSTRUCTION_CACHE_LINE_16B)
- 32 Bytes (ESP32S3_INSTRUCTION_CACHE_LINE_32B)

CONFIG_ESP32S3_DATA_CACHE_SIZE

Data cache size

Found in: Component config > ESP32S3-Specific > Cache config

Data cache size to be set on application startup. If you use 32KB data cache rather than 64KB data
cache, the other 32KB will be added to the heap.

Available options:

- 16KB (ESP32S3_DATA_CACHE_16KB)
Chapter 2. API Reference

• 32KB (ESP32S3_DATA_CACHE_32KB)
• 64KB (ESP32S3_DATA_CACHE_64KB)

**CONFIG_ESP32S3_DCACHE_ASSOCIATED_WAYS**

Data cache associated ways

*Found in: Component config > ESP32S3-Specific > Cache config*

Data cache associated ways to be set on application startup.

**Available options:**

• 4 ways (ESP32S3_DATA_CACHE_4WAYS)
• 8 ways (ESP32S3_DATA_CACHE_8WAYS)

**CONFIG_ESP32S3_DATA_CACHE_LINE_SIZE**

Data cache line size

*Found in: Component config > ESP32S3-Specific > Cache config*

Data cache line size to be set on application startup.

**Available options:**

• 16 Bytes (ESP32S3_DATA_CACHE_LINE_16B)
• 32 Bytes (ESP32S3_DATA_CACHE_LINE_32B)
• 64 Bytes (ESP32S3_DATA_CACHE_LINE_64B)

**CONFIG_ESP32S3_SPIRAM_SUPPORT**

Support for external, SPI-connected RAM

*Found in: Component config > ESP32S3-Specific*

This enables support for an external SPI RAM chip, connected in parallel with the main SPI flash chip.

**Default value:**

• No (disabled)

**SPI RAM config**

Contains:

• `CONFIG_SPIRAM_FETCH_INSTRUCTIONS`
• `CONFIG_SPIRAM_RODATA`
• `CONFIG_SPIRAM_ECC_ENABLE`
• `CONFIG_SPIRAM_BOOT_INIT`
• `CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL`
• `CONFIG_SPIRAM_MODE`
• `PSRAM Clock and CS IO for ESP32S3`
• `CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL`
• `CONFIG_SPIRAM_MEMTEST`
• `CONFIG_SPIRAM_SPEED`
• `CONFIG_SPIRAM_USE`
• `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
• `CONFIG_SPIRAM_TYPE`

**CONFIG_SPIRAM_MODE**

Mode (QUAD/OCT) of SPI RAM chip in use

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config*

**Available options:**
Chapter 2. API Reference

- Quad Mode PSRAM (SPIRAM_MODE_QUAD)
- Octal Mode PSRAM (SPIRAM_MODE_OCT)

**CONFIG_SPIRAM_TYPE**
Type of SPIRAM chip in use

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config*

*Available options:*
- Auto-detect (SPIRAM_TYPE_AUTO)
- ESP-PSRAM16 or APS1604 (SPIRAM_TYPE_ESPPSRAM16)
- ESP-PSRAM32 or IS25WP032 (SPIRAM_TYPE_ESPPSRAM32)
- ESP-PSRAM64, LY68L6400 or APS6408 (SPIRAM_TYPE_ESPPSRAM64)

**PSRAM Clock and CS IO for ESP32S3**
Contains:
- `CONFIG_DEFAULT_PSRAM_CLK_IO`
- `CONFIG_DEFAULT_PSRAM_CS_IO`

**CONFIG_DEFAULT_PSRAM_CLK_IO**
PSRAM CLK IO number

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config > PSRAM Clock and CS IO for ESP32S3*

The PSRAM Clock IO can be any unused GPIO, please refer to your hardware design.

*Range:*
- from 0 to 33 if `CONFIG_ESP32S3_SPIRAM_SUPPORT` & `CONFIG_DEFAULT_PSRAM_CLK_IO`

*Default value:*
- 30 if `CONFIG_ESP32S3_SPIRAM_SUPPORT` & `CONFIG_DEFAULT_PSRAM_CLK_IO`

**CONFIG_DEFAULT_PSRAM_CS_IO**
PSRAM CS IO number

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config > PSRAM Clock and CS IO for ESP32S3*

The PSRAM CS IO can be any unused GPIO, please refer to your hardware design.

*Range:*
- from 0 to 33 if `CONFIG_ESP32S3_SPIRAM_SUPPORT` & `CONFIG_DEFAULT_PSRAM_CS_IO`

*Default value:*
- 26 if `CONFIG_ESP32S3_SPIRAM_SUPPORT` & `CONFIG_DEFAULT_PSRAM_CS_IO`

**CONFIG_SPIRAM_FETCH_INSTRUCTIONS**
Cache fetch instructions from SPI RAM

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config*

If enabled, instruction in flash will be copied into SPIRAM. If SPIRAM_RODATA also enabled, you can run the instruction when erasing or programming the flash.

*Default value:*
- No (disabled) if `CONFIG_ESP32S3_SPIRAM_SUPPORT`
CONFIG_SPIRAM_RODATA
Cache load read only data from SPI RAM

Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config

If enabled, rodata in flash will be copied into SPIRAM. If SPIRAM_FETCH_INSTRUCTIONS is also enabled, you can run the instruction when erasing or programming the flash.

Default value:
• No (disabled) if CONFIG_ESP32S3_SPIRAM_SUPPORT

CONFIG_SPIRAM_SPEED
Set RAM clock speed

Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config

Select the speed for the SPI RAM chip.

Available options:
• 120MHz clock speed (SPIRAM_SPEED_120M)
• 80MHz clock speed (SPIRAM_SPEED_80M)
• 40Mhz clock speed (SPIRAM_SPEED_40M)

CONFIG_SPIRAM_BOOT_INIT
Initialize SPI RAM during startup

Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > 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_ESP32S3_SPIRAM_SUPPORT

CONFIG_SPIRAM_IGNORE_NOTFOUND
Ignore PSRAM when not found

Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config > CONFIG_SPIRAM_BOOT_INIT

Normally, if pfram 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_ESP32S3_SPIRAM_SUPPORT

CONFIG_SPIRAM_USE
SPI RAM access method

Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > 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.
Chapter 2. API Reference

Available options:

- Integrate RAM into memory map (SPIRAM_USE_MEMMAP)
- Make RAM allocatable using heap_caps_malloc(…, MALLOC_CAP_SPIRAM) (SPIRAM_USE_CAPS_ALLOC)
- Make RAM allocatable using malloc() as well (SPIRAM_USE_MALLOC)

**CONFIG_SPIRAM_MEMTEST**

Run memory test on SPI RAM initialization

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > 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_ESP32S3_SPIRAM_SUPPORT

**CONFIG_SPIRAM_MALLOC_ALWAYSINTERNAL**

Maximum malloc() size, in bytes, to always put in internal memory

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > 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 SPIRAM_USE_MALLOC && CONFIG_ESP32S3_SPIRAM_SUPPORT

**Default value:**

- 16384 if SPIRAM_USE_MALLOC && CONFIG_ESP32S3_SPIRAM_SUPPORT

**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 > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > 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 (SPIRAM_USE_CAPS_ALLOC || SPIRAM_USE_MALLOC) && CONFIG_ESP32S3_SPIRAM_SUPPORT

**CONFIG_SPIRAM_MALLOC_RESERVE_INTERNAL**

Reserve this amount of bytes for data that specifically needs to be in DMA or internal memory

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > 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 SPIRAM_USE_MALLOC && CONFIG_ESP32S3_SPIRAM_SUPPORT

**Default value:**
- 32768 if SPIRAM_USE_MALLOC && CONFIG_ESP32S3_SPIRAM_SUPPORT

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**CONFIG_SPIRAM_ECC_ENABLE**
Enable SPI RAM ECC

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_SPIRAM_SUPPORT > SPI RAM config*

Enable MSPI Error-Correcting Code function when accessing SPIRAM.

If enabled, 1/16 of the SPI RAM total size will be reserved for error-correcting code.

**Default value:**
- No (disabled) if SPIRAM_MODE_OCT && CONFIG_ESP32S3_SPIRAM_SUPPORT

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**CONFIG_ESP32S3_TRAX**
Use TRAX tracing feature

*Found in: Component config > ESP32S3-Specific*

The esp32-s3 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)

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**CONFIG_ESP32S3_TRAX_TWOBANKS**
Reserve memory for tracing both pro as well as app cpu execution

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_TRAX*

The esp32-s3 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) if CONFIG_ESP32S3_TRAX && CONFIG_FREERTOS_UNICORE

---

**CONFIG_ESP32S3_DEBUG_OCD_AWARE**
Make exception and panic handlers JTAG/OCD aware

*Found in: Component config > ESP32S3-Specific*

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_ESP32S3_BROWNOUT_DET

Hardware brownout detect & reset

Found in: Component config > ESP32S3-Specific

The ESP32-S3 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_ESP32S3_BROWNOUT_DET_LVL_SEL

Brownout voltage level

Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_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 ESP3-S3 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:
- 2.44V (ESP32S3_BROWNOUT_DET_LVL_SEL_7)
- 2.56V (ESP32S3_BROWNOUT_DET_LVL_SEL_6)
- 2.67V (ESP32S3_BROWNOUT_DET_LVL_SEL_5)
- 2.84V (ESP32S3_BROWNOUT_DET_LVL_SEL_4)
- 2.98V (ESP32S3_BROWNOUT_DET_LVL_SEL_3)
- 3.19V (ESP32S3_BROWNOUT_DET_LVL_SEL_2)
- 3.30V (ESP32S3_BROWNOUT_DET_LVL_SEL_1)

CONFIG_ESP32S3_TIME_SYSCALL

Timers used for gettimeofday function

Found in: Component config > ESP32S3-Specific

This setting defines which hardware timers are used to implement `gettimeofday` and `time` functions in C library.

- If both high-resolution 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 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 microsecond 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 (ESP32S3_TIME_SYSCALL_USE_RTC_SYSTIMER)
- RTC (ESP32S3_TIME_SYSCALL_USE_RTC)
- High-resolution timer (ESP32S3_TIME_SYSCALL_USE_SYSTIMER)
- None (ESP32S3_TIME_SYSCALL_USE_NONE)

CONFIG_ESP32S3_RTC_CLK_SRC

RTC clock source

Found in: Component config > ESP32S3-Specific

Choose which clock is used as RTC clock source.
Available options:
• Internal 150kHz RC oscillator (ESP32S3_RTC_CLK_SRC_INT_RC)
• External 32kHz crystal (ESP32S3_RTC_CLK_SRC_EXT_CRYSTAL)
• External 32kHz oscillator at 32K_XP pin (ESP32S3_RTC_CLK_SRC_EXT_OSC)
• Internal 8MHz oscillator, divided by 256 (~32kHz) (ESP32S3_RTC_CLK_SRC_INT_8MD256)

CONFIG_ESP32S3_RTC_CLK_CAL_CYCLES
Number of cycles for RTC_SLOW_CLK calibration

Found in: Component config > ESP32S3-Specific

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 ESP32S3_RTC_CLK_SRC_EXT_CRYSTAL || ESP32S3_RTC_CLK_SRC_EXT_OSC || ESP32S3_RTC_CLK_SRC_INT_8MD256
• from 0 to 32766

Default value:
• 3000 if ESP32S3_RTC_CLK_SRC_EXT_CRYSTAL || ESP32S3_RTC_CLK_SRC_EXT_OSC || ESP32S3_RTC_CLK_SRC_INT_8MD256
• 1024

CONFIG_ESP32S3_DEEP_SLEEP_WAKEUP_DELAY
Extra delay in deep sleep wake stub (in us)

Found in: Component config > ESP32S3-Specific

When ESP32S3 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_ESP32S3_NO_BLOBS

No Binary Blobs

Found in: Component config > ESP32S3-Specific
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) if `CONFIG_BT_ENABLED`

**CONFIG_ESP32S3_RTCDATA_IN_FAST_MEM**

Place RTC_DATA_ATTR and RTC_RODATA_ATTR variables into RTC fast memory segment

*Found in: Component config > ESP32S3-Specific*

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.

**Default value:**
- No (disabled)

**CONFIG_ESP32S3_USE_FIXED_STATIC_RAM_SIZE**

Use fixed static RAM size

*Found in: Component config > ESP32S3-Specific*

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 ESP32S3_FIXED_STATIC_RAM_SIZE

**Default value:**
- No (disabled)

**CONFIG_ESP32S3_FIXED_STATIC_RAM_SIZE**

Fixed Static RAM size

*Found in: Component config > ESP32S3-Specific > CONFIG_ESP32S3_USE_FIXED_STATIC_RAM_SIZE*

RAM size dedicated for static variables (.data & .bss sections).

**Range:**
- from 0 to 0x34000 if `CONFIG_ESP32S3_USE_FIXED_STATIC_RAM_SIZE`

**Default value:**
- “0x10000” if `CONFIG_ESP32S3_USE_FIXED_STATIC_RAM_SIZE`

**ADC-Calibration**

**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_USE_OPENETH`
  • `CONFIG_ETH_USE_SPI_ETHERNET`

**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:
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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`

**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_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

**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)

**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)

**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:

- MAC Config
- RTC Clock Config
- Sleep Config

MAC Config  Contains:

- CONFIG_ESP32S3_UNIVERSAL_MAC_ADDRESSES

CONFIG_ESP32S3_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 (ESP32S3_UNIVERSAL_MAC_ADDRESSES_TWO)
- Four (ESP32S3_UNIVERSAL_MAC_ADDRESSES_FOUR)

Sleep Config  Contains:

- CONFIG_ESP_SLEEP_FLASH_LEAKAGE_WORKAROUND
- CONFIG_ESP_SLEEP_GPIO_RESET_WORKAROUND
- CONFIG_ESP_SLEEP_POWER_DOWN_FLASH
- 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 in fact consider VDD_SDIO auto power value (ESP_PD_OPTION_AUTO) as OFF. Also, it is possible to force a power domain to stay ON during light sleep by using esp_sleep_pd_config() function.

Default value:
- Yes (enabled)
**CONFIG_ESP_SLEEP_GPIO_RESET_WORKAROUND**

Light sleep GPIO reset workaround

*Found in: Component config > Hardware Settings > Sleep Config*

Esp32c3 and esp32s3 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.

*Default value:*
- Yes (enabled)

**CONFIG_ESP_SLEEP_PSRAM_LEAKAGE_WORKAROUND**

PSRAM leakage current workaround in light sleep

*Found in: Component config > Hardware Settings > Sleep Config*

When the CS pin of SPIRAM is not pulled up, the sleep current will increase during light sleep. If the CS pin of SPIRAM has an external pull-up, you do not need to select this option, otherwise, you should enable this option.

**CONFIG_ESP_SLEEP_FLASH_LEAKAGE_WORKAROUND**

Flash leakage current workaround in light sleep

*Found in: Component config > Hardware Settings > Sleep Config*

When the CS pin of Flash is not pulled up, the sleep current will increase during light sleep. If the CS pin of Flash has an external pull-up, you do not need to select this option, otherwise, you should enable this option.

**RTC Clock Config**

Contains:

- **CONFIG_RTC_CLOCK_BBPLL_POWER_ON_WITH_USB**

**CONFIG_RTC_CLOCK_BBPLL_POWER_ON_WITH_USB**

Keep BBPLL clock always work

*Found in: Component config > Hardware Settings > RTC Clock Config*

When the chip goes sleep or software reset, the clock source would change to XTAL and switch off the BBPLL clock for saving power. However, this might make the USB_SERIAL_JTAG down which depends on BBPLL as its unique clock source. Therefore, this is used for keeping bbpll clock always on when USB_SERIAL_JTAG PORT is using. If you want to use USB_SERIAL_JTAG under sw_reset case or sleep-wakeup case, you shoule select this option. But be aware that this might increase the power consumption.

*Default value:*
- Yes (enabled)
LCD and Touch Panel  Contains:
  • LCD Peripheral Configuration

LCD Peripheral Configuration  Contains:
  • CONFIG_LCD_PANEL_IO_FORMAT_BUF_SIZE

**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

ESP NETIF Adapter  Contains:
  • CONFIG_ESP_NETIF_TCPIP_ADAPTER_COMPATIBLE_LAYER
  • CONFIG_ESP_NETIF_L2_TAP
  • CONFIG_ESP_NETIF_IP_LOST_TIMER_INTERVAL
  • CONFIG_ESP_NETIF_USE_TCPIP_STACK_LIB

**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 (ESP_NETIF_TCPIP_LWIP)
    LwIP is a small independent implementation of the TCP/IP protocol suite.
  • Loopback (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_TCPIP_ADAPTER_COMPATIBLE_LAYER
Enable backward compatible tcpip_adapter interface

*Found in: Component config > ESP NETIF Adapter*

Backward compatible interface to tcpip_adapter is enabled by default to support legacy TCP/IP stack initialisation code. Disable this option to use only esp-netif interface.

**Default value:**
- Yes (enabled)

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

PHY Contains:
- CONFIG_ESP_PHY_ENABLE_USB
- 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
Chapter 2. API Reference

**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 boot 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:
  • No (disabled) if CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN && CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION

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 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:**
- Yes (enabled) if ESP32_BROWNOUT_DET

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:**
- Yes (enabled)
- No (disabled)

**Power Management**

Contains:

- CONFIG_PM_SLP_DISABLE_GPIO
- CONFIG_PM_POWER_DOWN_CPU_IN_LIGHT_SLEEP
- CONFIG_PM_SLP_IRAM_OPT
- CONFIG_PMRTOS_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)

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)

CONFIG_PM_POWER_DOWN_TAGMEM_IN_LIGHT_SLEEP

Power down I/D-cache tag memory in light sleep

*Found in: Component config > Power Management > CONFIG_PM_POWER_DOWN_CPU_IN_LIGHT_SLEEP*

If enabled, the I/D-cache tag memory will be retained in light sleep. Depending on the the cache configuration, if this option is enabled, it will consume up to 9 KB of internal RAM.

**Default value:**
- Yes (enabled)

### ESP System Settings

Contains:

- `CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES`
- `CONFIG_ESP_CONSOLE_UART`
- `CONFIG_ESP_CONSOLE_SECONDARY`
- `CONFIG_ESP_CONSOLE_USB_CDC_SUPPORT_ETS_PRINTF`
- `CONFIG_ESP_SYSTEM_ALLOW_RTC_FAST_MEM_AS_HEAP`
- `CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE`
- `CONFIG_ESP_TASK_WDT`
- `CONFIG_ESP_XT_WDT`
- `CONFIG_ESP_SYSTEM_CHECK_INT_LEVEL`
- `CONFIG_ESP_INT_WDT`
- `CONFIG_ESP_MAIN_TASK_AFFINITY`
- `CONFIG_ESP_MAIN_TASK_STACK_SIZE`
- Memory protection
- `CONFIG_ESP_MINIMAL_SHARED_STACK_SIZE`
- `CONFIG_ESP_DEBUG_STUBS_ENABLE`
- `CONFIG_ESP_SYSTEM_PANIC`
- `CONFIG_ESP_PANIC_HANDLER_IRAM`
- `CONFIG_ESP_CONSOLE_USB_CDC_RX_BUF_SIZE`
- `CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE`
- `CONFIG_ESP_CONSOLE_UART_BAUDRATE`
- `CONFIG_ESP_CONSOLE_UART_NUM`
- `CONFIG_ESP_CONSOLE_UART_RX_GPIO`
- `CONFIG_ESP_CONSOLE_UART_TX_GPIO`

### 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 (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 (ESP_SYSTEM_PANIC_PRINT_REBOOT)**
  Outputs the relevant registers over the serial port and immediately reset the processor.

- **Silent reboot (ESP_SYSTEM_PANIC_SILENT_REBOOT)**
  Just resets the processor without outputting anything

- **GDBStub on panic (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 (ESP_SYSTEM_GDBSTUB_RUNTIME)**
  Invoke gdbstub on the serial port, allowing for gdb to attach to it and to do a debug on runtime. This feature will switch system to single core mode.

**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.

*Default value:*

- Yes (enabled)

**Memory protection** Contains:

- **CONFIG_ESP_SYSTEM_MEMPROT_FEATURE**

**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.
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 (ESP_MAIN_TASK_AFFINITY_CPU0)
- CPU1 (ESP_MAIN_TASK_AFFINITY_CPU1)
- No affinity (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 (ESP_CONSOLE_UART_DEFAULT)
• USB CDC (ESP_CONSOLE_USB_CDC)
• USB Serial/JTAG Controller (ESP_CONSOLE_USB_SERIAL_JTAG)
• Custom UART (ESP_CONSOLE_UART_CUSTOM)
• None (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 (ESP_CONSOLE_SECONDARY_NONE)
• USB_SERIAL_JTAG PORT (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 reconfigurable 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`.

**Available options:**

- UART0 (ESP_CONSOLE_UART_CUSTOM_NUM_0)
- UART1 (ESP_CONSOLE_UART_CUSTOM_NUM_1)

---

**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 ESP_CONSOLE_UART_CUSTOM

**Default value:**

- 43 if ESP_CONSOLE_UART_CUSTOM

---

**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 default default standard input of the app).

Note: The default ESP-IDF Bootloader configures this pin but doesn’t read anything from the UART.

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 ESP_CONSOLE_UART_CUSTOM

**Default value:**

- 44 if ESP_CONSOLE_UART_CUSTOM

---

**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_CONSOLE_USB_CDC_RX_BUF_SIZE**
Size of USB CDC RX buffer

*Found in: Component config > ESP System Settings*

Set the size of USB CDC RX buffer. Increase the buffer size if your application is often receiving data over USB CDC.

**Range:**
• from 4 to 16384 if ESP_CONSOLE_USB_CDC

**Default value:**
• 64 if ESP_CONSOLE_USB_CDC

**CONFIG_ESP_CONSOLE_USB_CDC_SUPPORT_ETS_PRINTF**
Enable esp_rom_printf/ESP_EARLY_LOG via USB CDC

*Found in: Component config > ESP System Settings*

If enabled, esp_rom_printf and ESP_EARLY_LOG output will also be sent over USB CDC. Disabling this option saves about 1kB or RAM.

**Default value:**
• No (disabled) if ESP_CONSOLE_USB_CDC

**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 ESP32_SPIRAM_SUPPORT && `CONFIG_ESP_INT_WDT`
• 800 if ESP32_SPIRAM_SUPPORT && `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.
Default value:
• Yes (enabled) if `CONFIG_ESP_INT_WDT` && `CONFIG_FREERTOS_UNICORE`

**CONFIG_ESP_TASK_WDT**

Initialize Task Watchdog Timer on startup

*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 cause the Task Watchdog Timer to be initialized automatically at startup. The Task Watchdog timer can be initialized after startup as well (see Task Watchdog Timer API Reference)

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*

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*

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*

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*

If this option is enabled, the Task Watchdog Timer will watch the CPU1 Idle Task.

Default value:
Chapter 2. API Reference

- Yes (enabled) if `CONFIG_ESP_TASK_WDT` && `CONFIG_FREERTOS_UNICORE`

**CONFIG_ESP_XT_WDT**

Initialize XTAL32K watchdog timer on startup

*Found in: Component config > ESP System Settings*

This watchdog timer can detect oscillation failure of the XTAL32K_CLK. When such a failure is detected the hardware can be set up to automatically switch to BACKUP32K_CLK and generate an interrupt.

**CONFIG_ESP_XT_WDT_TIMEOUT**

XTAL32K watchdog timeout period

*Found in: Component config > ESP System Settings > CONFIG_ESP_XT_WDT*

Timeout period configuration for the XTAL32K watchdog timer based on RTC_CLK.

**Range:**
- from 1 to 255 if `CONFIG_ESP_XT_WDT`

**Default value:**
- 200 if `CONFIG_ESP_XT_WDT`

**CONFIG_ESP_XT_WDT_BACKUP_CLK_ENABLE**

Automatically switch to BACKUP32K_CLK when timer expires

*Found in: Component config > ESP System Settings > CONFIG_ESP_XT_WDT*

Enable this to automatically switch to BACKUP32K_CLK as the source of RTC_SLOW_CLK when the watchdog timer expires.

**Default value:**
- Yes (enabled) if `CONFIG_ESP_XT_WDT`

**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 ESP32_TRAX && ESP32S2_TRAX && CONFIG_ESP32S3_TRAX

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 (ESP_SYSTEM_CHECK_INT_LEVEL_5)
  Using level 5 interrupt for Interrupt Watchdog and other system checks.
- Level 4 interrupt (ESP_SYSTEM_CHECK_INT_LEVEL_4)
  Using level 4 interrupt for Interrupt Watchdog and other system checks.

**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_STACK_SIZE
- CONFIG_ESP_TIMER_INTERRUPT_LEVEL
- CONFIG_ESP_TIMER_SUPPORTS_ISR_DISPATCH_METHOD
**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.

**Default value:**
- No (disabled)

**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” menu.

**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 1

**Default value:**
- 1

**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_ESP32_WIFI_ENABLE_WPA3_SAE`
- `CONFIG_ESP32_WIFI_SOFTAP_BEACON_MAX_LEN`
- `CONFIG_ESP32_WIFI_CACHE_TX_BUFFER_NUM`
- `CONFIG_ESP32_WIFI_DYNAMIC_RX_BUFFER_NUM`
- `CONFIG_ESP32_WIFI_DYNAMIC_TX_BUFFER_NUM`
- `CONFIG_ESP32_WIFI_STATIC_RX_BUFFER_NUM`
- `CONFIG_ESP32_WIFI_STATIC_TX_BUFFER_NUM`
- `CONFIG_ESP_WIFI_STA_DISCONNECTED_PM_ENABLE`
- `CONFIG_ESP32_WIFI_SW_COEXIST_ENABLE`
- `CONFIG_ESP32_WIFI_TX_BUFFER`
- `CONFIG_ESP32_WIFI_AMPDU_RX_ENABLED`
- `CONFIG_ESP32_WIFI_AMPDU_TX_ENABLED`
- `CONFIG_ESP32_WIFI_AMSDU_TX_ENABLED`
- `CONFIG_ESP32_WIFI_CSI_ENABLED`
- `CONFIG_ESP_WIFI_FTM_ENABLE`
- `CONFIG_ESP_WIFI_GCMP_SUPPORT`
- `CONFIG_ESP_WIFI_GMAC_SUPPORT`
- `CONFIG_ESP32_WIFI_IRAM_OPT`
- `CONFIG_ESP32_WIFI_MGMT_SBUF_NUM`
- `CONFIG_ESP32_WIFI_NVS_ENABLED`
- `CONFIG_ESP32_WIFI_RX_IRAM_OPT`
- `CONFIG_ESP_WIFI_SLP_IRAM_OPT`
- `CONFIG_ESP_WIFI_SOFTAP_SUPPORT`
- `CONFIG_ESP32_WIFI_TASK_CORE_ID`

**CONFIG_ESP32_WIFI_SW_COEXIST_ENABLE**

Software controls WiFi/Bluetooth coexistence

*Found in: Component config > Wi-Fi*

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`

**CONFIG_ESP32_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 ESP32_WIFI_AMPDU_RX_ENABLED is enabled, this value is recommended to set equal or bigger than ESP32_WIFI_RX_BA_WIN in order to achieve better throughput and compatibility with both stations and APs.

**Range:**
- from 2 to 25

**Default value:**
- 10 if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
- 16 if `CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP`
**CONFIG_ESP32_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_ESP32_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 (ESP32_WIFI_STATIC_TX_BUFFER)
- Dynamic (ESP32_WIFI_DYNAMIC_TX_BUFFER)

**CONFIG_ESP32_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 ESP32_WIFI_STATIC_TX_BUFFER

*Default value:*
- 16 if ESP32_WIFI_STATIC_TX_BUFFER
CONFIG_ESP32_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 ESP32_SPIRAM_SUPPORT || ESP32S2_SPIRAM_SUPPORT || CONFIG_ESP32S3_SPIRAM_SUPPORT

**Default value:**
- 32 if ESP32_SPIRAM_SUPPORT || ESP32S2_SPIRAM_SUPPORT || CONFIG_ESP32S3_SPIRAM_SUPPORT

CONFIG_ESP32_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_ESP32_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_ESP32_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_ESP32_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_ESP32_WIFI_TX_BA_WIN

WiFi AMPDU TX BA window size

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_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 the 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

**Default value:**
- 6

CONFIG_ESP32_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_ESP32_WIFI_RX_BA_WIN

WiFi AMPDU RX BA window size

*Found in:* Component config > Wi-Fi > CONFIG_ESP32_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 the 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 allocate 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

**Default value:**
- 6 if CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP && CONFIG_ESP32_WIFI_AMPDU_RX_ENABLED
- 16 if CONFIG_SPIRAM_TRY_ALLOCATE_WIFI_LWIP && CONFIG_ESP32_WIFI_AMPDU_RX_ENABLED

CONFIG_ESP32_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 ESP32_SPIRAM_SUPPORT || ESP32S2_SPIRAM_SUPPORT || CONFIG_ESP32S3_SPIRAM_SUPPORT
CONFIG_ESP32_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_ESP32_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 (ESP32_WIFI_TASK_PINNED_TO_CORE_0)
- Core 1 (ESP32_WIFI_TASK_PINNED_TO_CORE_1)

CONFIG_ESP32_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

Default value:
- 752

CONFIG_ESP32_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_ESP32_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` && `ESP32_SPIRAM_SUPPORT`
- Yes (enabled)

CONFIG_ESP32_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` && `ESP32_SPIRAM_SUPPORT`
- Yes (enabled)

CONFIG_ESP32_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_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 ESP32_WIFI_IRAM_OPT and ESP32_WIFI_RX_IRAM_OPT, or this one. If already enabled ESP32_WIFI_IRAM_OPT, the other 7.3KB IRAM memory would be taken by this option. If already enabled ESP32_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 `CONFIG_ESP_WIFI_SLP_IRAM_OPT`

**CONFIG_ESP_WIFI_SLP_DEFAULT_MAX_ACTIVE_TIME**

Maximum keep alive time

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_SLP_IRAM_OPT*

The maximum time that wifi keep alive, unit: seconds.

*RANGE:*

• from 10 to 60 if `CONFIG_ESP_WIFI_SLP_IRAM_OPT`

*Default value:*

• 10 if `CONFIG_ESP_WIFI_SLP_IRAM_OPT`

**CONFIG_ESP_WIFI_FTM_ENABLE**

WiFi FTM

*Found in: Component config > Wi-Fi*

Enable feature Fine Timing Measurement for calculating WiFi Round-Trip-Time (RTT).

*Default value:*

• No (disabled)

**CONFIG_ESP_WIFI_FTM_INITIATOR_SUPPORT**

FTM Initiator support

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_FTM_ENABLE*

*Default value:*

• Yes (enabled) if `CONFIG_ESP_WIFI_FTM_ENABLE`

**CONFIG_ESP_WIFI_FTM_RESPONDER_SUPPORT**

FTM Responder support

*Found in: Component config > Wi-Fi > CONFIG_ESP_WIFI_FTM_ENABLE*

*Default value:*

• Yes (enabled) if `CONFIG_ESP_WIFI_FTM_ENABLE`

**CONFIG_ESP_WIFI_STA_DISCONNECTED_PM_ENABLE**

Power Management for station at disconnected

*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.

**CONFIG_ESP_WIFI_GCMP_SUPPORT**

WiFi GCMP Support(GCMP128 and GCMP256)

*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)
**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)

**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_DECODE`
- `CONFIG_ESP_COREDUMP_MAX_TASKS_NUM`

**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 (ESP_COREDUMP_ENABLE_TO_FLASH)
- UART (ESP_COREDUMP_ENABLE_TO_UART)
- None (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 (ESP_COREDUMP_DATA_FORMAT_BIN)
- ELF format (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 (ESP_COREDUMP_CHECKSUM_CRC32)
  - Use SHA256 for integrity verification (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 ESP_COREDUMP_ENABLE_TO_FLASH

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 ESP_COREDUMP_ENABLE_TO_UART

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) (ESP_COREDUMP_DECODE_INFO)
  - Don’t decode (ESP_COREDUMP_DECODE_DISABLE)

FAT Filesystem support

Contains:

- CONFIG_FATFS_API_ENCODING
- CONFIG_FATFS_USE_FASTSEEK
- CONFIG_FATFS_CHOOSE_TYPE
- CONFIG_FATFS_LONG_FILENAMES
- CONFIG_FATFS_MAX_LFN
- CONFIG_FATFS_FS_LOCK
- CONFIG_FATFS_VOLUME_COUNT
- CONFIG_FATFS_CHOOSE_CODEPAGE
Chapter 2. API Reference

- `CONFIG_FATFS_ALLOC_PREFER_EXTRAM`
- `CONFIG_FATFS_SECTOR_SIZE`
- `CONFIG_FATFS_SECTORS_PER_CLUSTER`
- `CONFIG_FATFS_TIMEOUT_MS`
- `CONFIG_FATFS_PER_FILE_CACHE`

**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_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 (FATFS_SECTOR_512)
- 1024 (FATFS_SECTOR_1024)
- 2048 (FATFS_SECTOR_2048)
- 4096 (FATFS_SECTOR_4096)

**CONFIG_FATFS_SECTORS_PER_CLUSTER**

Sectors per cluster

*Found in: Component config > FAT Filesystem support*

This value specifies how many sectors there are in one cluster.

**Available options:**
- 1 (FATFS_SECTORS_PER_CLUSTER_1)
- 2 (FATFS_SECTORS_PER_CLUSTER_2)
- 4 (FATFS_SECTORS_PER_CLUSTER_4)
- 8 (FATFS_SECTORS_PER_CLUSTER_8)
- 16 (FATFS_SECTORS_PER_CLUSTER_16)
- 32 (FATFS_SECTORS_PER_CLUSTER_32)
- 64 (FATFS_SECTORS_PER_CLUSTER_64)
- 128 (FATFS_SECTORS_PER_CLUSTER_128)

**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) (FATFS_CODEPAGE_DYNAMIC)
• US (CP437) (FATFS_CODEPAGE_437)
• Arabic (CP720) (FATFS_CODEPAGE_720)
• Greek (CP737) (FATFS_CODEPAGE_737)
• KBL (CP771) (FATFS_CODEPAGE_771)
• Baltic (CP775) (FATFS_CODEPAGE_775)
• Latin 1 (CP850) (FATFS_CODEPAGE_850)
• Latin 2 (CP852) (FATFS_CODEPAGE_852)
• Cyrillic (CP855) (FATFS_CODEPAGE_855)
• Turkish (CP857) (FATFS_CODEPAGE_857)
• Portuguese (CP860) (FATFS_CODEPAGE_860)
• Icelandic (CP861) (FATFS_CODEPAGE_861)
• Hebrew (CP862) (FATFS_CODEPAGE_862)
• Canadian French (CP863) (FATFS_CODEPAGE_863)
• Arabic (CP864) (FATFS_CODEPAGE_864)
• Nordic (CP865) (FATFS_CODEPAGE_865)
• Russian (CP866) (FATFS_CODEPAGE_866)
• Greek 2 (CP869) (FATFS_CODEPAGE_869)
• Japanese (DBCS) (CP932) (FATFS_CODEPAGE_932)
• Simplified Chinese (DBCS) (CP936) (FATFS_CODEPAGE_936)
• Korean (DBCS) (CP949) (FATFS_CODEPAGE_949)
• Traditional Chinese (DBCS) (CP950) (FATFS_CODEPAGE_950)

**CONFIG_FATFS_CHOOSE_TYPE**

FAT type

*Found in: Component config > FAT Filesystem support*

If user specifies automatic detection of the FAT type, the FATFS generator will determine the type by the size.

**Available options:**

• Select a suitable FATFS type automatically. (FATFS_AUTO_TYPE)
• FAT12 (FATFS_FAT12)
• FAT16 (FATFS_FAT16)

**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 (Currently not supported by FATFS partition generator).

**Available options:**

• No long filenames (FATFS_LFN_NONE)
• Long filename buffer in heap (FATFS_LFN_HEAP)
• Long filename buffer on stack (FATFS_LFN_STACK)

**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:**
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 (FATFS_API_ENCODING_ANSI_OEM)
- API uses UTF-16 encoding (FATFS_API_ENCODING_UTF_16)
- API uses UTF-8 encoding (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 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 timeout 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 SPIRAM_USE_CAPSALLOC || 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 implement-
ation.

**Default value:**
- No (disabled)

**CONFIG_FATFS_FAST_SEEK_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

**Modbus configuration**

Contains:
- CONFIG_FMB_COMM_MODE_ASCII_EN
- CONFIG_FMB_COMM_MODE_RTU_EN
- CONFIG_FMB_COMM_MODE_TCP_EN
- CONFIG_FMB_CONTROLLER_NOTIFY_QUEUE_SIZE
- CONFIG_FMB_CONTROLLER_NOTIFY_TIMEOUT
- CONFIG_FMB_CONTROLLER_SLAVE_ID_SUPPORT
- CONFIG_FMB_CONTROLLER_STACK_SIZE
- CONFIG_FMB_PORT_TASK_PRIO
- CONFIG_FMB_PORT_TASK_STACK_SIZE
- CONFIG_FMB_QUEUE_LENGTH
- CONFIG_FMB_SERIAL_BUF_SIZE
- CONFIG_FMB_EVENT_QUEUE_TIMEOUT
- CONFIG_FMB_TIMER_PORT_ENABLED
Chapter 2. API Reference

- `CONFIG_FMB_PORT_TASK_AFFINITY`
- `CONFIG_FMB_TIMER_USE_ISR_DISPATCH_METHOD`
- `CONFIG_FMB_SERIAL_ASCII_BITS_PER_SYMB`
- `CONFIG_FMB_SERIAL_ASCII_TIMEOUT_RESPOND_MS`
- `CONFIG_FMB_MASTER_DELAY_MS_CONVERT`
- `CONFIG_FMB_MASTER_TIMEOUT_MS_RESPOND`

**CONFIG_FMB_COMM_MODE_TCP_EN**

Enable Modbus stack support for TCP communication mode

*Found in: Component config > Modbus configuration*

Enable Modbus TCP option for stack.

**Default value:**
- Yes (enabled)

**CONFIG_FMB_TCP_PORT_DEFAULT**

Modbus TCP port number

*Found in: Component config > Modbus configuration > CONFIG_FMB_COMM_MODE_TCP_EN*

Modbus default port number used by Modbus TCP stack

**Range:**
- from 0 to 65535

**Default value:**
- 502

**CONFIG_FMB_TCP_PORT_MAX_CONN**

Maximum allowed connections for TCP stack

*Found in: Component config > Modbus configuration > CONFIG_FMB_COMM_MODE_TCP_EN*

Maximum allowed connections number for Modbus TCP stack. This is used by Modbus master and slave port layer to establish connections. This parameter may decrease performance of Modbus stack and can cause increasing of processing time (increase only if absolutely necessary).

**Range:**
- from 1 to 6

**Default value:**
- 5

**CONFIG_FMB_TCP_CONNECTION_TOUT_SEC**

Modbus TCP connection timeout

*Found in: Component config > Modbus configuration > CONFIG_FMB_COMM_MODE_TCP_EN*

Modbus TCP connection timeout in seconds. Once expired the current connection with the client will be closed and Modbus slave will be waiting for new connection to accept.

**Range:**
- from 1 to 3600

**Default value:**
- 20
CONFIG_FMB_COMM_MODE_RTU_EN

Enable Modbus stack support for RTU mode

*Found in: Component config > Modbus configuration*

Enable RTU Modbus communication mode option for Modbus serial stack.

**Default value:**
- Yes (enabled)

CONFIG_FMB_COMM_MODE_ASCII_EN

Enable Modbus stack support for ASCII mode

*Found in: Component config > Modbus configuration*

Enable ASCII Modbus communication mode option for Modbus serial stack.

**Default value:**
- Yes (enabled)

CONFIG_FMB_MASTER_TIMEOUT_MS_RESPOND

Slave respond timeout (Milliseconds)

*Found in: Component config > Modbus configuration*

If master sends a frame which is not broadcast, it has to wait sometime for slave response. If slave is not respond in this time, the master will process timeout error.

**Range:**
- from 50 to 3000

**Default value:**
- 150

CONFIG_FMB_MASTER_DELAY_MS_CONVERT

Slave conversion delay (Milliseconds)

*Found in: Component config > Modbus configuration*

If master sends a broadcast frame, it has to wait conversion time to delay, then master can send next frame.

**Range:**
- from 50 to 400

**Default value:**
- 200

CONFIG_FMB_QUEUE_LENGTH

Modbus serial task queue length

*Found in: Component config > Modbus configuration*

Modbus serial driver queue length. It is used by event queue task. See the serial driver API for more information.

**Range:**
- from 0 to 200

**Default value:**
- 20
**CONFIG_FMB_PORT_TASK_STACK_SIZE**

Modbus port task stack size

*Found in: Component config > Modbus configuration*

Modbus port task stack size for rx/tx event processing. It may be adjusted when debugging is enabled (for example).

**Range:**
- from 2048 to 8192

**Default value:**
- 4096

**CONFIG_FMB_SERIAL_BUF_SIZE**

Modbus serial task RX/TX buffer size

*Found in: Component config > Modbus configuration*

Modbus serial task RX and TX buffer size for UART driver initialization. This buffer is used for modbus frame transfer. The Modbus protocol maximum frame size is 256 bytes. Bigger size can be used for non standard implementations.

**Range:**
- from 0 to 2048

**Default value:**
- 256

**CONFIG_FMB_SERIAL_ASCII_BITS_PER_SYMB**

Number of data bits per ASCII character

*Found in: Component config > Modbus configuration*

This option defines the number of data bits per ASCII character.

**Range:**
- from 7 to 8

**Default value:**
- 8

**CONFIG_FMB_SERIAL_ASCII_TIMEOUT_RESPOND_MS**

Response timeout for ASCII communication mode (ms)

*Found in: Component config > Modbus configuration*

This option defines response timeout of slave in milliseconds for ASCII communication mode. Thus the timeout will expire and allow the master program to handle the error.

**Range:**
- from 300 to 2000

**Default value:**
- 1000

**CONFIG_FMB_PORT_TASK_PRIO**

Modbus port task priority

*Found in: Component config > Modbus configuration*

Modbus port data processing task priority. The priority of Modbus controller task is equal to (CONFIG_FMB_PORT_TASK_PRIO - 1).
Chapter 2. API Reference

**CONFIG_FMB_PORT_TASK_AFFINITY**

Modbus task affinity

*Found in: Component config > Modbus configuration*

Allows setting the core affinity of the Modbus controller task, i.e. whether the task is pinned to particular CPU, or allowed to run on any CPU.

**Available options:**
- No affinity (FMB_PORT_TASK_AFFINITY_NO_AFFINITY)
- CPU0 (FMB_PORT_TASK_AFFINITY_CPU0)
- CPU1 (FMB_PORT_TASK_AFFINITY_CPU1)

**CONFIG_FMB_CONTROLLER_SLAVE_ID_SUPPORT**

Modbus controller slave ID support

*Found in: Component config > Modbus configuration*

Modbus slave ID support enable. When enabled the Modbus <Report Slave ID> command is supported by stack.

**Default value:**
- Yes (enabled)

**CONFIG_FMB_CONTROLLER_SLAVE_ID**

Modbus controller slave ID

*Found in: Component config > Modbus configuration > CONFIG_FMB_CONTROLLER_SLAVE_ID_SUPPORT*

Modbus slave ID value to identify modbus device in the network using <Report Slave ID> command. Most significant byte of ID is used as short device ID and other three bytes used as long ID.

**Range:**
- from 0 to 4294967295

**Default value:**
- “0x00112233”

**CONFIG_FMB_CONTROLLER_NOTIFY_TIMEOUT**

Modbus controller notification timeout (ms)

*Found in: Component config > Modbus configuration*

Modbus controller notification timeout in milliseconds. This timeout is used to send notification about accessed parameters.

**Range:**
- from 0 to 200

**Default value:**
- 20
CONFIG_FMB_CONTROLLER_NOTIFY_QUEUE_SIZE

Modbus controller notification queue size

*Found in: Component config > Modbus configuration*

Modbus controller notification queue size. The notification queue is used to get information about accessed parameters.

**Range:**
- from 0 to 200

**Default value:**
- 20

CONFIG_FMB_CONTROLLER_STACK_SIZE

Modbus controller stack size

*Found in: Component config > Modbus configuration*

Modbus controller task stack size. The Stack size may be adjusted when debug mode is used which requires more stack size (for example).

**Range:**
- from 0 to 8192

**Default value:**
- 4096

CONFIG_FMB_EVENT_QUEUE_TIMEOUT

Modbus stack event queue timeout (ms)

*Found in: Component config > Modbus configuration*

Modbus stack event queue timeout in milliseconds. This may help to optimize Modbus stack event processing time.

**Range:**
- from 0 to 500

**Default value:**
- 20

CONFIG_FMB_TIMER_PORT_ENABLED

Modbus stack use timer for 3.5T symbol time measurement

*Found in: Component config > Modbus configuration*

If this option is set the Modbus stack uses timer for T3.5 time measurement. Else the internal UART TOUT timeout is used for 3.5T symbol time measurement.

**Default value:**
- No (disabled)

CONFIG_FMB_TIMER_USE_ISR_DISPATCH_METHOD

Modbus timer uses ISR dispatch method

*Found in: Component config > Modbus configuration*

If this option is set the Modbus stack uses ISR dispatch method to send timeout events from the callback function called from ISR. This option has dependency with the UART_ISR_IN_IRAM option which places UART interrupt handler into IRAM to prevent delays related to processing of UART events.

**Default value:**
Chapter 2. API Reference

- No (disabled)

**FreeRTOS** Contains:

- `CONFIG_FREERTOS_CHECK_STACKOVERFLOW`
- `CONFIG_FREERTOS_CHECK_MUTEX_GIVEN_BY_OWNER`
- `CONFIG_FREERTOS_INTERRUPT_BACKTRACE`
- `CONFIG_FREERTOS_OPTIMIZED_SCHEDULER`
- `CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS`
- `CONFIG_FREERTOS_USE_TRACE_FACILITY`
- `CONFIG_FREERTOS_ENABLE_STATIC_TASK_CLEAN_UP`
- `CONFIG_FREERTOS_QUEUE_REGISTRY_SIZE`
- `CONFIG_FREERTOS_TIMER_QUEUE_LENGTH`
- `CONFIG_FREERTOS_TIMER_TASK_PRIORITY`
- `CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH`
- `CONFIG_FREERTOS_ASSERT_ON_UNTESTED_FUNCTION`
- `CONFIG_FREERTOS_IDLE_TASK_STACKSIZE`
- `CONFIG_FREERTOS_ISR_STACKSIZE`
- `CONFIG_FREERTOS_MAX_TASK_NAME_LEN`
- `CONFIG_FREERTOS_THREAD_LOCAL_STORAGE_POINTERS`
- `CONFIG_FREERTOS_PLACE_FUNCTIONS_INTO_FLASH`
- `CONFIG_FREERTOS_UNICORE`
- `CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK`
- `CONFIG_FREERTOS_ENABLE_BACKWARD_COMPATIBILITY`
- `CONFIG_FREERTOS_CHECK_PORT_CRITICAL_COMPLIANCE`
- `CONFIG_FREERTOS_HZ`
- `CONFIG_FREERTOS_USE_TICKLESS_IDLE`
- `CONFIG_FREERTOS_USE_IDLE_HOOK`
- `CONFIG_FREERTOS_USE_TICK_HOOK`
- `CONFIG_FREERTOS_CORETIMER`

**CONFIG_FREERTOS_UNICORE**

Run FreeRTOS only on first core

*Found in: Component config > FreeRTOS*

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.

# This invisible config value sets the value of tskNO_AFFINITY in task.h. # Intended to be used as a constant from other Kconfig files. # Value is (32-bit) INT_MAX.

**CONFIG_FREERTOS_CORETIMER**

Xtensa timer to use as the FreeRTOS tick source

*Found in: Component config > FreeRTOS*

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. Check

**Available options:**

- Timer 0 (int 6, level 1) (FREERTOS_CORETIMER_0)
  Select this to use timer 0
- Timer 1 (int 15, level 3) (FREERTOS_CORETIMER_1)
  Select this to use timer 1
• SYSTIMER0 (level 1) (FREERTOS_CORETIMER_SYSTIMER_LVL1)
  Select this to use systimer with the 1 interrupt priority.
• SYSTIMER0 (level 3) (FREERTOS_CORETIMER_SYSTIMER_LVL3)
  Select this to use systimer with the 3 interrupt priority.

**CONFIG_FREERTOS_OPTIMIZED_SCHEDULER**

Enable FreeRTOS platform optimized scheduler

*Found in: Component config > FreeRTOS*

On most platforms there are instructions that can speedup the ready task searching. Enabling this option the FreeRTOS with this instructions support will be built.

*Default value:*
  • Yes (enabled) if `CONFIG_FREERTOS_UNICORE`

**CONFIG_FREERTOS_HZ**

Tick rate (Hz)

*Found in: Component config > FreeRTOS*

Select the tick rate at which FreeRTOS does pre-emptive context switching.

*Range:*
  • from 1 to 1000

*Default value:*
  • 100

**CONFIG_FREERTOS_ASSERT_ON_UNTESTED_FUNCTION**

Halt when an SMP-untested function is called

*Found in: Component config > FreeRTOS*

Some functions in FreeRTOS have not been thoroughly tested yet when moving to the SMP implementation of FreeRTOS. When this option is enabled, these functions will throw an assert().

*Default value:*
  • Yes (enabled)

**CONFIG_FREERTOS_CHECK_STACKOVERFLOW**

Check for stack overflow

*Found in: Component config > FreeRTOS*

FreeRTOS can check for stack overflows in threads and trigger an user function called vApplicationStackOverflowHook when this happens.

*Available options:*
  • No checking (FREERTOS_CHECK_STACKOVERFLOW_NONE)
    Do not check for stack overflows (configCHECK_FOR_STACK_OVERFLOW=0)
  • Check by stack pointer value (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 (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_WATCHPOINT_END_OF_STACK**

Set a debug watchpoint as a stack overflow check

*Found in: Component config > FreeRTOS*

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’ing) 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_INTERRUPT_BACKTRACE**

Enable backtrace from interrupt to task context

*Found in: Component config > FreeRTOS*

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_THREAD_LOCAL_STORAGE_POINTERS**

Number of thread local storage pointers

*Found in: Component config > FreeRTOS*

FreeRTOS has the ability to store per-thread pointers in the task control block. This controls the number of pointers available.

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**
Idle Task stack size

*Found in: Component config > FreeRTOS*

The idle task has its own stack, sized in bytes. The default size is enough for most uses. Size can be reduced to 768 bytes if no (or simple) FreeRTOS idle hooks are used and pthread local storage or FreeRTOS local storage cleanup callbacks are not used.

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.

**Range:**
- from 768 to 32768

**Default value:**
- 1536

**CONFIG_FREERTOS_ISR_STACKSIZE**

ISR stack size

*Found in: Component config > FreeRTOS*

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 ESP_COREDUMP_DATA_FORMAT_ELF
- from 1536 to 32768

**Default value:**
- 2096 if ESP_COREDUMP_DATA_FORMAT_ELF
- 1536

**CONFIG_FREERTOS_USE_IDLE_HOOK**

Use FreeRTOS idle hook

*Found in: Component config > FreeRTOS*

- If enabled, configUSE_IDLE_HOOK will be defined as 1 in FreeRTOS.
- 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_TICK_HOOK**

Use FreeRTOS tick hook

*Found in: Component config > FreeRTOS*

- If enabled, configUSE_TICK_HOOK will be defined as 1 in FreeRTOS.
- 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

- **Maximum task name length**
  
  *Found in: Component config > FreeRTOS*

  Changes the maximum task name length. Each task allocated will include this many bytes for a task name. Using a shorter value saves a small amount of RAM, a longer value allows more complex names.

  For most uses, the default of 16 is OK.

  **Range:**
  - from 1 to 256

  **Default value:**
  - 16

## CONFIG_FREERTOS_ENABLE_BACKWARD_COMPATIBILITY

- **Support legacy FreeRTOS API**
  
  *Found in: Component config > FreeRTOS*

  This option enables the configENABLE_BACKWARD_COMPATIBILITY option, thus allowing the usage of legacy function names and types present in versions prior to FreeRTOS v8.0.0.

  **Default value:**
  - No (disabled)

## CONFIG_FREERTOS_ENABLE_STATIC_TASK_CLEAN_UP

- **Enable static task clean up hook**
  
  *Found in: Component config > FreeRTOS*

  Enable this option to make FreeRTOS call the static task clean up hook when a task is deleted.

  Bear in mind that if this option is enabled you will need to implement the following function:

  ```c
  void vPortCleanUpTCB ( void *pxTCB ) {
    // place clean up code here
  }
  ```

  **Default value:**
  - No (disabled)

## CONFIG_FREERTOS_TIMER_TASK_PRIORITY

- **FreeRTOS timer task priority**
  
  *Found in: Component config > FreeRTOS*

  The timer service task (primarily) makes use of existing FreeRTOS features, allowing timer functionality to be added to an application with minimal impact on the size of the application’s executable binary.

  Use this constant to define the priority that the timer task will run at.

  **Range:**
  - from 1 to 25

  **Default value:**
  - 1
**CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH**

FreeRTOS timer task stack size

*Found in: Component config > FreeRTOS*

The timer service task (primarily) makes use of existing FreeRTOS features, allowing timer functionality to be added to an application with minimal impact on the size of the application’s executable binary.

Use this constant to define the size (in bytes) of the stack allocated for the timer task.

**Range:**
- from 1536 to 32768

**Default value:**
- 2048

**CONFIG_FREERTOS_TIMER_QUEUE_LENGTH**

FreeRTOS timer queue length

*Found in: Component config > FreeRTOS*

FreeRTOS provides a set of timer related API functions. Many of these functions use a standard FreeRTOS queue to send commands to the timer service task. The queue used for this purpose is called the ‘timer command queue’. The ‘timer command queue’ is private to the FreeRTOS timer implementation, and cannot be accessed directly.

For most uses the default value of 10 is OK.

**Range:**
- from 5 to 20

**Default value:**
- 10

**CONFIG_FREERTOS_QUEUE_REGISTRY_SIZE**

FreeRTOS queue registry size

*Found in: Component config > FreeRTOS*

FreeRTOS uses the queue registry as a means for kernel aware debuggers to locate queues, semaphores, and mutexes. The registry allows for a textual name to be associated with a queue for easy identification within a debugging GUI. A value of 0 will disable queue registry functionality, and a value larger than 0 will specify the number of queues/semaphores/mutexes that the registry can hold.

**Range:**
- from 0 to 20

**Default value:**
- 0

**CONFIG_FREERTOS_USE_TRACE_FACILITY**

Enable FreeRTOS trace facility

*Found in: Component config > FreeRTOS*

If enabled, configUSE_TRACE_FACILITY will be defined as 1 in FreeRTOS. This will allow the usage of trace facility functions such as uxTaskGetSystemState().

**Default value:**
- No (disabled)
CONFIG_FREERTOS_USE_STATS_FORMATTING_FUNCTIONS

Enable FreeRTOS stats formatting functions

*Found in: Component config > FreeRTOS > CONFIG_FREERTOS_USE_TRACE_FACILITY*

If enabled, configUSE_STATS_FORMATTING_FUNCTIONS will be defined as 1 in FreeRTOS. This will allow the usage of stats formatting functions such as vTaskList().

**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 > 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_USE_STATS_FORMATTING_FUNCTIONS

CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS

Enable FreeRTOS to collect run time stats

*Found in: Component config > FreeRTOS*

If enabled, configGENERATE_RUN_TIME_STATS will be defined as 1 in FreeRTOS. This will allow FreeRTOS to collect information regarding the usage of processor time amongst FreeRTOS tasks. Run time stats are generated using either the ESP Timer or the CPU Clock as the clock source (Note that run time stats are only valid until the clock source overflows). The function vTaskGetRunTimeStats() will also be available if FREERTOS_USE_STATS_FORMATTING_FUNCTIONS and FREERTOS_USE_TRACE_FACILITY are enabled. vTaskGetRunTimeStats() will display the run time of each task as a % of the total run time of all CPUs (task run time / no of CPUs) / (total run time / 100 )

**Default value:**
- No (disabled)

CONFIG_FREERTOS_RUN_TIME_STATS_CLK

Choose the clock source for run time stats

*Found in: Component config > FreeRTOS > CONFIG_FREERTOS_GENERATE_RUN_TIME_STATS*

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 (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 (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 ESP32_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_USE_TICKLESS_IDLE**

Tickless idle support

*Found in: Component config > FreeRTOS*

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**

Minimum number of ticks to enter sleep mode for

*Found in: Component config > FreeRTOS > CONFIG_FREERTOS_USE_TICKLESS_IDLE*

FreeRTOS will enter light sleep mode if no tasks need to run for this number of ticks.

**Range:**

- from 2 to 4294967295 if `CONFIG_FREERTOS_USE_TICKLESS_IDLE`

**Default value:**

- 3 if `CONFIG_FREERTOS_USE_TICKLESS_IDLE`

**CONFIG_FREERTOS_TASK_FUNCTION_WRAPPER**

Enclose all task functions in a wrapper function

*Found in: Component config > FreeRTOS*

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_CHECK_MUTEX_GIVEN_BY_OWNER**

Check that mutex semaphore is given by owner task

*Found in: Component config > FreeRTOS*

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)
CONFIG_FREERTOS_CHECK_PORT_CRITICAL_COMPLIANCE

Tests compliance with Vanilla FreeRTOS port*_CRITICAL calls

Found in: Component config > FreeRTOS

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_PLACE_FUNCTIONS_INTO_FLASH

Place FreeRTOS functions into Flash

Found in: Component config > FreeRTOS

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_ENABLE_TASK_SNAPSHOT

Enable task snapshot functions

Found in: Component config > FreeRTOS

When enabled, the functions related to snapshots, such as vTaskGetSnapshot or uxTaskGetSnapshotAll, are compiled and linked.

Default value:
• Yes (enabled)

CONFIG_FREERTOS_PLACE_SNAPSHOT_FUNS_INTO_FLASH

Place task snapshot functions into flash

Found in: Component config > FreeRTOS > CONFIG_FREERTOS_ENABLE_TASK_SNAPSHOT

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

Hardware Abstraction Layer (HAL) and Low Level (LL) Contains:

• CONFIG_HAL_DEFAULT_ASSERTION_LEVEL

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 assert 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 (HAL_ASSERTION_EQUALS_SYSTEM)
• Disabled (HAL_ASSERTION_DISABLE)
• Silent (HAL_ASSERTION_SILENT)
• Enabled (HAL_ASSERTION_ENABLE)

**Heap memory debugging**  
Contains:

- `CONFIG_HEAP_ABORT_WHEN_ALLOCATION_FAILS`
- `CONFIG_HEAP_TASK_TRACKING`
- `CONFIG_HEAP_CORRUPTION_DETECTION`
- `CONFIG_HEAP_TRACING_DEST`
- `CONFIG_HEAP_TRACING_STACK_DEPTH`

**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) (HEAP_POISONING_DISABLED)
- Light impact (HEAP_POISONING_LIGHT)
- Comprehensive (HEAP_POISONING_COMPREHENSIVE)

**CONFIG_HEAP_TRACING_DEST**

Heap tracing

*Found in: Component config > Heap memory debugging*

Enables 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 (HEAP_TRACING_OFF)
- Standalone (HEAP_TRACING_STANDALONE)
- Host-based (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_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_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)

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 (LOG_DEFAULT_LEVEL_NONE)
- Error (LOG_DEFAULT_LEVEL_ERROR)
- Warning (LOG_DEFAULT_LEVEL_WARN)
- Info (LOG_DEFAULT_LEVEL_INFO)
- Debug (LOG_DEFAULT_LEVEL_DEBUG)
- Verbose (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 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 (LOG_MAXIMUM_EQUALS_DEFAULT)
- Error (LOG_MAXIMUM_LEVEL_ERROR)
- Warning (LOG_MAXIMUM_LEVEL_WARN)
- Info (LOG_MAXIMUM_LEVEL_INFO)
- Debug (LOG_MAXIMUM_LEVEL_DEBUG)
- Verbose (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)

**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 (LOG_TIMESTAMP_SOURCE_RTOS)
- System Time (LOG_TIMESTAMP_SOURCE_SYSTEM)

**LWIP**

Contains:

- Checksums
- 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_FRAG
- CONFIG_LWIP_IP6_FRAG
- CONFIG_LWIP_IP_FORWARD
- CONFIG_LWIP_NETBUF_RECVINFO
- 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_STATS
- CONFIG_LWIP_TIMERS_ONDEMAND
- CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES
- CONFIG_LWIP_PPP_MPPE_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_IPV6_ND6_NUM_NEIGHBORS
  CONFIG_LWIP_IPV6_MEMP_NUM_ND6_QUEUE
  CONFIG_LWIP_MAX_SOCKETS
  CONFIG_LWIP_ESP_GRATUITOUS_ARP
  SNTP
  CONFIG_LWIP_USE_ONLY_LWIP_SELECT
  CONFIG_LWIP_NETIF_LOOPBACK
  TCP
  CONFIG_LWIP_TCPIP_TASK_AFFINITY
  CONFIG_LWIP_TCPIP_TASK_STACK_SIZE
  CONFIG_LWIP_TCPIP_RECVMBOX_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 APIs (such as esp_netif_get_netif_impl_name())

**Default value:**
- No (disabled)

**CONFIG_LWIP_TCP_IP_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, TCP IP will perform tasks through context switching.

**Default value:**
- No (disabled)

**CONFIG_LWIP_DNS_SUPPORT_MDNS_QUERIES**

Enable mDNS queries in resolving host name

*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_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_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 reassemblying 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 reassemblying incoming fragmented IP6 packets.

**Default value:**
- No (disabled)

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.
**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:**
- Yes (enabled)

**CONFIG_LWIP_TCPIP_RECVMBOX_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 mailbox 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

**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_DHCPS_LEASE_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 the oldest device from its address pool, without notification.

*Range:*
  * from 1 to 64

*Default value:*
  * 8

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_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
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_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*
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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
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_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_RECCVMBOX_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 mailbox is too small, the mailbox may be full. If the mailbox is full, the LWIP drops the packets. So generally we need to make sure the TCP receive mailbox 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 (LWIP_TCP_OVERSIZE_MSS)
- 25% MSS (LWIP_TCP_OVERSIZE_QUARTER_MSS)
- Disabled (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_RECVMBOX_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_RECVMBOX_SIZE packets for each UDP socket, so the maximum possible cached UDP packets for all UDP sockets is UDP_RECVMBOX_SIZE multiples the maximum UDP socket number. In other words, the bigger UDP_RECVMBOX_SIZE means more memory. On the other hand, if the receiv 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_IP`
- `CONFIG_LWIP_CHECKSUM_CHECK_UDP`
- `CONFIG_LWIP_CHECKSUM_CHECK_ICMP`

**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 (LWIP_TCPIP_TASK_AFFINITY_NO_AFFINITY)
- CPU0 (LWIP_TCPIP_TASK_AFFINITY_CPU0)
- CPU1 (LWIP_TCPIP_TASK_AFFINITY_CPU1)

**CONFIG_LWIP_PPP_SUPPORT**

Enable PPP support (new/experimental)

*Found in: Component config > LWIP*

Enable PPP stack. Now only PPP over serial is possible.

PPP over serial support is experimental and unsupported.

**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.

**Range:**
- from 3 to 20

**Default value:**
- 3

**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:**
• 5

**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 PCB`

**CONFIG_LWIP_MAX_RAW_PCIE**
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` function 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_SNP_T_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_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 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_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 (LWIP_HOOK_TCP_ISN_NONE)
- Default implementation (LWIP_HOOK_TCP_ISN_DEFAULT)
- Custom implementation (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 (LWIP_HOOK_IP6_ROUTE_NONE)
- Default (weak) implementation (LWIP_HOOK_IP6_ROUTE_DEFAULT)
- Custom implementation (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 (LWIP_HOOK_ND6_GET_GW_NONE)
- Default (weak) implementation (LWIP_HOOK_ND6_GET_GW_DEFAULT)
- Custom implementation (LWIP_HOOK_ND6_GET_GW_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 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 (LWIP_HOOK_NETCONN_EXT_RESOLVE_NONE)
- Default (weak) implementation (LWIP_HOOK_NETCONN_EXT_RESOLVE_DEFAULT)
- Custom implementation (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 (LWIP_HOOK_IP6_INPUT_NONE)
- Default (weak) implementation (LWIP_HOOK_IP6_INPUT_DEFAULT)
- Custom implementation (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_DHCP_DEBUG`
- `CONFIG_LWIP_DHCP_STATE_DEBUG`
- `CONFIG_LWIP_ETHARP_DEBUG`
- `CONFIG_LWIP_ICMP_DEBUG`
- `CONFIG_LWIP_ICMP6_DEBUG`
- `CONFIG_LWIP_IP_DEBUG`
- `CONFIG_LWIP_IP6_DEBUG`
- `CONFIG_LWIP_NETIF_DEBUG`
- `CONFIG_LWIP_PBUF_DEBUG`
• `CONFIG_LWIP_SNTP_DEBUG`
• `CONFIG_LWIP_SOCKETS_DEBUG`
• `CONFIG_LWIP_TCP_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`

`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 & & 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_SNTP_DEBUG
Enable SNTP debug messages

*Found in: Component config > LWIP > CONFIG_LWIP_DEBUG*

*Default value:*
• No (disabled) if CONFIG_LWIP_DEBUG
**mbedTLS** Contains:

- `CONFIG_MBEDTLSASYMMETRIC.CONTENT.LEN`
- Certificate Bundle
- Certificates
- `CONFIG_MBEDTLSCHACHA20.C`
- `CONFIG_MBEDTLSDHM.C`
- `CONFIG_MBEDTLECP.C`
- `CONFIG_MBEDTLECDDH.C`
- `CONFIG_MBEDTLECP.JPAKE.C`
- `CONFIG_MBEDTLS.ECP.DP.BP256R1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.BP384R1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.BP512R1.ENABLED`
- `CONFIG_MBEDTLS.CMAC.C`
- `CONFIG_MBEDTLS.ECP.DP.CURVE25519.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.ECDH.DETERMINISTIC`
- `CONFIG_MBEDTLS_HARDWARE_AES`
- `CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN`
- `CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY`
- `CONFIG_MBEDTLS_HARDWARE_MPI`
- `CONFIG_MBEDTLS_HARDWARE_SHA`
- `CONFIG_MBEDTLS_DEBUG`
- `CONFIG_MBEDTLS.ECP.RESTARTABLE`
- `CONFIG_MBEDTLS_HAVE.TIME`
- `CONFIG_MBEDTLS_RIPEMD160.C`
- `CONFIG_MBEDTLS.ECP.DP.SECP192K1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP192R1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP224K1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP224R1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP256K1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP256R1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP384R1.ENABLED`
- `CONFIG_MBEDTLS.ECP.DP.SECP521R1.ENABLED`
- `CONFIG_MBEDTLS_SHA512.C`
- `CONFIG_MBEDTLS.THREADING.C`
- `CONFIG_MBEDTLS.X509.CHECK.EXTENDED.KEY.USAGE`
- `CONFIG_MBEDTLS.X509.CHECK.KEY.USAGE`
- `CONFIG_MBEDTLS.LARGE.KEY.SOFTWARE_MPI`
- `CONFIG_MBEDTLS.HKDF.C`
- `CONFIG_MBEDTLS.SSL.PROTO.SSL3`

**mbedTLS v2.28.x related**

- `CONFIG_MBEDTLS_MEM_ALLOC_MODE`
- `CONFIG_MBEDTLS.ECP.NIST_OPTIM`
- `CONFIG_MBEDTLS.POLY1305.C`
- `CONFIG_MBEDTLS_SECURITY.RISKS`
- `CONFIG_MBEDTLS.SSL_ALPN`
- `CONFIG_MBEDTLS.SSL.PROTO.DTLS`
- `CONFIG_MBEDTLS.SSL.PROTO.GMTSSL1_1`
- `CONFIG_MBEDTLS.SSL.PROTO.TLS1`
- `CONFIG_MBEDTLS.SSL.PROTO.TLS1_1`
- `CONFIG_MBEDTLS.SSL.PROTO.TLS1_2`
- `CONFIG_MBEDTLS.SSL.RENEGOTIATION`

**Symmetric Ciphers**

- `TLS Key Exchange Methods`
- `CONFIG_MBEDTLS.SSL.MAX CONTENT.LEN`
- `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 (MBEDTLS_INTERNAL_MEM_ALLOC)
• External SPIRAM (MBEDTLS_EXTERNAL_MEM_ALLOC)
• Default alloc mode (MBEDTLS_DEFAULT_MEM_ALLOC)
• Custom alloc mode (MBEDTLS_CUSTOM_MEM_ALLOC)
• Internal IRAM (MBEDTLS_IRAM_8BIT_MEM_ALLOC)
  Allows to use IRAM memory region as 8bit accessible region.
  TLS input and output buffers will be allocated in IRAM section which is 32bit aligned memory. Every unaligned (8bit or 16bit) access will result in an exception and incur penalty of certain clock cycles per unaligned read/write.

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_MBEDTLSASYMMETRIC_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_MBEDTLSASYMMETRIC_CONTENT_LEN*

This defines maximum incoming fragment length, overriding default maximum content length (MBEDTLS_SSL_MAX_CONTENT_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_MBEDTLSASYMMETRIC_CONTENT_LEN*

This defines maximum outgoing fragment length, overriding default maximum content length (MBEDTLS_SSL_MAX_CONTENT_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_SSL_PROTO_DTLS && CONFIG_MBEDTLS_SSL_VARIABLE_BUFFER_LENGTH

**CONFIG_MBEDTLS_DYNAMIC_FREE_PEER_CERT**

Free SSL peer certificate after its usage

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_DYNAMIC_BUFFER*

Free peer certificate after its usage in handshake process.

**Default value:**
- No (disabled) if CONFIG_MBEDTLS_DYNAMIC_BUFFER
**CONFIG_MBEDTLS_DYNAMIC_FREE_CONFIG_DATA**

Free private key and DHM data after its usage

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_DYNAMIC_BUFFER*

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 (MBEDTLS_DEBUG_LEVEL_WARN)
- Info (MBEDTLS_DEBUG_LEVEL_INFO)
- Debug (MBEDTLS_DEBUG_LEVEL_DEBUG)
- Verbose (MBEDTLS_DEBUG_LEVEL_VERBOSE)

**mbedTLS v2.28.x related** Contains:
- DTLS-based configurations
- CONFIG_MBEDTLS_SSL_CONTEXT.Serialization
- CONFIG_MBEDTLS_X509_TRUSTED_CERT_CALLBACK
- CONFIG_MBEDTLS_SSL_KEEP_PEER_CERTIFICATE
• \texttt{CONFIG_MBEDTLS_ECDH_LEGACY_CONTEXT}
• \texttt{CONFIG_MBEDTLS_SSL_VARIABLE_BUFFER_LENGTH}

\textbf{CONFIG_MBEDTLS_SSL_VARIABLE_BUFFER_LENGTH}

Variable SSL buffer length

\textit{Found in: Component config > mbedTLS > mbedTLS v2.28.x related}

This enables the SSL buffer to be resized automatically based on the negotiated maximum fragment length in each direction.

\textbf{Default value:}
• No (disabled)

\textbf{CONFIG_MBEDTLS_ECDH_LEGACY_CONTEXT}

Use a backward compatible ECDH context (Experimental)

\textit{Found in: Component config > mbedTLS > mbedTLS v2.28.x related}

Use the legacy ECDH context format. Define this option only if you enable \texttt{MBEDTLS_ECP_RESTARTABLE} or if you want to access ECDH context fields directly.

\textbf{Default value:}
• Yes (enabled) if \texttt{CONFIG_MBEDTLS_ECDH_C} \texttt{&&} \texttt{CONFIG_MBEDTLS_ECP_RESTARTABLE}

\textbf{CONFIG_MBEDTLS_X509_TRUSTED_CERT_CALLBACK}

Enable trusted certificate callbacks

\textit{Found in: Component config > mbedTLS > mbedTLS v2.28.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.

\textbf{Default value:}
• No (disabled)

\textbf{CONFIG_MBEDTLS_SSL_CONTEXT.Serialization}

Enable serialization of the TLS context structures

\textit{Found in: Component config > mbedTLS > mbedTLS v2.28.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.

\textbf{Default value:}
• No (disabled)

\textbf{CONFIG_MBEDTLS_SSL_KEEP_PEER_CERTIFICATE}

Keep peer certificate after handshake completion

\textit{Found in: Component config > mbedTLS > mbedTLS v2.28.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 `CONFIG_MBEDTLS_DYNAMIC_FREE_PEER_CERT`

**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 v2.28.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. The Connection ID extension is still in draft state. Refer: version draft-ietf-tls-dtls-connection-id-05

**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 v2.28.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`

**Default value:**
  • 32 if `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID`

**CONFIG_MBEDTLS_SSL_CID_OUT_LEN_MAX**
Maximum length of CIDs used for outgoing DTLS messages

*Found in: Component config > mbedTLS > mbedTLS v2.28.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`

**Default value:**
  • 32 if `CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID`

**CONFIG_MBEDTLS_SSL_CID_PADDING_GRANULARITY**
Record plaintext padding (for DTLS 1.2)

*Found in: Component config > mbedTLS > mbedTLS v2.28.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

Default value:
• 16 if CONFIG_MBEDTLS_SSL_DTLS_CONNECTION_ID

CONFIG_MBEDTLS_SSL_DTLS_SRTP
Enable support for negotiation of DTLS-SRTP (RFC 5764)

Found in: Component config > mbedTLS > mbedTLS v2.28.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 (MBEDTLS_CERTIFICATE_BUNDLE_DEFAULT_FULL)
• Use only the most common certificates from the default bundles (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 (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_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 SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST

**CONFIG_MBEDTLS_AES_USE_INTERRUPT**

Use interrupt for long AES operations

*Found in:* Component config > mbedTLS > CONFIG_MBEDTLS_HARDWARE_AES

Use an interrupt to coordinate long AES operations.

This allows other code to run on the CPU while an AES operation is pending. Otherwise the CPU busy-waits.

**Default value:**

- Yes (enabled)
**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 SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST

**CONFIG_MBEDTLS_MPI_USE_INTERRUPT**

Use interrupt for MPI exp-mod operations

*Found in: Component config > mbedTLS > CONFIG_MBEDTLS_HARDWARE_MPI*

Use an interrupt to coordinate long MPI operations.

This allows other code to run on the CPU while an MPI operation is pending. Otherwise the CPU busy-waits.

**Default value:**

- Yes (enabled)

**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 SPIRAM_CACHE_WORKAROUND_STRATEGY_DUPLDST

**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_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_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 MBEDTLS_X509_BADCERT_FUTURE or 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)
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)

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)

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 (MBEDTLS_TLS_SERVER_AND_CLIENT)
- Server (MBEDTLS_TLS_SERVER_ONLY)
- Client (MBEDTLS_TLS_CLIENT_ONLY)
- None (MBEDTLS_TLS_DISABLED)

TLS Key Exchange Methods
Contains:
- CONFIG_MBEDTLS_KEY_EXCHANGE_DHE_RSA
- CONFIG_MBEDTLS_KEY_EXCHANGE_ECJPAKE
- CONFIG_MBEDTLS_KEY_EXCHANGE_RSA
- 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 options 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 &amp; &amp; 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 &amp; &amp; 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_DHM_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_SSL3
Legacy SSL 3.0 support

*Found in: Component config > mbedtls*

Support the legacy SSL 3.0 protocol. Most servers will speak a newer TLS protocol these days.

**Default value:**
- No (disabled)

CONFIG_MBEDTLS_SSL_PROTO_TLS1
Support TLS 1.0 protocol

*Found in: Component config > mbedtls*

**Default value:**
- Yes (enabled)

CONFIG_MBEDTLS_SSL_PROTO_TLS1_1
Support TLS 1.1 protocol

*Found in: Component config > mbedtls*

**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 1.1 to be enabled for DTLS 1.0 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_X509_CHECK_KEY_USAGE
Enable verification of the keyUsage extension
*Found in: Component config > mbedTLS*
Disabling this avoids problems with mis-issued and/or misused (intermediate) CA and leaf certificates. Depending on your PKI use, disabling this can be a security risk.
*Default value:*
  * Yes (enabled)*

CONFIG_MBEDTLS_X509_CHECK_EXTENDED_KEY_USAGE
Enable verification of the extendedKeyUsage extension
*Found in: Component config > mbedTLS*
Disabling this avoids problems with mis-issued and/or misused certificates. Depending on your PKI use, disabling this can be a security risk.
*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_RC4_MODE`
• `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)
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**CONFIG_MBEDTLS_RC4_MODE**

RC4 Stream Cipher (legacy, insecure)

*Found in: Component config > mbedTLS > Symmetric Ciphers*

ARCFOUR (RC4) stream cipher can be disabled entirely, enabled but not added to default ciphersuites, or enabled completely.

Please consider the security implications before enabling RC4.

**Available options:**
- Disabled (MBEDTLS_RC4_DISABLED)
- Enabled, not in default ciphersuites (MBEDTLS_RC4_ENABLED_NO_DEFAULT)
- Enabled (MBEDTLS_RC4_ENABLED)

**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)
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**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 \((\text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{SIGN} \text{ || } \text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{VERIFY}) \text{ && } \text{CONFIG}_\text{MBEDTLS}_\text{ECP}_\text{C})\)

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 \((\text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{SIGN} \text{ || } \text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{VERIFY}) \text{ && } \text{CONFIG}_\text{MBEDTLS}_\text{ECP}_\text{C})\)

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 \((\text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{SIGN} \text{ || } \text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{VERIFY}) \text{ && } \text{CONFIG}_\text{MBEDTLS}_\text{ECP}_\text{C})\)

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 \((\text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{SIGN} \text{ || } \text{CONFIG}_\text{MBEDTLS}_\text{ATCA}_\text{HW}_\text{ECDSA}_\text{VERIFY}) \text{ && } \text{CONFIG}_\text{MBEDTLS}_\text{ECP}_\text{C})\)

CONFIG_MBEDTLS_ECP_DP_SECP192K1_ENABLED
Enable SECP192K1 curve

*Found in: Component config > mbedTLS*

Enable support for SECP192K1 Elliptic Curve.
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 (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && 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 (CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN || CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY) && CONFIG_MBEDTLS_ECP_C

CONFIG_MBEDTLS_ECP_DP_BP256R1_ENABLED
Enable BP256R1 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_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 \((\text{CONFIG_MBEDTLS_ATCA_HW_ECDSA_SIGN} \lor \text{CONFIG_MBEDTLS_ATCA_HW_ECDSA_VERIFY}) \land \text{CONFIG_MBEDTLS_ECP_C})\)

CONFIG_MBEDTLS_ECP_NIST_OPTIM
NIST ‘mod p’ optimisation

*Found in: Component config > mbedTLS*
NIST ‘mod p’ optimisations increase Elliptic Curve operation performance.
Disabling this option saves some code size.

# 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 \(\text{CONFIG_MBEDTLS_CHACHA20_C} \land \text{CONFIG_MBEDTLS_POLY1305_C}\)
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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:**
- 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)

CONFIG_MBEDTLS_SECURITY_RISKS
Show configurations with potential security risks

**Found in:** Component config > mbedTLS

**Default value:**
- No (disabled)
Contains:

- `CONFIG_MBEDTLS_ALLOW_UNSUPPORTED_CRITICAL_EXT`

**CONFIG_MBEDTLS_ALLOW_UNSUPPORTED_CRITICAL_EXT**

X.509 CRT parsing with unsupported critical extensions

*Found in: Component config > mbedtls > CONFIG_MBEDTLS_SECURITY_RISKS*

Allow the X.509 certificate parser to load certificates with unsupported critical extensions

**Default value:**

- No (disabled) if `CONFIG_MBEDTLS_SECURITY_RISKS`

**mDNS**

Contains:

- `CONFIG_MDNS_MAX_SERVICES`
- `CONFIG_MDNS_SERVICE_ADD_TIMEOUT_MS`
- `CONFIG_MDNS STRICT_MODE`
- `CONFIG_MDNS_TASK_AFFINITY`
- `CONFIG_MDNS_TASK_PRIORITY`
- `CONFIG_MDNS_TASK_STACK_SIZE`
- `CONFIG_MDNS_TIMER_PERIOD_MS`
- `CONFIG_MDNS_MULTIPLE_INSTANCE`
- `CONFIG_MDNS_NETWORKING_SOCKET`

**CONFIG_MDNS_MAX_SERVICES**

Max number of services

*Found in: Component config > mDNS*

Services take up a certain amount of memory, and allowing fewer services to be open at the same time conserves memory. Specify the maximum amount of services here. The valid value is from 1 to 64.

**Range:**

- from 1 to 64

**Default value:**

- 10

**CONFIG_MDNS_TASK_PRIORITY**

mDNS task priority

*Found in: Component config > mDNS*

Allows setting mDNS task priority. Please do not set the task priority higher than priorities of system tasks. Compile time warning/error would be emitted if the chosen task priority were too high.

**Range:**

- from 1 to 255

**Default value:**

- 1

**CONFIG_MDNS_TASK_STACK_SIZE**

mDNS task stack size

*Found in: Component config > mDNS*

Allows setting mDNS task stacksize.

**Default value:**
CONFIG_MDNS_TASK_AFFINITY

mDNS task affinity

*Found in: Component config > mDNS*

Allows setting mDNS tasks affinity, i.e. whether the task is pinned to CPU0, pinned to CPU1, or allowed to run on any CPU.

**Available options:**
- No affinity (MDNS_TASK_AFFINITY_NO_AFFINITY)
- CPU0 (MDNS_TASK_AFFINITY_CPU0)
- CPU1 (MDNS_TASK_AFFINITY_CPU1)

CONFIG_MDNS_SERVICE_ADD_TIMEOUT_MS

mDNS adding service timeout (ms)

*Found in: Component config > mDNS*

Configures timeout for adding a new mDNS service. Adding a service fails if could not be completed within this time.

**Range:**
- from 10 to 30000

**Default value:**
- 2000

CONFIG_MDNS_STRICT_MODE

mDNS strict mode

*Found in: Component config > mDNS*

Configures strict mode. Set this to 1 for the mDNS library to strictly follow the RFC6762: Currently the only strict feature: Do not repeat original questions in response packets (defined in RFC6762 sec. 6). Default configuration is 0, i.e. non-strict mode, since some implementations, such as lwIP mdns resolver (used by standard POSIX API like getaddrinfo, gethostbyname) could not correctly resolve advertised names.

**Default value:**
- No (disabled)

CONFIG_MDNS_TIMER_PERIOD_MS

mDNS timer period (ms)

*Found in: Component config > mDNS*

Configures period of mDNS timer, which periodically transmits packets and schedules mDNS searches.

**Range:**
- from 10 to 10000

**Default value:**
- 100
**CONFIG_MDNS_NETWORKING_SOCKET**

Use BSD sockets for mdns networking

*Found in: Component config > mDNS*

Enables optional mdns networking implementation using BSD sockets in UDP multicast mode. This option creates a new thread to serve receiving packets (TODO). This option uses additional N sockets, where N is number of interfaces.

**Default value:**
- No (disabled)

**CONFIG_MDNS_MULTIPLE_INSTANCE**

Multiple instances under the same service type

*Found in: Component config > mDNS*

Enables adding multiple service instances under the same service type.

**Default value:**
- Yes (enabled)

**ESP-MQTT Configurations**

Contains:

- `CONFIG_MQTT_CUSTOM_OUTBOX`
- `CONFIG_MQTT_TRANSPORT_SSL`
- `CONFIG_MQTT_TRANSPORT_WEBSOCKET`
- `CONFIG_MQTT_PROTOCOL_311`
- `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_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_TRANSPORT_SSL**

Enable MQTT over SSL

*Found in: Component config > ESP-MQTT Configurations*

Enable MQTT transport over SSL with mbedtls

**Default value:**
- Yes (enabled)
Chapter 2. API Reference

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 than 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_WEB_SOCKET

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:*

- 443 if CONFIG_MQTT_USE_CUSTOM_CONFIG & & CONFIG_MQTT_TRANSPORT_WEB_SOCKET & & CONFIG_MQTT_TRANSPORT_WEB_SOCKET_SECURE

CONFIG_MQTT_BUFFER_SIZE

Default MQTT Buffer Size

*Found in: Component config > ESP-MQTT Configurations > CONFIG_MQTT_USE_CUSTOM_CONFIG*

This buffer size using 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_TASK_CORE_SELECTION_ENABLED
Enable MQTT task core selection

Found in: Component config > ESP-MQTT Configurations

This will enable core selection

Default value:
- “false”

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 (MQTT_USE_CORE_0)
- Core 1 (MQTT_USE_CORE_1)

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_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 (NEWLIB_STDOUT_LINE_ENDING_CRLF)
- LF (NEWLIB_STDOUT_LINE_ENDING_LF)
- CR (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 (NEWLIB_STDIN_LINE_ENDING_CRLF)
- LF (NEWLIB_STDIN_LINE_ENDING_LF)
- CR (NEWLIB_STDIN_LINE_ENDING_CR)
CONFIG_NEWLIB_NANO_FORMAT

Enable ‘nano’ formatting options for printf/scanf family

*Found in: Component config > Newlib*

ESP32 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, 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.

If you need 64-bit integer formatting support or C99 features, keep this option disabled.

**Default value:**

- No (disabled)

NVS Contains:

- CONFIG_NVS_ENCRYPTION
- CONFIG_NVS_COMPATIBLE_PRE_V4_3_ENCRYPTION_FLAG

CONFIG_NVS_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.

OpenSSL Contains:

- CONFIG_OPENSSL_DEBUG
- CONFIG_OPENSSL_ERROR_STACK
- CONFIG_OPENSSL_LOWLEVEL_DEBUG
- CONFIG_OPENSSL_DEBUG_LEVEL
- CONFIG_OPENSSL_ASSERT
CONFIG.OPENSSL_DEBUG
Enable OpenSSL debugging

*Found in: Component config > OpenSSL*
Enable OpenSSL debugging function.
If the option is enabled, “SSL_DEBUG” works.

**Default value:**
- No (disabled)

CONFIG.OPENSSL_ERROR_STACK
Enable OpenSSL error structure

*Found in: Component config > OpenSSL*
Enable OpenSSL Error reporting

**Default value:**
- Yes (enabled)

CONFIG.OPENSSL_DEBUG_LEVEL
OpenSSL debugging level

*Found in: Component config > OpenSSL*
OpenSSL debugging level.
Only function whose debugging level is higher than “OPENSSL_DEBUG_LEVEL” works.
For example: If OPENSSL_DEBUG_LEVEL = 2, you use function “SSL_DEBUG(1, “malloc failed”)”. Because 1 < 2, it will not print.

**Range:**
- from 0 to 255 if CONFIG.OPENSSL_DEBUG

**Default value:**
- 0 if CONFIG.OPENSSL_DEBUG

CONFIG.OPENSSL_LOWLEVEL_DEBUG
Enable OpenSSL low-level module debugging

*Found in: Component config > OpenSSL*
If the option is enabled, low-level module debugging function of OpenSSL is enabled, e.g. mbedtls internal debugging function.

**Default value:**
- No (disabled) if CONFIG.OPENSSL_DEBUG

CONFIG.OPENSSL_ASSERT
Select OpenSSL assert function

*Found in: Component config > OpenSSL*
OpenSSL function needs “assert” function to check if input parameters are valid.
If you want to use assert debugging function, “OPENSSL_DEBUG” should be enabled.

**Available options:**
- Do nothing (OPENSSL_ASSERT_DO NOTHING)
  Do nothing and “SSL_ASSERT” does not work.
• Check and exit (OPENSSL_ASSERT_EXIT)
  Enable assert exiting, it will check and return error code.
• Show debugging message (OPENSSL_ASSERT_DEBUG)
  Enable assert debugging, it will check and show debugging message.
• Show debugging message and exit (OPENSSL_ASSERT_DEBUG_EXIT)
  Enable assert debugging and exiting, it will check, show debugging message and return error code.
• Show debugging message and block (OPENSSL_ASSERT_DEBUG_BLOCK)
  Enable assert debugging and blocking, it will check, show debugging message and block by “while (1);”.

OpenThread  Contains:
  • CONFIG_OPENTHREAD_ENABLED

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_RADIO_TYPE

Config the Thread radio type

Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED

Configure how OpenThread connects to the 15.4 radio

Available options:
  • Native 15.4 radio (OPENTHREAD_RADIO_NATIVE)
    Select this to use the native 15.4 radio.
  • Connect via UART (OPENTHREAD_RADIO_SPINEL_UART)
    Select this to connect to a Radio Co-Processor via UART.

CONFIG_OPENTHREAD_DEVICE_TYPE

Config the Thread device type

Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED

OpenThread can be configured to different device types (FTD, MTD, Radio)

Available options:
  • Full Thread Device (OPENTHREAD_FTD)
    Select this to enable Full Thread Device which can act as router and leader in a Thread network.
  • Minimal Thread Device (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 (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_DIAG**

Enable diag

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

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_COMMISIONER**

Enable Commissioner

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

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_JOINSER**

Enable Joiner

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

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 > CONFIG_OPENTHREAD_ENABLED*

Select this option to enable SRP Client in OpenThread. This allows a device to register SRP services to SRP Server.

**Default value:**
- No (disabled) if CONFIG_OPENTHREAD_ENABLED

**CONFIG_OPENTHREAD_BORDER_ROUTER**

Enable Border Router

*Found in: Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED*

Select this option to enable border router features in OpenThread.

**Default value:**
- No (disabled) if CONFIG_OPENTHREAD_ENABLED
CONFIG_OPENTHREAD_TREL

Enable Thread Radio Encapsulation Link

*Found in:* Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED > CONFIG_OPENTHREAD_BORDER_ROUTER

Select this option to enable sending 15.4 frames through the backbone interface.

**Default value:**
- No (disabled) if CONFIG_OPENTHREAD_BORDER_ROUTER

CONFIG_OPENTHREAD_ESP_LIB_FROM_INTERNAL_SRC

Build esp_openthread libraries from source

*Found in:* Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED

Override the shipped libopenthread_br.a and libopenthread_port.a, for internal builds.

**Default value:**
- No (disabled) if CONFIG_OPENTHREAD_ENABLED

CONFIG_OPENTHREAD_NUM_MESSAGE_BUFFERS

The number of openthread message buffers

*Found in:* Component config > OpenThread > CONFIG_OPENTHREAD_ENABLED

**Range:**
- from 50 to 100 if CONFIG_OPENTHREAD_ENABLED

**Default value:**
- 65 if CONFIG_OPENTHREAD_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
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 (PTHREAD_DEFAULT_CORE_NO_AFFINITY)
- Core 0 (PTHREAD_DEFAULT_CORE_0)
- Core 1 (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”

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
- CONFIG_SPI_FLASH_SHARE_SPI1_BUS
- CONFIG_SPI_FLASH_ROM_IMPL
- CONFIG_SPI_FLASH_USE_LEGACY_IMPL
- CONFIG_SPI_FLASH_VERIFY_WRITE
- CONFIG_SPI_FLASH_DANGEROUS_WRITE

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)
**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_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_SPI_FLASH_ENABLE_COUNTERS**

Enable operation counters

*Found in: Component config > SPI Flash driver*

This option enables the following APIs:

- `spi_flash_reset_counters`
- `spi_flash_dump_counters`
- `spi_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:**

- 0

**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)
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)

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 (SPI_FLASH_DANGEROUS_WRITE_ABORTS)
- Fails (SPI_FLASH_DANGEROUS_WRITE_FAILS)
- Allowed (SPI_FLASH_DANGEROUS_WRITE_ALLOWED)

CONFIG_SPI_FLASH_USE_LEGACY_IMPL

Use the legacy implementation before IDF v4.0

*Found in: Component config > SPI Flash driver*

The implementation of SPI flash has been greatly changed in IDF v4.0. Enable this option to use the legacy implementation.

*Default value:*
- No (disabled)

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_SPI_FLASH_USE_LEGACY_IMPL`

**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)

**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)

**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

**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

**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 options 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
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)

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_SPI_FLASH_USE_LEGACY_IMPL

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_SPI_FLASH_USE_LEGACY_IMPL

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_MXIC_OPI_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)

**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)

**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)

**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)

**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)

**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)
CONFIG_SPI_FLASH_SUPPORT_MXIC_OPI_CHIP

mxic (opi)

*Found in: Component config > SPI Flash driver > Auto-detect flash chips*

Enable this to support auto detection of Octal 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)

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)

**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`
- `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/disable 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 255

**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:**
- 32

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:**
- No (disabled)

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)
Chapter 2. API Reference

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

TinyUSB Stack  Contains:
  • CONFIG_TINYUSB

CONFIG_TINYUSB
Use TinyUSB Stack

*Found in: Component config > TinyUSB Stack*
Enable TinyUSB stack support. Note that, esp-idf only uses the device stack provided by TinyUSB.

**Default value:**
  • No (disabled)

CONFIG_TINYUSB_DEBUG_LEVEL
TinyUSB log level (0-3)

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB*
Specify verbosity of TinyUSB log output.

**Range:**
  • from 0 to 3 if CONFIG_TINYUSB

**Default value:**
  • 0 if CONFIG_TINYUSB

TinyUSB task configuration  Contains:
  • CONFIG_TINYUSB_NO_DEFAULT_TASK
  • CONFIG_TINYUSB_TASK_PRIORITY
  • CONFIG_TINYUSB_TASK_STACK_SIZE
**CONFIG_TINYUSB_NO_DEFAULT_TASK**

Do not create a TinyUSB task

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > TinyUSB task configuration*

This option allows to not create the FreeRTOS task during the driver initialization. User will have to handle TinyUSB events manually.

**Default value:**
- No (disabled) if `CONFIG_TINYUSB`

**CONFIG_TINYUSB_TASK_PRIORITY**

TinyUSB task priority

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > TinyUSB task configuration*

Set the priority of the default TinyUSB main task.

**Default value:**
- 5 if `CONFIG_TINYUSB_NO_DEFAULT_TASK` && `CONFIG_TINYUSB`

**CONFIG_TINYUSB_TASK_STACK_SIZE**

TinyUSB task stack size (bytes)

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > TinyUSB task configuration*

Set the stack size of the default TinyUSB main task.

**Default value:**
- 4096 if `CONFIG_TINYUSB_NO_DEFAULT_TASK` && `CONFIG_TINYUSB`

**Descriptor configuration**

Contains:

- `CONFIG_TINYUSB_DESC_BCD_DEVICE`
- `CONFIG_TINYUSB_DESC_CDC_STRING`
- `CONFIG_TINYUSB_DESC_HID_STRING`
- `CONFIG_TINYUSB_DESC_MANUFACTURER_STRING`
- `CONFIG_TINYUSB_DESC_MSC_STRING`
- `CONFIG_TINYUSB_DESC_CUSTOM_PID`
- `CONFIG_TINYUSB_DESC_USE_DEFAULT_PID`
- `CONFIG_TINYUSB_DESC_PRODUCT_STRING`
- `CONFIG_TINYUSB_DESC_SERIAL_STRING`
- `CONFIG_TINYUSB_DESC_CUSTOM_VID`
- `CONFIG_TINYUSB_DESC_USE_ESPRESSIF_VID`

**CONFIG_TINYUSB_DESC_USE_ESPRESSIF_VID**

VID: Use Espressif’s vendor ID

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Enable this option, USB device will use Espressif’s vendor ID as its VID. This is helpful at product develop stage.

**Default value:**
- Yes (enabled) if `CONFIG_TINYUSB`
**CONFIG_TINYUSB_DESC_CUSTOM_VID**

VID: Custom vendor ID

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Custom Vendor ID.

**Default value:**
- “0x1234” if CONFIG_TINYUSB_DESC_USE_ESPRESSIF_VID && CONFIG_TINYUSB

**CONFIG_TINYUSB_DESC_USE_DEFAULT_PID**

PID: Use a default PID assigned to TinyUSB

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Default TinyUSB PID assigning uses values 0x4000—0x4007.

**Default value:**
- Yes (enabled) if CONFIG_TINYUSB

**CONFIG_TINYUSB_DESC_CUSTOM_PID**

PID: Custom product ID

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Custom Product ID.

**Default value:**
- “0x5678” if CONFIG_TINYUSB_DESC_USE_DEFAULT_PID && CONFIG_TINYUSB

**CONFIG_TINYUSB_DESC_BCD_DEVICE**

bcdDevice

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Version of the firmware of the USB device.

**Default value:**
- “0x0100” if CONFIG_TINYUSB

**CONFIG_TINYUSB_DESC_MANUFACTURER_STRING**

Manufacturer name

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Name of the manufacturer of the USB device.

**Default value:**
- “Espressif Systems” if CONFIG_TINYUSB

**CONFIG_TINYUSB_DESC_PRODUCT_STRING**

Product name

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Name of the USB device.

**Default value:**
- “Espressif Device” if CONFIG_TINYUSB
CONFIG_TINYUSB_DESC_SERIAL_STRING
Serial string

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Serial number of the USB device.

**Default value:**
- 123456 if CONFIG_TINYUSB

CONFIG_TINYUSB_DESC_CDC_STRING
CDC Device String

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Name of the CDC device.

**Default value:**
- “Espressif CDC Device” if CONFIG_TINYUSB_CDC_ENABLED && CONFIG_TINYUSB

CONFIG_TINYUSB_DESC_MSC_STRING
MSC Device String

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Name of the MSC device.

**Default value:**
- “Espressif MSC Device” if CONFIG_TINYUSB_MSC_ENABLED && CONFIG_TINYUSB

CONFIG_TINYUSB_DESC_HID_STRING
HID Device String

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Descriptor configuration*

Name of the HID device

**Default value:**
- “Espressif HID Device” if TINYUSB_HID_ENABLED && CONFIG_TINYUSB

Massive Storage Class (MSC) Contains:
- CONFIG_TINYUSB_MSC_ENABLED

CONFIG_TINYUSB_MSC_ENABLED
Enable TinyUSB MSC feature

*Found in: Component config > TinyUSB Stack > CONFIG_TINYUSB > Massive Storage Class (MSC)*

Enable TinyUSB MSC feature.

**Default value:**
- No (disabled) if CONFIG_TINYUSB_CDC_COUNT < 2 && CONFIG_TINYUSB
CONFIG_TINYUSB_MSC_BUFSIZE
MSC FIFO size

*Found in:* Component config > TinyUSB Stack > CONFIG_TINYUSB > Massive Storage Class (MSC) > CONFIG_TINYUSB_MSC_ENABLED

MSC FIFO size, in bytes.

**Default value:**
- 512 if CONFIG_TINYUSB_MSC_ENABLED && CONFIG_TINYUSB

Communication Device Class (CDC) Contains:
- CONFIG_TINYUSB_CDC_ENABLED

CONFIG_TINYUSB_CDC_ENABLED
Enable TinyUSB CDC feature

*Found in:* Component config > TinyUSB Stack > CONFIG_TINYUSB > Communication Device Class (CDC)

Enable TinyUSB CDC feature.

**Default value:**
- No (disabled) if CONFIG_TINYUSB

CONFIG_TINYUSB_CDC_COUNT
CDC Channel Count

*Found in:* Component config > TinyUSB Stack > CONFIG_TINYUSB > Communication Device Class (CDC) > CONFIG_TINYUSB_CDC_ENABLED

Number of independent serial ports.

**Range:**
- from 1 to 2 if CONFIG_TINYUSB_CDC_ENABLED && CONFIG_TINYUSB

**Default value:**
- 1 if CONFIG_TINYUSB_CDC_ENABLED && CONFIG_TINYUSB

CONFIG_TINYUSB_CDC_RX_BUFSIZE
CDC FIFO size of RX channel

*Found in:* Component config > TinyUSB Stack > CONFIG_TINYUSB > Communication Device Class (CDC) > CONFIG_TINYUSB_CDC_ENABLED

CDC FIFO size of RX channel.

**Default value:**
- 64 if CONFIG_TINYUSB_CDC_ENABLED && CONFIG_TINYUSB

CONFIG_TINYUSB_CDC_TX_BUFSIZE
CDC FIFO size of TX channel

*Found in:* Component config > TinyUSB Stack > CONFIG_TINYUSB > Communication Device Class (CDC) > CONFIG_TINYUSB_CDC_ENABLED

CDC FIFO size of TX channel.

**Default value:**
- 64 if CONFIG_TINYUSB_CDC_ENABLED && CONFIG_TINYUSB
Ultra Low Power (ULP) Co-processor  Contains:
  - CONFIG_ULP_COPROC_ENABLED

**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. Please note that ESP32 only supports ULP FSM.

**Available options:**
- ULP FSM (Finite State Machine) (ULP_COPROC_TYPE_FSM)
- ULP RISC-V (ULP_COPROC_TYPE_RISCV)

**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:**
- 4096 if CONFIG_ULP_COPROC_ENABLED

**Unity unit testing library**  Contains:
  - CONFIGUNITY_ENABLE_COLOR
  - CONFIGUNITY_ENABLE_IDF_TEST_RUNNER
  - CONFIGUNITY_ENABLE_FIXTURE
  - CONFIGUNITY_ENABLE_BACKTRACE_ON_FAIL
  - CONFIGUNITY_ENABLE_64BIT
  - CONFIGUNITY_ENABLE_DOUBLE
  - CONFIGUNITY_ENABLE_FLOAT

**CONFIGUNITY_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:**
Chapter 2. API Reference

• 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)

**CONFIGUNITY_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)

**USB-OTG** Contains:

• **CONFIG_USB_HOST_HW_BUFFER_BIAS**
• **CONFIG_USB_HOST_CONTROL_TRANSFER_MAX_SIZE**

**CONFIG_USB_HOST_CONTROL_TRANSFER_MAX_SIZE**

Largest size (in bytes) of transfers to/from default endpoints

*Found in: Component config > USB-OTG*

Each USB device attached is allocated a dedicated buffer for its OUT/IN transfers to/from the device’s control endpoint. The maximum size of that buffer is determined by this option. The limited size of the transfer buffer have the following implications: - The maximum length of control transfers is limited - Device’s with configuration descriptors larger than this limit cannot be supported

**Default value:**

• 256

**CONFIG_USB_HOST_HW_BUFFER_BIAS**

Hardware FIFO size biasing

*Found in: Component config > USB-OTG*

The underlying hardware has size adjustable FIFOs to cache USB packets on reception (IN) or for transmission (OUT). The size of these FIFOs will affect the largest MPS (maximum packet size) and the maximum number of packets that can be cached at any one time. The hardware contains the following FIFOs: RX (for all IN packets), Non-periodic TX (for Bulk and Control OUT packets), and Periodic TX (for Interrupt and Isochronous OUT packets). This configuration option allows biasing the FIFO sizes towards a particular use case, which may be necessary for devices that have endpoints with large MPS. The MPS limits for each biasing are listed below:

Balanced: - IN (all transfer types), 408 bytes - OUT non-periodic (Bulk/Control), 192 bytes (i.e., 3 x 64 byte packets) - OUT periodic (Interrupt/Isochronous), 192 bytes

Bias IN: - IN (all transfer types), 600 bytes - OUT non-periodic (Bulk/Control), 64 bytes (i.e., 1 x 64 byte packets) - OUT periodic (Interrupt/Isochronous), 128 bytes

Bias Periodic OUT: - IN (all transfer types), 128 bytes - OUT non-periodic (Bulk/Control), 64 bytes (i.e., 1 x 64 byte packets) - OUT periodic (Interrupt/Isochronous), 600 bytes

**Available options:**

• Balanced (USB_HOST_HW_BUFFER_BIAS_BALANCED)
• Bias IN (USB_HOST_HW_BUFFER_BIAS_IN)
• Periodic OUT (USB_HOST_HW_BUFFER_BIAS_PERIODIC_OUT)
Virtual file system  Contains:
  • CONFIG_VFS_SUPPORT_IO

CONFIG_VFS_SUPPORT_IO
  Provide basic I/O functions
  
  Found in: Component config > Virtual file system

  If enabled, the following functions are provided by the VFS component.
  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:
  close, read, write, ioctl, fcntl.

  Default value:
  • Yes (enabled)

CONFIG_VFS_SUPPORT_DIR
  Provide directory related functions
  
  Found in: Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO

  If enabled, the following functions are provided by the VFS component.
  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.

  Default value:
  • Yes (enabled)

CONFIG_VFS_SUPPORT_SELECT
  Provide select function
  
  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.

  Default value:
  • Yes (enabled) if CONFIG_VFS_SUPPORT_IO && 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 unconditionally 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)

Host File System I/O (Semihosting) Contains:

- CONFIG_VFS_SEMIHOSTFS_MAX_MOUNT_POINTS
- CONFIG_VFS_SEMIHOSTFS_HOST_PATH_MAX_LEN

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

CONFIG_VFS_SEMIHOSTFS_HOST_PATH_MAX_LEN

Host FS: Maximum path length for the host base directory

*Found in:* Component config > Virtual file system > CONFIG_VFS_SUPPORT_IO > Host File System I/O (Semihosting)

Define maximum path length for the host base directory which is to be mounted. If host path passed to esp_vfs_semihost_register() is longer than this value it will be truncated.

**Default value:**
- 128

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 (WL_SECTOR_SIZE_512)
- 4096 (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 (WL_SECTOR_MODE_PERF)
- Safety (WL_SECTOR_MODE_SAFE)

**Wi-Fi Provisioning Manager**

Contains:

- `CONFIG_WIFI_PROV_BLE_BONDING`
- `CONFIG_WIFI_PROV_SCAN_MAX_ENTRIES`
- `CONFIG_WIFI_PROV_AUTOSTOP_TIMEOUT`

**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:*

- 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.

**Default value:**
- No (disabled) if `CONFIG_BT_ENABLED`

**Supplicant** Contains:
- `CONFIG_WPA_TESTING_OPTIONS`
- `CONFIG_WPA_11KV_SUPPORT`
- `CONFIG_WPA_SUITE_B_192`
- `CONFIG_WPA_WAPI_PSK`
- `CONFIG_WPA_DEBUG_PRINT`
- `CONFIG_WPA_WPS_STRICT`
- `CONFIG_WPA_MBEDTLS_CRYPTO`

CONFIG_WPA_MBEDTLS_CRYPTO

Use MbedTLS crypto APIs

*Found in: Component config > Supplicant*

Select this option to use MbedTLS crypto APIs which utilize hardware acceleration.

**Default value:**
- Yes (enabled)

CONFIG_WPA_WAPI_PSK

Enable WAPI PSK support

*Found in: Component config > Supplicant*

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_WPA_SUITE_B_192

Enable NSA suite B support with 192 bit key

*Found in: Component config > Supplicant*

Select this option to enable 192 bit NSA suite-B. This is necessary to support WPA3 192 bit security.
Chapter 2. API Reference

**Default value:**
- No (disabled)

**CONFIG_WPA_DEBUG_PRINT**
Print debug messages from WPA Supplicant

*Found in: Component config > Supplicant*

Select this option to print logging information from WPA supplicant, 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_WPA_TESTING_OPTIONS**
Add DPP testing code

*Found in: Component config > Supplicant*

Select this to enable unity test for DPP.

*Default value:*
- No (disabled)

**CONFIG_WPA_WPS_STRICT**
Strictly validate all WPS attributes

*Found in: Component config > Supplicant*

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_WPA_11KV_SUPPORT**
Enable 802.11k, 802.11v APIs handling in supplicant

*Found in: Component config > Supplicant*

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)

Contains:
- **CONFIG_WPA_MBO_SUPPORT**
- **CONFIG_WPA_SCAN_CACHE**
CONFIG_WPA_SCAN_CACHE

Keep scan results in cache

*Found in: Component config > Supplicant > CONFIG_WPA_11KV_SUPPORT*

Keep scan results in cache, if not enabled, those will be flushed immediately.

**Default value:**

- No (disabled) if `CONFIG_WPA_11KV_SUPPORT`

CONFIG_WPA_MBO_SUPPORT

Enable MBO support in supplicant

*Found in: Component config > Supplicant > CONFIG_WPA_11KV_SUPPORT*

Select this option to enable WiFi Multiband operation certification support.

**Default value:**

- No (disabled) if `CONFIG_WPA_11KV_SUPPORT`

**Deprecated options and their replacements**

- `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`
  - `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`
Chapter 2. API Reference

- **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_BLE_ACTIVE_SCAN_REPORT_ADV_SCAN_RSP_INDIVIDUALLY** *(CONFIG_BT_BLE_ACTIVE_SCAN_REPORT_ADV_SCAN)*
- **CONFIG_BLE_ESTABLISH_LINK_CONNECTION_TIMEOUT** *(CONFIG_BT_BLE_ESTABLISH_LINK_CONNECTION_TIMEOUT)*
- **CONFIG_BLE_HOST_QUEUE_CONGESTION_CHECK** *(CONFIG_BT_BLE_HOST_QUEUE_CONGESTION_CHECK)*
- **CONFIG_BLE_MESH_GATT_PROXY** *(CONFIG_BT_BLE_MESH_GATT_PROXY_SERVER)*
- **CONFIG_BLE_SMP_ENABLE** *(CONFIG_BT_BLE_SMP_ENABLE)*
- **CONFIG_BLUEDROID_MEM_DEBUG** *(CONFIG_BT_BLUEDROID_MEM_DEBUG)*
- **CONFIG_BLUEDROID_PINNED_TO_CORE_CHOICE** *(CONFIG_BT_BLUEDROID_PINNED_TO_CORE_CHOICE)*
  - CONFIG_BLUEDROID_PINNED_TO_CORE_0
  - CONFIG_BLUEDROID_PINNED_TO_CORE_1
- **CONFIG_BLUFI_INITIAL_TRACE_LEVEL** *(CONFIG_BT_LOG_BLUFI_TRACE_LEVEL)*
  - CONFIG_BLUFI_TRACE_LEVEL_NONE
  - CONFIG_BLUFI_TRACE_LEVEL_ERROR
  - CONFIG_BLUFI_TRACE_LEVEL_WARNING
  - CONFIG_BLUFI_TRACE_LEVEL_API
  - CONFIG_BLUFI_TRACE_LEVEL_EVENT
  - CONFIG_BLUFI_TRACE_LEVEL_DEBUG
  - CONFIG_BLUFI_TRACE_LEVEL_VERBOSE
- **CONFIG_BNEP_INITIAL_TRACE_LEVEL** *(CONFIG_BT_LOG_BNEP_TRACE_LEVEL)*
- **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_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_BTIFInicial_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_BT_TRACE_LEVEL_API
- CONFIG_BT_TRACE_LEVEL_EVENT
- CONFIG_BT_TRACE_LEVEL_DEBUG
- CONFIG_BT_TRACE_LEVEL_VERBOSE

- CONFIG_BTU_TASK_STACK_SIZE (CONFIG_BTU_TASK_STACK_SIZE)
- 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_DISABLE_GCC8_WARNINGS (CONFIG_COMPILER_DISABLE_GCC8_WARNINGS)
- 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_DESTINATION (CONFIG_APPTRACE_DESTINATION)
  - CONFIG_ESP32_APPTRACE_DEST_TRAX
  - CONFIG_ESP32_APPTRACE_DEST_NONE

- 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_THRESH)

- CONFIG_ESP32_CORE_DUMP_DECODE (CONFIG_ESP_COREDUMP_DECODE)
  - CONFIG_ESP32_CORE_DUMP_DODE_CODEC
  - CONFIG_ESP32_CORE_DUMP_CODEC_DISABLE

- CONFIG_ESP32_CORE_DUMP_MAX_TASKS_NUM (CONFIG_ESP_COREDUMP_MAX_TASKS_NUM)
- CONFIG_ESP32_DEBUG_STUBS_ENABLE (CONFIG_ESP_DEBUG_STUBS_ENABLE)
- CONFIG_ESP32_GCOV_ENABLE (CONFIG_APPTRACE_GCOV_ENABLE)

- CONFIG_ESP32_PHY_CALIBRATION_AND_DATA_STORAGE (CONFIG_ESP_PHY_CALIBRATION_AND_DATA_STORAGE)
- CONFIG_ESP32_PHY_DEFAULT_INIT_IF_INVALID (CONFIG_ESP_PHY_DEFAULT_INIT_IF_INVALID)
- CONFIG_ESP32_PHY_INIT_DATA_ERROR (CONFIG_ESP_PHY_INIT_DATA_ERROR)
- CONFIG_ESP32_PHY_INIT_DATA_IN_PARTITION (CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION)
- CONFIG_ESP32_PHY_MAC_BB_PD (CONFIG_ESP_PHY_MAC_BB_PD)
- CONFIG_ESP32_PHY_MAX_WIFI_TX_POWER (CONFIG_ESP_PHY_MAX_WIFI_TX_POWER)

- CONFIG_ESP32_PTHREAD_STACK_MIN (CONFIG_PTHREAD_STACK_MIN)
- CONFIG_ESP32_PTHREAD_TASK_CORE_DEFAULT (CONFIG_PTHREAD_TASK_CORE_DEFAULT)
  - CONFIG_ESP32_PTHREAD_TASK_CORE_NO_AFFINITY
  - CONFIG_ESP32_PTHREAD_TASK_CORE_0
  - CONFIG_ESP32_PTHREAD_TASK_CORE_1

- CONFIG_ESP32_PTHREAD_TASK_NAME_DEFAULT (CONFIG_PTHREAD_TASK_NAME_DEFAULT)
- CONFIG_ESP32_PTHREAD_TASK_PRIO_DEFAULT (CONFIG_PTHREAD_TASK_PRIO_DEFAULT)
- CONFIG_ESP32_PTHREAD_TASK_STACK_SIZE_DEFAULT (CONFIG_PTHREAD_TASK_STACK_SIZE_DEFAULT)

- CONFIG_ESP32_REDUCE_PHY_TX_POWER (CONFIG_ESP_PHY_REDUCE_TX_POWER)
- CONFIG_ESP32_RTC_XTAL_BOOTSTRAP_CYCLES (CONFIG_ESP_SYSTEM_RTC_EXT_XTAL_BOOTSTRAP_CYCLES)

- CONFIG_ESP32_SUPPORT_MULTIPLE_PHY_INIT_DATA_BIN (CONFIG_ESP_PHY_MULTIPLE_INIT_DATA_BIN)

- CONFIG_ESP32_PHY_DEFAULT_INIT_IF_INVALID (CONFIG_ESP_PHY_DEFAULT_INIT_IF_INVALID)

- CONFIG_ESP_SYSTEM_PD_FLASH (CONFIG_ESP_SLEEP_POWER_DOWN_FLASH)
- CONFIG_ESP_SYSTEM_PM_POWER_DOWN_CPU (CONFIG_PM_POWER_DOWN_CPU_IN_LIGHT_SLEEP)
• CONFIG_EVENT_LOOP_PROFILING (CONFIG_ESP_EVENT_LOOP_PROFILING)
• CONFIG_FLASH_ENCRYPTION_ENABLED (CONFIG_SECURE_FLASH_ENC_ENABLED)
• CONFIG_FLASH_ENCRYPTION_UART_BOOTLOADER_ALLOW_CACHE (CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_CACHE)
• CONFIG_FLASH_ENCRYPTION_UART_BOOTLOADER_ALLOW_ENCRYPT (CONFIG_SECURE_FLASH_UART_BOOTLOADER_ALLOW_ENCRYPT)
• 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_GAP_TMR_INTERVAL (CONFIG_LWIP_GARP_TMR_INTERVAL)
• CONFIG_GATT_CACHE_NVS_FLASH (CONFIG_BT_GATT_CACHE_NVS_FLASH)
• CONFIG_GATT_ENABLE (CONFIG_BT_GATT_ENABLE)
• CONFIG_GATT_SEND_SERVICE_CHANGE_MODE (CONFIG_BT_GATTSEND_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_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_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_MB_CONTROLLER_NOTIFY_QUEUE_SIZE (CONFIG_FMB_CONTROLLER_NOTIFY_QUEUE_SIZE)
• CONFIG_MB_CONTROLLER_NOTIFY_TIMEOUT (CONFIG_FMB_CONTROLLER_NOTIFY_TIMEOUT)
• CONFIG_MB_CONTROLLER_SLAVE_ID (CONFIG_FMB_CONTROLLER_SLAVE_ID)
• CONFIG_MB_CONTROLLER_SLAVE_ID_SUPPORT (CONFIG_FMB_CONTROLLER_SLAVE_ID_SUPPORT)
• CONFIG_MB_CONTROLLER_STACK_SIZE (CONFIG_FMB_CONTROLLER_STACK_SIZE)
• CONFIG_MB_EVENT_QUEUE_TIMEOUT (CONFIG_FMB_EVENT_QUEUE_TIMEOUT)
• CONFIG_MB_MASTER_DELAY_MS_CONVERT (CONFIG_FMB_MASTER_DELAY_MS_CONVERT)
• CONFIG_MB_MASTER_TIMEOUT_MS_RESPONSE (CONFIG_FMB_MASTER_TIMEOUT_MS_RESPONSE)
• CONFIG_MB_QUEUE_LENGTH (CONFIG_FMB_QUEUE_LENGTH)
• CONFIG_MB_SERIAL_BUF_SIZE (CONFIG_FMB_SERIAL_BUF_SIZE)
• CONFIG_MB_SERIAL_TASK_PRIO (CONFIG_FMB_PORT_TASK_PRIO)
• CONFIG_MB_SERIAL_TASK_STACK_SIZE (CONFIG_FMB_PORT_TASK_STACK_SIZE)
• CONFIG_MB_TIMER_PORT_ENABLED (CONFIG_FMB_TIMER_PORT_ENABLED)
• 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_NIMBLE_ACL_BUF_COUNT (CONFIG_BT_NIMBLE_ACL_BUF_COUNT)
• CONFIG_NIMBLE_ACL_BUF_SIZE (CONFIG_BT_NIMBLE_ACL_BUF_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_HCI_EVT_BUF_SIZE (CONFIG_BT_NIMBLE_HCI_EVT_BUF_SIZE)
• CONFIG_NIMBLE_HCI_EVT_HI_BUF_COUNT (CONFIG_BT_NIMBLE_HCI_EVT_HI_BUF_COUNT)
• CONFIG_NIMBLE_HCI_EVT_LO_BUF_COUNT (CONFIG_BT_NIMBLE_HCI_EVT_LO_BUF_COUNT)
• CONFIG_NIMBLE_HS_FLOW_CTRL (CONFIG_BT_NIMBLE_HS_FLOW_CTRL)
  - CONFIG_BT_NIMBLE_HS_FLOW_CTRL_ITVL
  - 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_BT_NIMBLE_MEM_ALLOC_MODE_INTERNAL
  - CONFIG_BT_NIMBLE_MEM_ALLOC_MODE_EXTERNAL
  - CONFIG_BT_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_NIMBLE_MESH_LOW_POWER
• CONFIG_NIMBLE_MESH_PB_ADV
• CONFIG_NIMBLE_MESH_PB_GATT
• CONFIG_NIMBLE_MESH_PROV
• CONFIG_NIMBLE_MESH_PROXY
• CONFIG_NIMBLE_MESH_RELAY
• CONFIG_NIMBLE_MSYS1_BLOCK_COUNT
• CONFIG_NIMBLE_NVS_PERSIST
• CONFIG_NIMBLE_PINNED_TO_CORE_CHOICE
  - CONFIG_NIMBLE_PINNED_TO_CORE_0
  - CONFIG_NIMBLE_PINNED_TO_CORE_1
• CONFIG_NIMBLE_ROLE_BROADCASTER
• CONFIG_NIMBLE_ROLE_CENTRAL
• CONFIG_NIMBLE_ROLE_OBSERVER
• CONFIG_NIMBLE_RPA_TIMEOUT
• CONFIG_NIMBLE_SM_LEGACY
• CONFIG_NIMBLE_SM_SC
• CONFIG_NIMBLE_SM_SC_DEBUG_KEYS
• CONFIG_NIMBLE_SVC_GAP_APPEARANCE
• CONFIG_NIMBLE_SVC_GAP_DEVICE_NAME
• CONFIG_NIMBLE_TASK_STACK_SIZE
• CONFIG_OPTIMIZATION_ASSERTION_LEVEL
  - CONFIG_OPTIMIZATION_ASSERTIONS_ENABLED
  - CONFIG_OPTIMIZATION_ASSERTIONS_SILENT
  - CONFIG_OPTIMIZATION_ASSERTIONS_DISABLED
• CONFIG_OPTIMIZATION_COMPILER
• CONFIG_OSI_INITIAL_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
  - CONFIG_OSI_TRACE_LEVEL_VERBOSE
• CONFIG_OSI_INITIAL_TRACE_LEVEL
• CONFIG_POST_EVENTS_FROM_IRAM_ISR
• CONFIG_POST_EVENTS_FROM_ISR
• CONFIG_PPP_CHAP_SUPPORT
• CONFIG_PPP_DEBUG_ON
• CONFIG_PPP_MPPE_SUPPORT
• CONFIG_PPP_MSCHAP_SUPPORT
• CONFIG_PPP_NOTIFY_PHASE_SUPPORT
• CONFIG_PPP_PAP_SUPPORT
• CONFIG_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_SEMIHOSTFS_HOST_PATH_MAX_LEN (CONFIG_VFS_SEMIHOSTFS_HOST_PATH_MAX_LEN)
• 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_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_ESP32_WIFI_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_APPTRACE_SV_BUF_WAIT_TMO)
• 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_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)
• 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)
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- 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_OVERSIZE (CONFIG_LWIP_TCP_OVERSIZE)
  - CONFIG_TCP_OVERSIZE_MSS
  - CONFIG_TCP_OVERSIZE_QUARTER_MSS
  - CONFIG_TCP_OVERSIZE_DISABLE
- CONFIG_TCP_QUEUE_OOSEQ (CONFIG_LWIP_TCP_QUEUE_OOSEQ)
- CONFIG_TCP_RECVMBOX_SIZE (CONFIG_LWIP_TCP_RECVMBOX_SIZE)
- CONFIG_TCP_SND_BUF_DEFAULT (CONFIG_LWIP_TCP_SND_BUF_DEFAULT)
- 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_SIZE)
- CONFIG_TIMER_TASK_STACK_SIZE (CONFIG_FREERTOS_TIMER_TASK_STACK_SIZE)
- CONFIG_TIMER_TASK_STACK_SIZE (CONFIG_FREERTOS_TIMER_TASK_STACK_SIZE)
- CONFIG_TIMER_TASK_STACK_SIZE (CONFIG_ESP_TIMER_TASK_STACK_SIZE)
- CONFIG_UDP_RECVMBOX_SIZE (CONFIG_LWIP_UDP_RECVMBOX_SIZE)
- CONFIG_USB_CDC_ENABLED (CONFIG_TINYUSB_CDC_ENABLED)
- CONFIG_USB_CDC_RX_BUFSIZE (CONFIG_TINYUSB_CDC_RX_BUFSIZE)
- CONFIG_USB_CDC_TX_BUFSIZE (CONFIG_TINYUSB_CDC_TX_BUFSIZE)
- CONFIG_USB_DEBUG_LEVEL (CONFIG_TINYUSB_DEBUG_LEVEL)
- CONFIG_USB_DESC_BCDDEVICE (CONFIG_TINYUSB_DESC_BCD_DEVICE)
- CONFIG_USB_DESC_CDC_STRING (CONFIG_TINYUSB_DESC_CDC_STRING)
- CONFIG_USB_DESC_CUSTOM_PID (CONFIG_TINYUSB_DESC_CUSTOM_PID)
- CONFIG_USB_DESC_CUSTOM_VID (CONFIG_TINYUSB_DESC_CUSTOM_VID)
- CONFIG_USB_DESC_HID_STRING (CONFIG_TINYUSB_DESC_HID_STRING)
- CONFIG_USB_DESC_MANUFACTURER_STRING (CONFIG_TINYUSB_DESC_MANUFACTURER_STRING)
- CONFIG_USB_DESC_MSC_STRING (CONFIG_TINYUSB_DESC_MSC_STRING)
- CONFIG_USB_DESC_PRODUCT_STRING (CONFIG_TINYUSB_DESC_PRODUCT_STRING)
- CONFIG_USB_DESC_SERIAL_STRING (CONFIG_TINYUSB_DESC_SERIAL_STRING)
- CONFIG_USB_DESC_USE_DEFAULT_PID (CONFIG_TINYUSB_DESC_USE_DEFAULT_PID)
- CONFIG_USB_DESC_USE_ESPRESSIF_VID (CONFIG_TINYUSB_DESC_USE_ESPRESSIF_VID)
- CONFIG_USB_DO_NOT_CREATE_TASK (CONFIG_TINYUSB_NO_DEFAULT_TASK)
- CONFIG_USB_ENABLED (CONFIG_TINYUSB)
- CONFIG_USB_MSC_BUFSIZE (CONFIG_TINYUSB_MSC_BUFSIZE)
- CONFIG_USB_MSC_ENABLED (CONFIG_TINYUSB_MSC_ENABLED)
- CONFIG_USB_TASK_PRIORITY (CONFIG_TINYUSB_TASK_PRIORITY)
- CONFIG_WARN_WRITE_STRINGS (CONFIG_COMPILER_WARN_WRITE_STRINGS)

2.10 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
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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): Id 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): 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_NVS_CONTENT_DIFERS (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_UNDEFINED_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
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**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_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

**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_DHCPC_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)
ESP_ERR_ESP_NETIF_MLD6_FAILED (0x500b)
ESP_ERR_ESP_NETIF_IP6_ADDR_FAILED (0x500c)
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_NOT_INITIALISED (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
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**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_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

**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_KEYVERIFY_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)
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**ESP_ERR_HTTPS_OOTA_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 3

ESP32-S3 Hardware Reference

3.1 Chip Series Comparison

The comparison below covers key features of chips supported by ESP-IDF. For the full list of features please refer to respective datasheets in Section Related Documents.

<table>
<thead>
<tr>
<th>Feature</th>
<th>ESP32 Series</th>
<th>ESP32-S2 Series</th>
<th>ESP32-C3 Series</th>
<th>ESP32-S3 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch year</td>
<td>2016</td>
<td>2020</td>
<td>2020</td>
<td>2020</td>
</tr>
<tr>
<td>Variants</td>
<td>See ESP32 Datasheet (PDF)</td>
<td>See ESP32-S2 Datasheet (PDF)</td>
<td>See ESP32-C3 Datasheet (PDF)</td>
<td>See ESP32-S3 Datasheet (PDF)</td>
</tr>
<tr>
<td>Core</td>
<td>Xtensa® dual-/single core 32-bit LX6</td>
<td>Xtensa® single-core 32-bit LX7</td>
<td>32-bit single-core RISC-V</td>
<td>Xtensa® dual-core 32-bit LX7</td>
</tr>
<tr>
<td>Wi-Fi protocols</td>
<td>802.11 b/g/n, 2.4 GHz</td>
<td>802.11 b/g/n, 2.4 GHz</td>
<td>802.11 b/g/n, 2.4 GHz</td>
<td>802.11 b/g/n, 2.4 GHz</td>
</tr>
<tr>
<td>Bluetooth®</td>
<td>Bluetooth v4.2 BR/EDR and Bluetooth Low Energy</td>
<td>✗</td>
<td>Bluetooth 5.0</td>
<td>Bluetooth 5.0</td>
</tr>
<tr>
<td>Typical frequency</td>
<td>240 MHz (160 MHz for ESP32-S0WD)</td>
<td>240 MHz</td>
<td>160 MHz</td>
<td>240 MHz</td>
</tr>
<tr>
<td>SRAM</td>
<td>520 KB</td>
<td>320 KB</td>
<td>400 KB</td>
<td>512 KB</td>
</tr>
<tr>
<td>ROM</td>
<td>448 KB for booting and core functions</td>
<td>128 KB for booting and core functions</td>
<td>384 KB for booting and core functions</td>
<td>384 KB for booting and core functions</td>
</tr>
<tr>
<td>Embedded flash</td>
<td>2 MB, 4 MB, or none, depending on variants</td>
<td>2 MB, 4 MB, or none, depending on variants</td>
<td>4 MB or none, depending on variants</td>
<td>8 MB or none, depending on variants</td>
</tr>
<tr>
<td>External flash</td>
<td>Up to 16 MB device, address 11 MB + 248 KB each time</td>
<td>Up to 1 GB device, address 11.5 MB each time</td>
<td>Up to 16 MB device, address 8 MB each time</td>
<td>Up to 1 GB device, address 32 MB each time</td>
</tr>
<tr>
<td>External RAM</td>
<td>Up to 8 MB device, address 4 MB each time</td>
<td>Up to 1 GB device, address 11.5 MB each time</td>
<td>✗</td>
<td>Up to 1 GB device, address 32 MB each time</td>
</tr>
<tr>
<td>Cache</td>
<td>✓ Two-way set associative</td>
<td>✓ Four-way set associative, independent instruction cache and data cache</td>
<td>✓ Eight-way set associative, 32-bit data/instruction bus width</td>
<td>✓ Four-way or eight-way set associative for instruction cache; four-way set associative for data cache, 32-bit data/instruction bus width</td>
</tr>
</tbody>
</table>

Continued on next page
<table>
<thead>
<tr>
<th>Feature</th>
<th>ESP32 Series</th>
<th>ESP32-S2 Series</th>
<th>ESP32-C3 Series</th>
<th>ESP32-S3 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peripherals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADC</td>
<td>Two 12-bit, 18 channels</td>
<td>Two 12-bit, 20 channels</td>
<td>Two 12-bit SAR ADCs, at most 6 channels</td>
<td>Two 12-bit SAR ADCs, 20 channels</td>
</tr>
<tr>
<td>DAC</td>
<td>Two 8-bit channels</td>
<td>Two 8-bit channels</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Timers</td>
<td>Four 64-bit general-purpose timers, and three watchdog timers</td>
<td>Four 64-bit general-purpose timers, and three watchdog timers</td>
<td>Two 54-bit general-purpose timers, and three watchdog timers</td>
<td>Four 54-bit general-purpose timers, and three watchdog timers</td>
</tr>
<tr>
<td>Temperature sensor</td>
<td>✗</td>
<td>1</td>
<td>✗</td>
<td>1</td>
</tr>
<tr>
<td>Touch sensor</td>
<td>10</td>
<td>14</td>
<td>✗</td>
<td>14</td>
</tr>
<tr>
<td>Hall sensor</td>
<td>1</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>GPIO</td>
<td>34</td>
<td>43</td>
<td>22</td>
<td>45</td>
</tr>
<tr>
<td>SPI</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>LCD interface</td>
<td>1</td>
<td>1</td>
<td>✗</td>
<td>1</td>
</tr>
<tr>
<td>UART</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I2C</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>I2S</td>
<td>2, can be configured to operate with 8/16/32/40/48-bit resolution as an input or output channel.</td>
<td>1, can be configured to operate with 8/16/24/32/48/64-bit resolution as an input or output channel.</td>
<td>1, can be configured to operate with 8/16/24/32-bit resolution as an input or output channel.</td>
<td>2, can be configured to operate with 8/16/24/32-bit resolution as an input or output channel.</td>
</tr>
<tr>
<td>Camera interface</td>
<td>1</td>
<td>1</td>
<td>✗</td>
<td>1</td>
</tr>
<tr>
<td>DMA</td>
<td>Dedicated DMA to UART, SPI, I2S, SD/MMC host, EMAC, BT, and Wi-Fi</td>
<td>Dedicated DMA to UART, SPI, AES, SHA, I2S, and ADC Controller</td>
<td>General-purpose, 3 TX channels, 3 RX channels</td>
<td>General-purpose, 5 TX channels, 5 RX channels</td>
</tr>
<tr>
<td>RMT</td>
<td>8 channels</td>
<td>4 channels ¹, can be configured to TX/RX channels</td>
<td>4 channels ², 2 TX channels, 2 RX channels</td>
<td>8 channels ³, 4 TX channels, 4 RX channels</td>
</tr>
<tr>
<td>Pulse counter</td>
<td>8 channels</td>
<td>4 channels ¹</td>
<td>✗</td>
<td>4 channels ¹</td>
</tr>
<tr>
<td>LED PWM</td>
<td>16 channels</td>
<td>8 channels ¹</td>
<td>6 channels ²</td>
<td>8 channels ¹</td>
</tr>
<tr>
<td>MCPWM</td>
<td>2, six PWM outputs</td>
<td>✗</td>
<td>✗</td>
<td>2, six PWM outputs</td>
</tr>
<tr>
<td>USB OTG</td>
<td>✗</td>
<td>1</td>
<td>✗</td>
<td>1</td>
</tr>
<tr>
<td>TWAI® controller (compatible with ISO 11898-1)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SD/MMC host controller</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>1</td>
</tr>
<tr>
<td>SDIO slave controller</td>
<td>1</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

Continued on next page
### Table 1 – continued from previous page

<table>
<thead>
<tr>
<th>Feature</th>
<th>ESP32 Series</th>
<th>ESP32-S2 Series</th>
<th>ESP32-C3 Series</th>
<th>ESP32-S3 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethernet MAC</td>
<td>1</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td>ULP</td>
<td>ULP FSM</td>
<td>PicoRV32 core with 8 KB SRAM, ULP FSM</td>
<td>❌</td>
<td>PicoRV32 core with 8 KB SRAM, ULP FSM</td>
</tr>
<tr>
<td>Debug Assist</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
<td>❌</td>
</tr>
<tr>
<td>Security</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secure boot</td>
<td>✓</td>
<td>✓ Faster and safer, compared with ESP32</td>
<td>✓ Faster and safer, compared with ESP32</td>
<td>✓ Faster and safer, compared with ESP32</td>
</tr>
<tr>
<td>Flash encryption</td>
<td>✓</td>
<td>✓ Support for PSRAM encryption. Safer, compared with ESP32</td>
<td>✓ Support for PSRAM encryption. Safer, compared with ESP32</td>
<td>✓ Support for PSRAM encryption. Safer, compared with ESP32</td>
</tr>
<tr>
<td>OTP</td>
<td>1024-bit</td>
<td>4096-bit</td>
<td>4096-bit</td>
<td>4096-bit</td>
</tr>
<tr>
<td>AES</td>
<td>✓ AES-128, AES-192, AES-256 (FIPS PUB 197)</td>
<td>✓ AES-128, AES-192, AES-256 (FIPS PUB 197); DMA support</td>
<td>✓ AES-128, AES-256 (FIPS PUB 197); DMA support</td>
<td>✓ AES-128, AES-256 (FIPS PUB 197); DMA support</td>
</tr>
<tr>
<td>HASH</td>
<td>SHA-1, SHA-256, SHA-384, SHA-512 (FIPS PUB 180-4)</td>
<td>SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256, SHA-512/t (FIPS PUB 180-4); DMA support</td>
<td>SHA-1, SHA-224, SHA-256 (FIPS PUB 180-4); DMA support</td>
<td>SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256, SHA-512/t (FIPS PUB 180-4); DMA support</td>
</tr>
<tr>
<td>RSA</td>
<td>Up to 4096 bits</td>
<td>Up to 4096 bits</td>
<td>Up to 3072 bits</td>
<td>Up to 4096 bits</td>
</tr>
<tr>
<td>RNG</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>HMAC</td>
<td>❌</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Digital signature</td>
<td>❌</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>XTS</td>
<td>❌</td>
<td>✓ XTS-AES-128, XTS-AES-256</td>
<td>✓ XTS-AES-128</td>
<td>✓ XTS-AES-128, XTS-AES-256</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep sleep (ULP sensor-monitored pattern)</td>
<td>100 μA (when ADC work with a duty cycle of 1%)</td>
<td>22 μA (when touch sensors work with a duty cycle of 1%)</td>
<td>No such pattern</td>
<td>TBD</td>
</tr>
<tr>
<td>Size</td>
<td>QFN48 5<em>5, 6</em>6, depending on variants</td>
<td>QFN56 7*7</td>
<td>QFN32 5*5</td>
<td>QFN56 7*7</td>
</tr>
</tbody>
</table>

- **Note 1**: Reduced chip area compared with ESP32
- **Note 2**: Reduced chip area compared with ESP32 and ESP32-S2
- **Note 3**: Die size: ESP32-C3 < ESP32-S2 < ESP32-S3 < ESP32-S3

### 3.1.1 Related Documents

- ESP32 Datasheet (PDF)
- ESP32-PICO Datasheets (PDF)
  - ESP32-PICO-D4
  - ESP32-PICO-V3
  - ESP32-PICO-V3-02
- ESP32-S2 Datasheet (PDF)
- ESP32-C3 Datasheet (PDF)
• ESP32-S3 Datasheet (PDF)
• ESP Product Selector
Chapter 4

API Guides

4.1 Application Level Tracing library

4.1.1 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-S3 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 info 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 behavior analysis, see System Behavior Analysis with SEGGER SystemView
4. Source code coverage, see Gcov (Source Code Coverage)

Tracing components 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, the tracing module does not check whether host has read all the data from the HW UP BUFFER and overwrites it with new data. This mode is useful when only the latest trace data is interesting to the user, e.g. for analyzing the program’s behavior just before a crash. Host can read the data later upon user request, e.g. via a special OpenOCD command in case of working via JTAG interface.

Streaming mode. Tracing module enters this mode when host connects to ESP32-S3. In this mode, before writing new data to HW UP BUFFER, the tracing module checks that 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. When an application tries to write data to the trace buffer with a finite wait time, it is possible that the data will be dropped. This is especially true when tracing from time critical code (ISRs, OS scheduler code etc.) where infinite timeouts can lead to a system malfunction. In order to avoid loss of such critical data, developers can enable additional data buffering via menuconfig option CONFIG_APPTRACE_PENDING_DATA_SIZE_MAX. This macro specifies the size of data which can be buffered in such scenarios. This option can also help to overcome a situation when data transfer to the host is temporarily slowed down, e.g. due to USB bus congestions, etc. But it will not help when the average bitrate of the trace data stream exceeds the HW 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. Component config > Application Level Tracing menu allows selecting destination for the trace data (HW interface for transport). Choosing any of the destinations automatically enables `CONFIG_APPTRACE_ENABLE` option.

**Note:** In order to achieve higher data rates and minimize the number of dropped packets, it is recommended to optimize the setting of the JTAG clock frequency, so it is at maximum and still provides stable operation of JTAG, see [Optimize JTAG speed](#).

There are two additional menuconfig options that are available to users:

1. **Threshold for flushing last trace data to host on panic** (`CONFIG_APPTRACE_POSTMORTEM_FLUSH_THRESH`). This option is useful when working over JTAG wherein the 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 it for post-analysis. System panic may occur when a very small amount of data has been accumulated but not yet exposed to the host. In this case the previous 16 KB of collected data will be lost and the host will see the latest, very small piece of the trace. This data may be insufficient to diagnose the problem. Thus, this menuconfig option allows avoiding such situations. It controls the threshold for flushing data in case of a panic. For example, users can decide that they need no less than 512 bytes of the recent trace data for meaningful analysis. If there is less than 512 bytes of pending data at the moment of panic, it 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 controls the maximum time tracing module will wait for the host to read the last data in case of panic.
4.1.4 How to use this library

This library provides APIs for transferring arbitrary data between the host and ESP32-S3. When enabled in menu-config, target application tracing module is initialized automatically at the system startup. All that the user needs to do is to call corresponding APIs to send, receive or flush the data.

Application Specific Tracing

In general the user should decide what type of data should be transferred in either direction and how this data must be interpreted (processed). The following steps must be performed to transfer data between ESP32-S3 and the host:

1. On target side user should implement algorithms for writing trace data to the host. The following piece of code demonstrates an example of 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) {
    ESP_LOGE(TAG, "Failed to put buffer!");
    return res;
}
```

The user may also want to receive data from the host. The following piece of code shows an example of 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");
```

(continues on next page)
if (res != ESP_OK) {
    ESP_LOGE(TAG, "Failed to read data from host!");
    return res;
}
if (sz > 0) {
    /* we have data, process them */
    ...
}

esp_aptrace_read() function uses memcpy to copy host data to user buffer. In some cases it can be more optimal to use esp_aptrace_down_buffer_get() and esp_aptrace_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_aptrace_down_buffer_config(down_buf, sizeof(down_buf));
char *ptr = (char *)esp_aptrace_down_buffer_get(ESP_APPTRACE_DEST_TRAX, &sz, ...
    /* tmo in us*/);
if (ptr == NULL) {
    ESP_LOGE(TAG, "Failed to get buffer!");
    return ESPFAIL;
}
if (sz > 4) {
    number = (uint32_t *)ptr;
    printf("Here is the number %d", *number);
} else {
    printf("No data");
}
esp_err_t res = esp_aptrace_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 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 format of data is defined by user 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 filling of the allocated memory is performed on behalf of the API caller (in task or ISR context). In a multithreaded environment, it can happen that the task/ISR which fills the buffer is preempted by another high priority task/ISR.
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It is possible that the user data preparation process is not complete when that chunk is read by the host. To handle such scenarios, the tracing module prepends all user data chunks with a header that contains allocated user buffer size (2 bytes) and the length of the actual written data (2 bytes). So total length of the header is 4 bytes. OpenOCD command which reads trace data reports an error when it reads an incomplete user data chunk. 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:

```bash
esp apptrace [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 (tracesizestoptriggerisdisabled).
- **stop_tmo**: Idle timeout (in sec). Tracing is stopped if there is no data for a specified period of time. By default -1 (disable this stop trigger). Optionally set it to a value longer than the longest pause between tracing commands from the 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 a file “trace.log”. The file will be saved in “openocd-esp32” directory.

   ```bash
   esp apptrace 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 a “Data timeout!” message, 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 a function `esp_apptrace_flush()` to flush the data on specific intervals.

2. Retrieve tracing data indefinitely in non-blocking mode.
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```
estp 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.

```
estp 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 OpenOCD window.

4. Wait for target to be halted. Then resume target’s operation and start data retrieval. Stop after collecting 2048
bytes of data:

```
estp 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

IDF implements a useful feature: logging to host via application level tracing library. This is a kind of semihosting
when all `ESP_LOGx` calls are redirected 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, IDF’s logging library uses a 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 a 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). Hence, it is quite common to observe
that with additional logging added to a program for debugging, the program behavior changes and the problem is not
reproduced. In the worst case, the program may not 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 move
string formatting procedure to the host.

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, and instead just calculates the number of arguments passed and sends them along with the format string
address to the host. On the host, log data are processed and printed out by a special Python script.

Limitations Current implementation of logging over JTAG has some limitations:

1. Tracing from `ESP_EARLY_LOGx` macros is not supported.
2. No support for printf arguments which size exceeds 4 bytes (e.g. `double` and `uint64_t`).
3. Only strings from .rodata section are supported as format strings and arguments.
4. Maximum number of printf arguments is 256.

How To Use It In order to use logging via trace module user needs to perform the following steps:

1. On target side, the user must use the `esp_aptrace_vprintf()` function to send log data to the host.
   Example code is provided in `system/app_trace_to_host`.
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.
   ```

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**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 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.

**Note:** Currently, IDF based applications are able to generate SystemView compatible traces in form of files to be opened in the SystemView application. The tracing process cannot yet be controlled using that tool.

**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. ESP32-S3 timer to use as SystemView timestamp source: `(CONFIG_APPTRACE_SV_TS_SOURCE)` selects the source of timestamps for SystemView events. In single core mode timestamps are generated using ESP32-S3 internal cycle counter running at maximum 240 Mhz (~4 ns granularity). In dual-core mode external timer working at 40 Mhz is used, so timestamp granularity is 25 ns.

2. 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
   - Timer Exit Event

IDF has all the code required to produce SystemView compatible traces, so user 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.

**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.
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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 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 SystemView tracing data to files “pro-cpu.SVDat” and “app-cpu.SVDat”. The files will be saved in “openocd-esp32” directory.
```
estart file://pro-cpu.SVDat file://app-cpu.SVDat
```

   The tracing data will be retrieved and saved in non-blocking mode. To stop data this process enter `esp sysview stop` command on OpenOCD telnet prompt, optionally pressing Ctrl+C in OpenOCD window.

2. Retrieve tracing data and save them indefinitely.
```
estart 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 OpenOCD window.

**Data Visualization** After trace data is 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-S3 working in dual-core mode two files are generated: one for PRO CPU and another one for APP CPU. Users can load both files into separate instances of the tool.

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 and makes 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 free version of SystemView.

Good instruction on how to install, configure and visualize data in Impulse from one core can be found here.

**Note**: IDF uses its own mapping for SystemView FreeRTOS events IDs, so user needs to replace original file with mapping:
```
$SYSVIEW_INSTALL_DIR/Description/SYSVIEW_FreeRTOS.txt with $IDF_PATH/docs/api-guides/SYSVIEW_FreeRTOS.txt.
```

Also contents of that IDF specific file should be used when configuring SystemView serializer using 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 in Eclipse:
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2. In ‘Signal Ports’ view right-click on ‘Ports’ and select ‘Add …’ -> New Multi Adapter Port
4. In open dialog select ‘SystemView Serializer’ as Serializer and set path to PRO CPU trace file. Press OK.
5. Repeat steps 3-4 for APP CPU trace file.
6. Double-click on created port. View for this port should open.
7. Click Start/Stop Streaming button. Data should be loaded.
8. Use ‘Zoom Out’, ‘Zoom In’ and ‘Zoom Fit’ button to inspect data.
9. For settings measurement cursors and other features please see Impulse documentation).

**Note:** If you have problems with visualization (no data are shown or strange behavior of zoom action is observed) you can try to delete current signal hierarchy and double-click on the necessary file or port. Eclipse will ask you to create 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 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 generate a code coverage based on the .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 and not on 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 \texttt{--coverage} option, you can add \	exttt{set_source_files_properties(source1.c source2.c PROPERTIES COMPILE_FLAGS --coverage)} to the \texttt{CMakeLists.txt} file of the component.

When a source file is compiled with the \texttt{--coverage} option (e.g. gcov_example.c), the compiler will generate the gcov_example.gcno file in the project’s build directory.

**Project Configuration** Before building a project with source code coverage, ensure that the following project configuration options are enabled by running \texttt{idf.py menuconfig}.

- Enable the application tracing module by choosing *Trace Memory* for the *CONFIG_APPTRACE_DESTINATION* option.
- Enable Gcov to host via the *CONFIG_APPTRACE_GCOV_ENABLE* option.

**Dumping Code Coverage Data** Once a project has been compiled with the \texttt{--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 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 \texttt{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 \texttt{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 was compiled with the \texttt{--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 Dump
- Hard-coded Dump

**Instant Run-Time Dump** An Instant Run-Time Dump is triggered by calling the ESP32-S3 gcov OpenOCD command (via a telnet session). Once called, OpenOCD will immediately preempt the ESP32-S3’s current state and execute a built-in IDF Gcov debug stub function. The debug stub function will handle the dumping of data to the Host. Upon completion, the ESP32-S3 will resume its current state.

**Hard-coded Dump** A Hard-coded Dump is triggered by the application itself by calling \texttt{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 \texttt{esp_gcov_dump()} is called, the Host must execute the \texttt{esp gcov dump} OpenOCD command (via a telnet session). The \texttt{esp gcov dump} command will cause OpenOCD to connect to the ESP32-S3, retrieve the code coverage data, then disconnect from the ESP32-S3 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 \texttt{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 \texttt{esp_gcov_dump()}, then call \texttt{mon esp gcov dump} automatically via the use a \texttt{gdbinit} script (see *Using GDB from Command Line*).

The following GDB script is will add a breakpoint at \texttt{esp_gcov_dump()}, then call \texttt{mon esp gcov dump} OpenOCD command.
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```
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 Gcov 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.

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 0x0.
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-S3 chip and cannot be modified.

Startup code called from the reset vector determines the boot mode by checking GPIO Strap register for bootstrap pin states. Depending on the reset reason, the following takes place:
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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-S3 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 the start of flash at offset 0x0.

4.2.2 Second stage bootloader

In ESP-IDF, the binary image which resides at offset 0x0 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.

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.
- 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 permanently limiting ROM download modes).
- 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.

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_cpu1` 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-S3 is a Wi-Fi network configuration function via Bluetooth channel. It provides a secure protocol to pass Wi-Fi configuration and credentials to the ESP32-S3. Using this information ESP32-S3 can then e.g. connect to an AP or establish a SoftAP.

Fragmenting, data encryption, 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, connection status backhaul.

1. Set the ESP32-S3 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-S3 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-S3 (see the section *The Frame Formats Defined in BluFi* for details).
4. After ESP32-S3 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-S3 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-S3.
7. When receiving this control frame, ESP32-S3 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-S3, including SSID, password, etc.
9. The mobile phone sends a control frame of Wi-Fi connection request to ESP32-S3. When receiving this control frame, ESP32-S3 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-S3 will send a control frame of Wi-Fi connection status report to the mobile phone, to report the connection status. At this point the networking procedure is completed.

**Note:**

1. After ESP32-S3 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

![BluFi Flow Chart](image-url)
4.3.4 The Frame Formats Defined in BluFi

The frame formats for the communication between the mobile phone App and ESP32-S3 are defined as follows:

The frame format with no fragment (8 bit):

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</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>${Data Length}</td>
</tr>
<tr>
<td>CheckSum (Most Significant Bit)</td>
<td>2</td>
</tr>
</tbody>
</table>

If the **Frame Ctrl** bit is enabled, the **Total length** bit indicates the length of remaining part of the frame. It can tell the remote how much memory needs to be allocated.

The frame format with fragments (8 bit):

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type (Least Significant Bit)</td>
<td>1</td>
</tr>
<tr>
<td>Frame Control (Frag)</td>
<td>1</td>
</tr>
<tr>
<td>Sequence Number</td>
<td>1</td>
</tr>
<tr>
<td>Data Length</td>
<td>1</td>
</tr>
</tbody>
</table>
| Data                            | • Total Content Length: 2  
|                                 | • Content: ${Data Length} - 2 |
| CheckSum (Most Significant Bit) | 2      |

Normally, the control frame does not contain data bits, except for ACK Frame.

The format of ACK Frame (8 bit):

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</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**

The **Type** field, taking 1 byte, is divided into **Type** and **Subtype**, that Type uses the lower 2 bits and **Subtype** uses the upper 6 bits.

- 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 ESP device to the security mode.</td>
<td>To inform 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, 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 ESP device is controlled by this control frame.</td>
<td>The data field consumes a byte. The higher 4 bits are for the security mode setting of the control frame, and the lower 4 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 ESP device.</td>
<td>data[0] is for opmode settings, including:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 0x00: NULL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 0x01: STA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 0x02: SoftAP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 0x03: SoftAP &amp; STA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Please set the SSID/Password/Max Connection Number of the AP mode in the first place if an AP gets involved.</td>
<td></td>
</tr>
<tr>
<td>0x3 (b’ 000011)</td>
<td>Connect ESP device to the AP.</td>
<td>To notify 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 ESP device from the AP.</td>
<td></td>
<td>No data field is contained.</td>
</tr>
<tr>
<td>0x5 (b’ 000101)</td>
<td>To get the information of ESP device’s Wi-Fi mode and its status.</td>
<td></td>
<td>No data field is contained. When receiving this control frame, 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>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• The types of information sent to the mobile phone is defined by the application installed on the phone.</td>
</tr>
<tr>
<td>0x6 (b’ 000110)</td>
<td>Disconnect the STA device from the SoftAP (in SoftAP mode).</td>
<td></td>
<td>Date[0<del>5] is taken as the MAC address for the STA device. If there is a second STA device, then it uses data[6</del>11] and the rest can be done in the same manner.</td>
</tr>
<tr>
<td>0x7 (b’ 000111)</td>
<td>Get the version information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0x8 (b’ 010000)</td>
<td>Disconnect the BLE GATT link.</td>
<td>ESP device will disconnect the BLE GATT link after receives this command.</td>
<td></td>
</tr>
<tr>
<td>0x9 (b’ 010001)</td>
<td>Get the Wi-Fi list.</td>
<td>To get ESP device to scan the Wi-Fi access points around.</td>
<td>No data field is contained. When receiving this control frame, ESP device will send back a follow-up frame of Wi-Fi list report to the mobile phone.</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 BSSID 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’ 000010)</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’ 000011)</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’ 000100)</td>
<td>Send the SSID for SoftAP mode.</td>
<td></td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x5 (b’ 000101)</td>
<td>Send the password for SoftAP mode.</td>
<td></td>
<td>Please refer to Note 1 below.</td>
</tr>
<tr>
<td>0x6 (b’ 000110)</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’ 000111)</td>
<td>Set the authentication mode for the SoftAP.</td>
<td>data[0]: 0x00: OPEN 0x01: WEP 0x02: WPA_PSK 0x03: WPA2_PSK 0x04: WPA_WPA2_PSK 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>0x8 (b’ 001000)</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 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’ 001001)</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’ 001010)</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’ 001011)</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’ 001100)</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>0xd (b’ 001101)</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>
<tr>
<td>0xe (b’ 001110)</td>
<td>Server Private Key</td>
<td>It provides the private key of the server when using encryption of enterprise level.</td>
<td>Please refer to Note 2 below.</td>
</tr>
</tbody>
</table>
Note:

- Note 1: The length of the data depends on the length field. When the transmission direction is 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 length field. The frame supports to be fragmented if the data length is not enough.

2. Frame Control
   Control field, takes 1 byte and each bit has a different meaning.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x01</td>
<td>Indicates whether the frame is encrypted.</td>
</tr>
<tr>
<td></td>
<td>• 1 means encryption</td>
</tr>
<tr>
<td></td>
<td>• 0 means unencrypted</td>
</tr>
<tr>
<td></td>
<td>The encrypted part of the frame includes the full clear data before</td>
</tr>
<tr>
<td></td>
<td>the DATA field is encrypted (no checksum). Control frame is not</td>
</tr>
<tr>
<td></td>
<td>encrypted, so this bit is 0.</td>
</tr>
<tr>
<td>0x02</td>
<td>The data field that indicates whether a frame contains a checksum (such</td>
</tr>
<tr>
<td></td>
<td>as SHA1, MD5, CRC, etc.) for the end of the frame. Data field includes</td>
</tr>
<tr>
<td></td>
<td>sequence + data length + clear text. Both the control frame and the</td>
</tr>
<tr>
<td></td>
<td>data frame can contain a check bit or not.</td>
</tr>
<tr>
<td>0x04</td>
<td>Represents the data direction.</td>
</tr>
<tr>
<td></td>
<td>• 0 means the mobile phone to ESP device;</td>
</tr>
<tr>
<td></td>
<td>• 1 means ESP device to the mobile phone.</td>
</tr>
<tr>
<td>0x08</td>
<td>Indicates whether the other person is required to reply to an ACK.</td>
</tr>
<tr>
<td></td>
<td>• 0 indicates no requirement;</td>
</tr>
<tr>
<td></td>
<td>• 1 indicates to reply ACK.</td>
</tr>
<tr>
<td>0x10</td>
<td>Indicates whether there are subsequent data fragments.</td>
</tr>
<tr>
<td></td>
<td>• 0 indicates that there are no subsequent data fragments for this</td>
</tr>
<tr>
<td></td>
<td>frame;</td>
</tr>
<tr>
<td></td>
<td>• 1 indicates that there are subsequent data fragments and used to</td>
</tr>
<tr>
<td></td>
<td>transmit longer data.</td>
</tr>
<tr>
<td></td>
<td>In the case of a frag frame, the total length of the current content</td>
</tr>
<tr>
<td></td>
<td>section + subsequent content section is given, in the first 2 bytes of</td>
</tr>
<tr>
<td></td>
<td>the data field (that is, the content data of the maximum support 64 K).</td>
</tr>
<tr>
<td>0x10-0x80</td>
<td>reserved</td>
</tr>
</tbody>
</table>

3. Sequence Control
   Sequence control field. When a frame is sent, the value of sequence field is automatically incremented by 1 regardless of the type of frame, which prevents Replay Attack. The sequence is cleared after each reconnection.

4. Length
   The length of the data field that does not include CheckSum.

5. Data
   The instruction of the data field is different according to various values of Type or Subtype. Please refer to the table above.

6. CheckSum
   This field takes 2 bytes that is used to check “sequence + data length + clear text data”.

4.3.5 The Security Implementation of ESP32-S3

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 field and used during the checksum verification.
For the coding of ESP32-S3, you can determine and develop the security processing, such as key negotiation.
The mobile application sends the negotiation data to ESP32-S3 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-S3 to receive normal data during negotiation, and 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 "*", because the length of the data to be emitted is unknown that requires the function to allocate itself (malloc) or point to the global variable, and 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 use the same length. The IV8 is a 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 use the same length. The IV8 is a 8 bit sequence value of frames, which can be used as a 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-S3): 0xFF01, writable
Blufi (ESP32-S3 -> 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.
Chapter 4. API Guides

Bootloader is located at the address 0x0 in the flash.

For a full description of the startup process including the 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.

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.

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-S3 datasheet for details on pin internal pullups.

### 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 (32768) 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-S3 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 64KB (0x10000 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 webserver that shows the current humidity, there could be:
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- The ESP-IDF base libraries (libc, ROM bindings, etc)
- The Wi-Fi drivers
- A TCP/IP stack
- The FreeRTOS operating system
- A webserver
- 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.

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 customise the configuration of the project. A single project contains exactly one project configuration.
- An “app” is an executable which 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 which are compiled into static libraries (.a files) and linked into 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
- A command-line build tool (either Ninja build or GNU Make)
- esptool.py for flashing the target.

The getting started guide contains a brief introduction to how to set up idf.py to configure, build, and flash projects. idf.py should be run in an ESP-IDF “project” directory, i.e. one containing a CMakeLists.txt file. Older style projects with a Makefile will not work with idf.py.

Type idf.py --help for a list of commands. Here are a summary of the most useful ones:

- idf.py set-target <target> sets the target (chip) for which the project is built. See Selecting the Target.
- idf.py menuconfig runs the “menuconfig” tool to configure the project.
- idf.py build will build 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.

• idf.py clean will “clean” the project by deleting build output files from the build directory, forcing a “full rebuild” the next time the project is built. Cleaning doesn’t delete CMake configuration output and some other files.
• idf.py fullclean will delete the entire “build” directory contents. This 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.
• idf.py flash will automatically build the project if necessary, and then flash it to the target. The -p and -b options can be used to set serial port name and flasher baud rate, respectively.
• idf.py monitor will display serial output from the target. The -p option can be used to set the serial port name. Type Ctrl-] to exit the monitor. See IDF Monitor for more details about using the monitor.

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.

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 (see also).

To enable autocompletion for idf.py use the export command (see this). 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.

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.

Advanced Commands

• idf.py app, idf.py bootloader, idf.py partition-table can be used to build only the app, bootloader, or partition table from the project as applicable.
• There are matching commands idf.py app-flash, etc. to flash only that single part of the project to the target.
• idf.py -p PORT erase-flash will use esptool.py to erase the target’s entire flash chip.
• idf.py size prints some size information about the app. size-components and size-files are similar commands which print more detailed per-component or per-source-file information, respectively. If you define variable -DOUTPUT_JSON=1 when running CMake (or idf.py), the output will be formatted as JSON not as human readable text. See idf.py-size for more information.
• idf.py reconfigure re-runs CMake even if it doesn’t seem to need re-running. This isn’t necessary 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.
• idf.py python-clean deletes generated Python byte code from the IDF directory which may cause issues when switching between IDF and Python versions. It is advised to run this target after switching versions of Python.
• idf.py docs will open direct link to documentation for project’s chip target and version in browser. To see all options use idf.py docs --help

The order of multiple idf.py commands on the same invocation is not important, they will automatically be executed in the correct order for everything to take effect (ie building before flashing, erasing before flashing, etc.).
**idf.py 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*, for example *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` flag can be used to enable CCache when compiling source files, if the CCache tool is installed. This can dramatically reduce some build times.

Note that some older versions of CCache may exhibit bugs on some platforms, so if files are not rebuilt as expected then try disabling CCache and build again. CCache can be enabled by default by setting 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`) will cause CMake to print uninitialized variable warnings inside the project directory (not for directories not found inside the project directory). 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.

**Start a new project**

Use the command *idf.py create-project* for starting a new project. Execute *idf.py create-project --help* for more information.

Example:

```
idf.py create-project --path my_projects my_new_project
```

This example will create a new project called `my_new_project` directly into the directory `my_projects`.

**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-invoke `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*.

**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.
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**Flashing 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.
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Possible issues  The user of idf.py may sometimes experience ImportError described below.

Traceback (most recent call last):
  File "/Users/user_name/e/esp-idf/tools/kconfig_new/confgen.py", line 27, in
    import kconfiglib
ImportError: bad magic number in 'kconfiglib': b'\x03\xf3\r\n'

The exception is often caused by .pyc files generated by different Python versions. To solve the issue run the following command:

idf.py python-clean

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 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. 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”.
- “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.
- “build” directory is where 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 3.5)
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 3.5)` tells CMake the minimum version that is required to build the project. ESP-IDF is designed to work with CMake 3.5 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 behaviour. 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` ie `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 specifying its dependencies. Specifically, the steps to renaming main are as follows:

1. Rename main directory.
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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 gets 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 3.5)
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 (i.e., 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 into 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.

Create a new component

Use the command `idf.py create-component` for creating a new component. The new component will contain set of files necessary for building a component. You may include the component’s header file into your project and use its functionality. For more information execute `idf.py create-component --help`.

Example:

```
idf.py -C components create-component my_component
```

The example will create a new component in the subdirectory `components` under the current working directory. For more information about components follow the documentation page see above.

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 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_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 describe will be used.
  – Otherwise, PROJECT_VER will be “1”.

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(myfile.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.
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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

```c
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 **REQUIRES** and **PRIV_REQUIRES** should not depend on any configuration choices (CONFIG_xxx macros). This is because requirements are expanded before configuration is loaded. Other component variables (like include paths or source files) can depend on configuration choices.
- Not setting either or both **REQUIRES** 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 into the build, but does not support the selected target.

**Note:** In CMake terms, **REQUIRES** & **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
    - plug.c
    - 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"
#endif 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 sparkplug but this is a private dependency. sparkplug.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 sparkplug)
```

As a result, source files in the car component don’t need the sparkplug 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 sparkplug component doesn’t depend on anything else. It has a public header file sparkplug.h, but this doesn’t include headers from any other components.

This means that the sparkplug/CMakeLists.txt file doesn’t need any REQUIRES or PRIV_REQUIRES clauses:

```c
idf_component_register(
  SRCS "sparkplug.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:
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```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 (i.e., all current component’s public and private dependencies).
- Recursively, all of the INCLUDE_DIRS of those components REQUIRES lists (i.e., 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, lwip, soc, hal, esp_rom, esp_common, esp_system.

## 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 doesn’t always work, and it’s possible the build will 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:

```c
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 is 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:

```cmake
# 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 into 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.)

**4.5.9 Overriding Parts of the Project**

`project_include.cmake`

For components that have build requirements which 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”.

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 customised 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 into 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”.

#### 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 include paths.

#### 4.5.11 Debugging CMake

For full details about CMake and CMake commands, see the CMake v3.5 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 -DDDEBUG=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.txt` 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, idf.py passes the `--warn-uninitialized` flag to CMake 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.

If you don’t want this behaviour, it can be disabled by passing `--no-warnings` to idf.py.

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 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:

```c
config FOO_ENABLE_BAR
  bool "Enable the BAR feature."
  help
    This enables the BAR feature of the FOO component.
```  

CMakeLists.txt:

```c
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:

```c
config ENABLE_LCD_OUTPUT
  bool "Enable LCD output."
  help
    Select this if your board has a 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}"
                        ...
)
```

### Conditions which depend on the target

The current target is available to CMake files via `IDF_TARGET` variable.

In addition to that, if target `xyz` is used (`IDF_TARGET=xyz`), then `Kconfig` variable `CONFIG_IDF_TARGET_XYZ` will be set.

Note that component dependencies may depend on `IDF_TARGET` variable, but not on `Kconfig` variables. Also one cannot use `Kconfig` variables in `include` statements in CMake files, but `IDF_TARGET` can be used in such context.

### Source Code Generation

Some components will have a situation where a source file isn’t supplied with the component itself but has to be generated from another file. Say your component has a header file that consists of the converted binary data of a BMP file, converted using a hypothetical tool called `bmp2h`. The header file is then included in as C source file called `graphics_lib.c`:

```cmake
add_custom_command(OUTPUT logo.h
                    COMMAND bmp2h -i ${COMPONENT_DIR}/logo.bmp -o log.h
                    DEPENDS ${COMPONENT_DIR}/logo.bmp
                    VERBATIM)

add_custom_target(logo DEPENDS logo.h)
add_dependencies(${COMPONENT_LIB} logo)

set_property(DIRECTORY "${COMPONENT_DIR}" APPEND PROPERTY
             ADDITIONAL_MAKE_CLEAN_FILES logo.h)
```

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_MAKE_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 C source.

You can specify argument EMBED_FILES in the component registration, giving space-delimited names of the files to embed:

```c
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:

```c
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:

```c
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 embed a generated file:

```c
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:

```c
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 linker script 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
  ${COMPONENT_DIR}/quirc/lib)
set_directory_properties( PROPERTIES ADDITIONAL_MAKE_CLEAN_FILES
  "${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_MAKE_CLEAN_FILES. This means make clean will delete this library. (Note that the other object files from the build won’t be deleted.)

ExternalProject dependencies, clean builds  CMake has some unusual behaviour around external project builds:

- ADDITIONAL_MAKE_CLEAN_FILES only works when “make” is used as the build system. If Ninja or 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 behaviour, 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. If specifying multiple files, use semicolon as the list separator. File names not specified as full paths are resolved relative to current project.

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.

### 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 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 built by default as part of `idf.py build`, or can be built standalone via `idf.py 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 Selecting the 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`.

To select the target before building the project, use `idf.py set-target <target>` command, for example:

```
idf.py set-target esp32s2
```

**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 `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, add `CONFIG_IDF_TARGET` value to `sdkconfig.defaults`. For example, `CONFIG_IDF_TARGET="esp32s2"`. This value will be used if `IDF_TARGET` is not specified by other method: using an environment variable, CMake variable, or `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.

### 4.5.17 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`:

```
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 behaviour 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.
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4.5.18 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
# Register the component
idf_component_register(...)

# Set values of hypothetical variables that control the build of `foo`
set(FOO_BUILD_STATIC OFF)
set(FOO_BUILD_TESTS OFF)

# Create and import the library targets
add_subdirectory(foo)

# Publicly link `foo` to `main` component
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 if (ESP_PLATFORM) can be used in generic CMake code if special IDF-specific logic is required.

Using ESP-IDF components from external libraries

The above example assumes that the external library foo (or tinyxml in the case of the import_lib example) doesn’t need to use any ESP-IDF APIs apart from common APIs such as libc, libstdc++, etc. If the external library needs to use APIs provided by other ESP-IDF components, this needs to be specified in the external CMakeLists.txt file by adding a dependency on the library target idf::<componentname>.

For example, in the foo/CMakeLists.txt file:

```cmake
add_library(foo bar.c fizz.cpp buzz.cpp)

if(ESP_PLATFORM)
    # On ESP-IDF, bar.c needs to include esp_spi_flash.h from the spi_flash component
    target_link_libraries(foo PRIVATE idf::spi_flash)
endif()
```

4.5.19 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 ...
```

where:

- `target_name` - name that can be used to reference the imported library, such as when linking to other targets
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- **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**.

### 4.5.20 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
# 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
# specific 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.

### 4.5.21 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.

```cmake
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:
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
- COMPILER_OPTIONS - compile options applied to all components’ source files, regardless of it being C or C++
- COMPILER_DEFINITIONS - compile definitions applied to all component source files
- CXX_COMPILE_OPTIONS - compile options applied to all components’ C++ source files
- 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_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_VERS - 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_VERS - version of the project; set from `idf_build_process` PROJECT_VERS 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**

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.

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 it is currently empty, the specified value becomes the first element/member instead.
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 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 globed files.
- **INCLUDE_DIRS** - paths, relative to the component directory, which will be added to the include search path for all other components which require this 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
- **LDFFRAGMENTS** - 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.projobuild file

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:

```
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

• PRIV_INCLUDE_DIRS - list of component private include directories; set from idf_component_register PRIV_INCLUDE_DIRS on components of type LIBRARY

• PRIV_REQUIRES - list of private component dependencies; set from idf_component_register PRIV_REQUIRES argument

• REQUIRED>IDF_TARGETS - list of targets the component supports; set from idf_component_register EMBED_TXTFILES argument

• REQUIRES - list of public component dependencies; set from idf_component_register REQUIRES argument

• SRCS - list of component source files; set from SRCS or SRC_DIRS/EXCLUDE_SRCS argument of idf_component_register

4.5.22 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:

```
idf_component_register(SRCS library/a.c library/b.c platform/platform.c ...
```

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 SRCS 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.

4.5.23 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.
- 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 confserver.py is provided to allow IDEs to easily integrate with the configuration system logic. confserver.py 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 confserver.py from a project via idf.py confserver or ninja confserver, or a similar target triggered from a different build generator.

For more information about confserver.py, see tools/kconfig_new/README.md.

4.5.24 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:

**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_COMPONENTS_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.
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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 CMake-
  Lists.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.

4.5.25 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.

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_LDFLAGS: 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.
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- **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_MAKE_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 Deep Sleep Wake Stubs

ESP32-S3 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.

#### 4.6.1 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.

### 4.6.2 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/esp32s3.

### 4.6.3 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.

### 4.6.4 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:

```c
RTC_DATA_ATTR int wake_count;
void RTC_IRAM_ATTR esp_wake_deep_sleep(void) {
    esp_default_wake_deep_sleep();
    static RTC_RODATA_ATTR const char fmt_str[] = "Wake count $d
    esp_rom_printf(fmt_str, wake_count);
}
```

The RTC memory area where this data will be placed can be configured via menuconfig option named `CONFIG_ESP32S3_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 forced 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 %d\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.

### 4.6.5 CRC Check For Wake Stubs

During deep sleep, only the wake stubs area of RTC Fast memory is validated with CRC. When ESP32-S3 wakes up from deep sleep, the wake stubs area is validated again. If the validation passes, the wake stubs code will be executed. Otherwise, the normal initialization, bootloader, and esp-idfcodes 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.

### 4.7 Device Firmware Upgrade through USB

Device Firmware Upgrade (DFU) is a mechanism for upgrading the firmware of devices through Universal Serial Bus (USB). DFU is supported by ESP32-S3 chips. The necessary connections for the USB peripheral are shown in the following table.

<table>
<thead>
<tr>
<th>GPIO</th>
<th>USB</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>D+ (green)</td>
</tr>
<tr>
<td>19</td>
<td>D- (white)</td>
</tr>
<tr>
<td>GND</td>
<td>GND (black)</td>
</tr>
<tr>
<td>+5V</td>
<td>+5V (red)</td>
</tr>
</tbody>
</table>

By default, USB_SERIAL_JTAG module is connected to the internal PHY of the ESP32-S3, while USB_OTG peripheral can be used only if the external USB PHY is connected. Since DFU mode is provided via USB_OTG peripheral, it cannot be used through the internal PHY in this configuration.

You can permanently switch the internal USB PHY to work with USB_OTG peripheral instead of USB_SERIAL_JTAG by burning USB_PHY_SEL eFuse. See ESP32-S3 Technical Reference Manual for more details about USB_SERIAL_JTAG and USB_OTG.

**Note:** The ESP32-S3 chip needs to be in bootloader mode for the detection as a DFU device and flashing. This can be achieved by pulling GPIO0 down (e.g. pressing the BOOT button), pulsing RESET down for a moment and releasing GPIO0.
Warning: Some cables are wired up with non-standard colors and some drivers are able to work with swapped D+ and D- connections. Please try to swap the cables connecting to D+ and D- if your device is not detected.

The software requirements of DFU are included in Software of the Getting Started Guide.

Section Building the DFU Image describes how to build firmware for DFU with ESP-IDF and Section Flashing the Chip with the DFU Image deals with flashing the firmware.

### 4.7.1 Building the DFU Image

The DFU image can be created by running:

```bash
idf.py dfu
```

which creates `dfu.bin` in the build directory.

**Note:** Don’t forget to set the target chip by `idf.py set-target` before running `idf.py dfu`. Otherwise, you might create an image for a different chip or receive an error message something like `unknown target 'dfu`.

### 4.7.2 Flashing the Chip with the DFU Image

The DFU image is downloaded into the chip by running:

```bash
idf.py dfu-flash
```

which relies on `dfu-util`. Please see Software for installing `dfu-util`. `dfu-util` needs additional setup for USB drivers (Windows only) or setting up an `udev rule (Linux only)`. Mac OS users should be able to use `dfu-util` without further setup.

If there are more boards with the same chip connected then `idf.py dfu-list` can be used to list the available devices, for example:

```
Found Runtime: [303a:0002] ver=0723, devnum=4, intf=2, path="1-10", alt=0, ... 
```

Consequently, the desired device can be selected for flashing by the `--path` argument. For example, the devices listed above can be flashed individually by the following commands:

```bash
idf.py dfu-flash --path 1-10
idf.py dfu-flash --path 1-2
```

**Note:** The vendor and product identificators are set based on the selected chip target by the `idf.py set-target` command and it is not selectable during the `idf.py dfu-flash` call.

See Common errors and known issues and their solutions.

**udev rule (Linux only)**

`udev` is a device manager for the Linux kernel. It allows us to run `dfu-util` (and `idf.py dfu-flash`) without `sudo` for gaining access to the chip.
Create file `/etc/udev/rules.d/40-dfuse.rules` with the following content:

```
SUBSYSTEMS=="usb", ATTRS{idVendor}=="303a", ATTRS{idProduct}=="00??", GROUP=
"plugdev", MODE="0666"
```

**Note:** Please check the output of command `groups`. The user has to be a member of the `GROUP` specified above. You may use some other existing group for this purpose (e.g. `uucp` on some systems instead of `plugdev`) or create a new group for this purpose.

Restart your computer so the previous setting could take into affect or run `sudo udevadm trigger` to force manually udev to trigger your new rule.

**USB drivers (Windows only)**

dfu-util uses `libusb` to access the device. You have to register on Windows the device with the WinUSB driver. Please see the `libusb wiki` for more details.

The drivers can be installed by the Zadig tool. Please make sure that the device is in download mode before running the tool and that it detects the ESP32-S3 device before installing the drivers. The Zadig tool might detect several USB interfaces of ESP32-S3. Please install the WinUSB driver for only that interface for which there is no driver installed (probably it is Interface 2) and don’t re-install the driver for the other interface.

**Warning:** The manual installation of the driver in Device Manager of Windows is not recommended because the flashing might not work properly.

**Common errors and known issues**

- `dfu-util: command not found` might indicate that the tool hasn’t been installed or is not available from the terminal. An easy way of checking the tool is running `dfu-util --version`. Please see `Software` for installing dfu-util.
- The reason for `No DFU capable USB device available` could be that the USB driver wasn’t properly installed on Windows (see `USB drivers (Windows only)`), udev rule was not setup on Linux (see `udev rule (Linux only)`) or the device isn’t in bootloader mode.
- Flashing with `dfu-util` on Windows fails on the first attempt with error `Lost device after RESET?`. Please retry the flashing and it should succeed the next time.

### 4.8 Error Handling

#### 4.8.1 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.

### 4.8.2 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.

### 4.8.3 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.

### 4.8.4 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 0x40087328:0x3ffb5010 0x400d1fdf:0x3ffb5030...->0x400d0816:0x3ffb5050
```

**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 occured is printed as well.
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- 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.

### 4.8.5 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().

### 4.8.6 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.

### 4.8.7 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.

### 4.8.8 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.

### 4.8.9 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.

### 4.8.10 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, printed if `x` is not `ESP_OK`, and then `abort()`.
    ESP_ERROR_CHECK WITHOUT_ABORT(x); // err message, printed if `x` is not `ESP_OK`, without `abort()`.
    ESP_RETURN_ON_ERROR(x, TAG, "fail reason 1"); // err message, printed if `x` is not `ESP_OK`, without `abort()`, and then function returns with code `x`.
    ESP_GOTO_ON_ERROR(x, TAG, "fail reason 2"); // err message, printed if `x` is not `ESP_OK`, and then function returns with code `x`.
    ESP_GOTO_ON_FALSE(a, TAG, "fail reason 3"); // err message, printed if `a` is not `true`, and then function returns with code `err_code`.
    ESP_GOTO_ON_FALSE(a, err_code, err, TAG, "fail reason 4"); // err message, printed if `a` is not `true`, `ret` is set to `a`, and then jumps to `err`.

    ESP_ERROR_CHECK(x2); // err message, printed if `x2` is not `ESP_OK`, and then `abort()`.
    ESP_ERROR_CHECK WITHOUT_ABORT(x2); // err message, printed if `x2` is not `ESP_OK`, without `abort()`.
    ESP_RETURN_ON_ERROR(x2, TAG, "fail reason 1"); // err message, printed if `x2` is not `ESP_OK`, without `abort()`, and then function returns with code `x2`.
    ESP_GOTO_ON_ERROR(x2, TAG, "fail reason 2"); // err message, printed if `x2` is not `ESP_OK`, and then function returns with code `x2`.
    ESP_GOTO_ON_FALSE(a2, TAG, "fail reason 3"); // err message, printed if `a2` is not `true`, and then function returns with code `err_code`.
    ESP_GOTO_ON_FALSE(a2, err_code, err, TAG, "fail reason 4"); // err message, printed if `a2` is not `true`, `ret` is set to `err_code`, and then jumps to `err`.
```

(continues on next page)
// 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.

### 4.8.11 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);
   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:

   ```c
   ESP_ERROR_CHECK(spi_bus_initialize(host, bus_config, dma_chan));
   ```
4.8.12 C++ Exceptions

Support for C++ Exceptions in ESP-IDF is disabled by default, but can be enabled using `CONFIG_COMPILER_CXX_EXCEPTIONS` option.

Enabling exception handling normally increases application binary size by a few KB. Additionally it may be necessary to reserve some amount of RAM for exception emergency pool. Memory from this pool will be used if it is not possible to allocate exception object from the heap. Amount of memory in the emergency pool can be set using `CONFIG_COMPILER_CXX_EXCEPTIONS_EMG_POOL_SIZE` variable.

If an exception is thrown, but there is no `catch` block, the program will be terminated by `abort` function, and backtrace will be printed. See Fatal Errors for more information about backtraces.

See `cxx/exceptions` for an example of C++ exception handling.

4.9 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 dependent 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 architecture 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-S3, please check another product by Espressif called ESP-WIFI-MESH. For more information and documentation see ESP-WIFI-MESH.

4.9.1 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-S3 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 Model 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-S3 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-S3 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.

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. 4: ESP-BLE-MESH Devices Power On

Fig. 5: nRF Mesh - Scanner
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.

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.
Fig. 7: nRF Mesh - Configuration Complete

Fig. 8: nRF Mesh - Initial Configuration Failed
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Fig. 9: nRF Mesh - Reconnect - Initial Configuration

Fig. 10: nRF Mesh - Reconnect - Three Nodes
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.

---

**4.9.2 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 node model, a Configuration Client model and a Generic OnOff Client model, see example code .
Fig. 12: nRF Mesh - Generic OnOff Control

Fig. 13: Three ESP-BLE-MESH Nodes On
• 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-S3. 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.

4.9.3 ESP-BLE-MESH Demo Videos

• Provisioning of ESP-BLE-MESH nodes using Smartphone App
• Espressif Fast Provisioning using ESP-BLE-MESH App
• Espressif ESP-BLE-MESH and Wi-Fi Coexistence

4.9.4 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

4.9.5 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
  – 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 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
Chapter 4. API Guides

- 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.

- 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:

<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.
Fig. 14: Figure 1.1 ESP-BLE-MESH Architecture Diagram
• 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>
<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</td>
<td>The Provisioning PDUs are transmitted to an unprovisioned device using a Generic Provisioning layer or Proxy protocol layer.</td>
</tr>
<tr>
<td>PDU/Proxy PDU</td>
<td>These layers define how the Provisioning PDUs are transmitted as transactions that can be segmented and reassembled.</td>
</tr>
<tr>
<td>PB-ADV/PB-GATT</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>
<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:

• 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>
<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 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>trans-</td>
<td>ESP-BLE-MESH Lower/Upper Transport Layer</td>
</tr>
<tr>
<td>port.c</td>
<td></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</td>
</tr>
<tr>
<td></td>
<td>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.
Table 8: 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</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>cfg_srv.c</td>
<td>Receive Configuration Client messages and send</td>
</tr>
<tr>
<td></td>
<td>proper response messages</td>
</tr>
<tr>
<td>health_cli.c</td>
<td>Send Health Client messages and receive</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>health_srv.c</td>
<td>Receive Health Client messages and send proper</td>
</tr>
<tr>
<td></td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>lighting_client.c</td>
<td>Send ESP-BLE-MESH Lighting Client messages and receive</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>sensor_client.c</td>
<td>Send ESP-BLE-MESH Sensor Client messages and receive</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>time_scene_client.c</td>
<td>Send ESP-BLE-MESH Time Scene Client messages and</td>
</tr>
<tr>
<td></td>
<td>receive corresponding response messages</td>
</tr>
<tr>
<td>generic_server.c</td>
<td>Receive ESP-BLE-MESH Generic Client messages and send</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>lighting_server.c</td>
<td>Receive ESP-BLE-MESH Lighting Client messages and send</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>sensor_server.c</td>
<td>Receive ESP-BLE-MESH Sensor Client messages and send</td>
</tr>
<tr>
<td></td>
<td>corresponding response messages</td>
</tr>
<tr>
<td>time_scene_server.c</td>
<td>Receive ESP-BLE-MESH Time Scene Client messages and</td>
</tr>
<tr>
<td></td>
<td>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 9: 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</td>
</tr>
<tr>
<td></td>
<td>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
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 recovery procedure, Key Refresh procedure related functionalities</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.
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- 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_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_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 cannot 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: 0C001A000080030000010501000080010000103103F002A00
// 0C00 1A00 0100 0800 0300 0001 05 01 0000 0800 0100 0001 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, 0x1003
```

(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 * 2) {
        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\n", 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\n", 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\n", 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[] = {
        0x0C, 0x00, 0x1A, 0x00,
        0x01, 0x00, 0x08, 0x00,
        0x03, 0x00, 0x00, 0x01,
        0x05, 0x01, 0x00, 0x00,
        0x00, 0x80, 0x01, 0x00,
        0x00, 0x10, 0x03, 0x10,
        0x3F, 0x00, 0x2A, 0x00};

    int ret;
    ret = decode_comp_data(&head, &data, mystr, sizeof(mystr));
    if (ret == -1) {
        printf("decode_comp_data error\n");
    }
}

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.

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++) {
        // Further configuration...
    }
}
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.
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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.
• 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?
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-octets 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.

And 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 fast_prov_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.
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- 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-S3?

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 menu-config to change it.
### ESP-BLE-MESH Terminology

#### Table 11: 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 12: 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</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 13: 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>
</tbody>
</table>
Table 14: Table 4 ESP-BLE-MESH Terminology - Provisioning

<table>
<thead>
<tr>
<th>Term</th>
<th>Official Definition</th>
<th>Detailed Explanation</th>
</tr>
</thead>
<tbody>
<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>
<tr>
<td>Term</td>
<td>Official Definition</td>
<td>Detailed Explanation</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<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 16: 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 17: 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 18: 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 19: 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 (Initialisation 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
4.10 ESP-WIFI-MESH

This guide provides information regarding the ESP-WIFI-MESH protocol. Please see the ESP-WIFI-MESH API Reference for more information about API usage.

4.10.1 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

4.10.2 Introduction

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.

Fig. 17: ESP-WIFI-MESH Network Architecture

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.

4.10.3 ESP-WIFI-MESH Concepts
# 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 Connection</td>
<td>The connection from a node to its parent node</td>
</tr>
<tr>
<td>Downstream Connection</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.
Fig. 18: ESP-WIFI-MESH Tree Topology

Fig. 19: 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
- Maximum 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.

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...
4.10.4 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 ids 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 propagated 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.

**Fig. 25: 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.
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Fig. 26: Network Building with Asynchronous Power On Example

Node Powered Off
Idle Node
Root Node
Intermediate Parent Node

Synchronous Power-On

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Release v5.0-dev-1648-g94089edbc3
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).

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.

4.10.5 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.

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**Fig. 29: 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.

4.10.6 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. 30: 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
\texttt{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 \textbf{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 \texttt{mesh\_opt\_t} and \texttt{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 a 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 \texttt{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 \texttt{MESH\_DATA\_GROUP} flag must set. Using groups to multicast incurs less overhead, but requires nodes to previously added into groups.

\textbf{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.

\section*{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 throughout 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.

\section*{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 \textbf{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.

![Bi-Directional Data Stream Diagram]

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.

### 4.10.7 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.
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 indicate 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 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 the 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**
  - 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 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.
4.10.8 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>
</tr>
<tr>
<td>N</td>
<td>X</td>
<td>Y</td>
<td>N</td>
<td>X</td>
<td>Channel Only</td>
</tr>
<tr>
<td>N</td>
<td>X</td>
<td>Y</td>
<td>Y</td>
<td>X</td>
<td>Channel and Router</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>X</td>
<td>X</td>
<td>Channel and Router</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>X</td>
<td>N</td>
<td>Router Only</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>X</td>
<td>Y</td>
<td>Channel and Router</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>X</td>
<td>Channel Only</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Channel Only</td>
</tr>
<tr>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Channel Only</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Router Only</td>
</tr>
<tr>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<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.

### 4.10.9 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

### 4.11 Core Dump

#### 4.11.1 Overview

ESP-IDF provides support to generate core dumps on unrecoverable software errors. This useful technique allows post-mortem analysis of software state at the moment of failure. Upon the crash system enters panic state, prints some information and halts or reboots depending configuration. User can choose to generate core dump in order to analyse the reason of failure on PC later on. Core dump contains snapshots of all tasks in the system at the moment of failure. Snapshots include tasks control blocks (TCB) and stacks. So it is possible to find out what task, at what instruction (line of code) and what callstack of that task lead to the crash. It is also possible dumping variables content on demand if previously attributed accordingly. ESP-IDF provides special script `espcoredump.py` to help users to retrieve and analyse core dumps. This tool provides two commands for core dumps analysis:

- `info_corefile` - prints crashed task’s registers, callstack, list of available tasks in the system, memory regions and contents of memory stored in core dump (TCBs and stacks)
- `dbg_corefile` - creates core dump ELF file and runs GDB debug session with this file. User can examine memory, variables and tasks states manually. Note that since not all memory is saved in core dump only values of variables allocated on stack will be meaningful

For more information about core dump internals see the - [Core dump internals](#)

#### 4.11.2 Configurations

There are a number of core dump related configuration options which user can choose in project configuration menu (`idf.py menuconfig`).

**Core dump data destination (Components -> Core dump -> Data destination)**

- Save core dump to Flash (Flash)
- Print core dump to UART (UART)
- Disable core dump generation (None)

**Core dump data format (Components -> Core dump -> Core dump data format)**

- ELF format (Executable and Linkable Format file for core dump)
- Binary format (Basic binary format for core dump)

The ELF format contains extended features and allow to save more information about broken tasks and crashed software but it requires more space in the flash memory. This format of core dump is recommended for new software designs and is flexible enough to extend saved information for future revisions.

The Binary format is kept for compatibility standpoint, it uses less space in the memory to keep data and provides better performance.

**Core dump data integrity check (Components -> Core dump -> Core dump data integrity check)**

- Use CRC32 for core dump integrity verification
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Maximum number of tasks snapshots in core dump (Components -> Core dump -> Maximum number of tasks)

Delay before core dump is printed to UART (Components -> Core dump -> Delay before print to UART)

The value is in ms.

Handling of UART core dumps in IDF Monitor (Components -> Core dump -> Delay before print to UART)

The value is base64 encoded.

- Decode and show summary (info_corefile)
- Don’t decode

4.11.3 Save core dump to flash

When this option is selected core dumps are saved to special partition on flash. When using default partition table files which are provided with ESP-IDF it automatically allocates necessary space on flash, but if user wants to use its own layout file together with core dump feature it should define separate partition for core dump as it is shown 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
```

There are no special requirements for partition name. It can be chosen according to the user application needs, but partition type should be ‘data’ and sub-type should be ‘coredump’. Also when choosing partition size note that core dump data structure introduces constant overhead of 20 bytes and per-task overhead of 12 bytes. This overhead does not include size of TCB and stack for every task. So partition size should be at least 20 + max tasks number x (12 + TCB size + max task stack size) bytes.

The example of generic command to analyze core dump from flash is:

```
espcoredump.py -p </path/to/serial/port> info_corefile </path/to/program/elf/file>
```
or

```
espcoredump.py -p </path/to/serial/port> dbg_corefile </path/to/program/elf/file>
```

4.11.4 Print core dump to UART

When this option is selected base64-encoded core dumps are printed on UART upon system panic. In this case user should save core dump text body to some file manually and then run the following command:

```
espcoredump.py --chip esp32s3 info_corefile -t b64 -c </path/to/saved/base64/text> 
</path/to/program/elf/file>
```
or

```
espcoredump.py --chip esp32s3 dbg_corefile -t b64 -c </path/to/saved/base64/text> 
</path/to/program/elf/file>
```

Base64-encoded body of core dump will be between the following header and footer:

```
==
==
==
==
==
==
==
==

<body of base64-encoded core dump, save it to file on disk>

==
==
==
==
==
==
==
==
==
```

The CORE DUMP START and CORE DUMP END lines must not be included in core dump text file.
4.11.5 ROM Functions in Backtraces

It is possible situation that at the moment of crash some tasks or/and crashed task itself have one or more ROM functions in their callstacks. Since ROM is not part of the program ELF it will be impossible for GDB to parse such callstacks, because it tries to analyse functions’ prologues to accomplish that. In that case callstack printing will be broken with error message at the first ROM function. To overcome this issue you can use ROM ELF provided by Espressif (https://dl.espressif.com/dl/esp32s3_rom.elf) and pass it to ‘espcoredump.py’.

4.11.6 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 attributing special notations declared variables.

Supported notations and RAM regions

- COREDUMP_DRAM_ATTR places variable into DRAM area which will be included into dump.
- COREDUMP_RTC_ATTR places variable into RTC area which will be included into dump.
- COREDUMP_RTC_FAST_ATTR places variable into RTC_FAST area which will be included into dump.

Example

1. In Project Configuration Menu, enable COREDUMP TO FLASH, then save and exit.
2. In your project, create a global variable in DRAM area as such as:

```c
// uint8_t global_var;
COREDUMP_DRAM_ATTR uint8_t global_var;
```

3. In 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
espcoredump.py -p PORT dbg_corefile <path/to/elf>
```

6. In GDB shell, type `p global_var` to get the variable content:

```gdb
(gdb) p global_var
$1 = 25 '\031'
```

4.11.7 Running espcoredump.py

Generic command syntax: espcoredump.py [options] command [args]

Script Options

- `--chip {auto,esp32,esp32s2,esp32s3,esp32c3}` Target chip type. Default value is “auto”
- `--port PORT, -p PORT` Serial port device. Either “chip” or “port” need to be specified to determine the port when you have multi-target connected at the same time.
- `--baud BAUD, -b BAUD` Serial port baud rate used when flashing/reading
- `--gdb-timeout-sec GDB_TIMEOUT_SEC` Overwrite the default internal delay for gdb responses

Commands
dbg_corefile Starts GDB debugging session with specified corefile
info_corefile Print core dump info from file
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Command Arguments
--debug DEBUG, -d DEBUG   Log level (0..3)
--gdb GDB, -g GDB        Path to gdb
--core CORE, -c CORE     Path to core dump file (if skipped core dump will be read from flash)
--core-format {b64,elf,raw}, -t {b64,elf,raw} File specified with “-c” is an ELF (“elf”), raw (raw) or base64-encoded (b64) binary
--off OFF, -o OFF        Offset of coredump partition in flash (type “idf_py_partition-table” to see).
--save-core SAVE_CORE, -s SAVE_CORE  Save core to file. Otherwise temporary core file will be deleted. Does not work with “-c”
--rom-elf ROM_ELF, -r ROM_ELF  Path to ROM ELF file. Will use “<target>_rom.elf” if not specified
--print-mem, -m          Print memory dump. Only valid when info_corefile.
<prog> Path to program ELF file.

Related Documents

Anatomy of core dump image  Core dump component can be configured to use old legacy binary format or the new ELF one. The ELF format is recommended for new designs. It provides more information about the CPU and memory state of a program at the moment when panic handler is entered. 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. Core dump file uses a subset of the ELF structures to register these information. Loadable ELF segments are used for the memory state of the process while ELF notes (ELF.PT_NOTE) are used for process metadata (pid, registers, signal, ...). Especially, the CPU status is stored in a note with a special name and type (CORE, NT_PRSTATUS type).

Here is an overview of coredump layout:
Note: The format of image file showed on the above pictures represents current version of image and can be changed in future releases.

Overview of implementation  The figure below describes some basic aspects related to implementation of core dump:
Note: The diagram above hide some details and represents current implementation of the core dump and can be changed later.

4.12 Event Handling

Several ESP-IDF components use events to inform application about state changes, such as connection or disconnection. This document gives an overview of these event mechanisms.

4.12.1 Wi-Fi, Ethernet, and IP Events

Before the introduction of esp_event library, events from Wi-Fi driver, Ethernet driver, and TCP/IP stack were dispatched using the so-called legacy event loop. The following sections explain each of the methods.

esp_event Library Event Loop

esp_event library is designed to supersede the legacy event loop for the purposes of event handling in ESP-IDF. In the legacy event loop, all possible event types and event data structures had to be defined in system_event_id_t enumeration and system_event_info_t union, which made it impossible to send custom events to the event loop, and use the event loop for other kinds of events (e.g. Mesh). Legacy event loop also supported only one event
Fig. 32: Core dump ELF image format

Fig. 33: Core dump binary image format
handler function, therefore application components could not handle some of Wi-Fi or IP events themselves, and required application to forward these events from its event handler function.

See esp_event library API reference for general information on using this library. Wi-Fi, Ethernet, and IP events are sent to the default event loop provided by this library.

**Legacy Event Loop**

This event loop implementation is started using `esp_event_loop_init()` function. Application typically supplies an event handler, a function with the following signature:

```c
esp_err_t event_handler(void *ctx, system_event_t *event) {
}
```

Both the pointer to event handler function, and an arbitrary context pointer are passed to `esp_event_loop_init()`.

When Wi-Fi, Ethernet, or IP stack generate an event, this event is sent to a high-priority event task via a queue. Application-provided event handler function is called in the context of this task. Event task stack size and event queue size can be adjusted using `CONFIG_ESP_SYSTEM_EVENT_TASK_STACK_SIZE` and `CONFIG_ESP_SYSTEM_EVENT_QUEUE_SIZE` options, respectively.

Event handler receives a pointer to the event structure (`system_event_t`) which describes current event. This structure follows a tagged union pattern: `event_id` member indicates the type of event, and `event_info` member is a union of description structures. Application event handler will typically use `switch(event->event_id)` to handle different kinds of events.

If application event handler needs to relay the event to some other task, it is important to note that event pointer
passed to the event handler is a pointer to temporary structure. To pass the event to another task, application has to make a copy of the entire structure.

### Event IDs and Corresponding Data Structures

<table>
<thead>
<tr>
<th>Event ID (legacy event ID)</th>
<th>Event data structure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wi-Fi</strong></td>
<td></td>
</tr>
<tr>
<td>WIFI_EVENT_WIFI_READY</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_SCAN_DONE</td>
<td>wifi_event_sta_scan_done_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_START</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_STOP</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_CONNECTED</td>
<td>wifi_event_sta_connected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_DISCONNECTED</td>
<td>wifi_event_sta_disconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_AUTHMODE_CHANGE</td>
<td>wifi_event_sta_authmode_change_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_SUCCESS</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_FAILED</td>
<td>wifi_event_sta_wps_fail_reason_t</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_TIMEOUT</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_STA_WPS_ER_PIN</td>
<td>wifi_event_sta_wps_er_pin_t</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_START</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_STOP</td>
<td>n/a</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_STACONNECTED</td>
<td>wifi_event_ap_staconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_STADISCONNECTED</td>
<td>wifi_event_ap_stadisconnected_t</td>
</tr>
<tr>
<td>WIFI_EVENT_AP_PROBEREQRECVED</td>
<td>wifi_event_ap_probe_req_rx_t</td>
</tr>
<tr>
<td><strong>Ethernet</strong></td>
<td></td>
</tr>
<tr>
<td>ETHERNET_EVENT_START</td>
<td>n/a</td>
</tr>
<tr>
<td>ETHERNET_EVENT_STOP</td>
<td>n/a</td>
</tr>
<tr>
<td>ETHERNET_EVENT_CONNECTED</td>
<td>n/a</td>
</tr>
<tr>
<td>ETHERNET_EVENT_DISCONNECTED</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>IP</strong></td>
<td></td>
</tr>
<tr>
<td>IP_EVENT_STA_GOT_IP</td>
<td>ip_event_got_ip_t</td>
</tr>
<tr>
<td>IP_EVENT_STA_LOST_IP</td>
<td>n/a</td>
</tr>
<tr>
<td>IP_EVENT_AP_STAIPASSIGNED</td>
<td>n/a</td>
</tr>
<tr>
<td>IP_EVENT_GOT_IP6</td>
<td>ip_event_got_ip6_t</td>
</tr>
<tr>
<td>IP_EVENT_ETH_GOT_IP</td>
<td>ip_event_got_ip_t</td>
</tr>
</tbody>
</table>

### 4.12.2 Mesh Events

ESP-WIFI-MESH uses a system similar to the Legacy Event Loop to deliver events to the application. See System Events for details.
4.12.3 Bluetooth Events

Various modules of the Bluetooth stack deliver events to applications via dedicated callback functions. Callback functions receive the event type (enumerated value) and event data (union of structures for each event type). The following list gives the registration API name, event enumeration type, and event parameter type.

- **BLE GAP**: `esp_ble_gap_register_callback()`, `esp_gap_ble_cb_event_t`, `esp_ble_gap_cb_param_t`.
- **BT GAP**: `esp_bt_gap_register_callback()`, `esp_bt_gap_cb_event_t`, `esp_bt_gap_cb_param_t`.
- **GATT**: `esp_ble_gattc_register_callback()`, `esp_bt_gattc_cb_event_t`, `esp_ble_gattc_cb_param_t`.
- **GATTS**: `esp_ble_gatts_register_callback()`, `esp_bt_gatts_cb_event_t`, `esp_ble_gatts_cb_param_t`.
- **SPP**: `esp_spp_register_callback()`, `esp_spp_cb_event_t`, `esp_spp_cb_param_t`.
- **Blufi**: `esp_blufi_register_callbacks()`, `esp_blufi_cb_event_t`, `esp_blufi_cb_param_t`.
- **A2DP**: `esp_a2d_register_callback()`, `esp_a2d_cb_event_t`, `esp_a2d_cb_param_t`.
- **AVRC**: `esp_avrc_ct_register_callback()`, `esp_avrc_ct_cb_event_t`, `esp_avrc_ct_cb_param_t`.
- **HFP Client**: `esp_hf_client_register_callback()`, `esp_hf_client_cb_event_t`, `esp_hf_client_cb_param_t`.
- **HFP AG**: `esp_hf_ag_register_callback()`, `esp_hf_ag_cb_event_t`, `esp_hf_ag_cb_param_t`.

4.13 Support for External RAM

4.13.1 Introduction

ESP32-S3 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, so ESP32-S3 has the ability to also use up to 16 MB of 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-S3 supports SPI PSRAM (Psuedostatic RAM) connected in parallel with the SPI flash chip. While ESP32-S3 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-S3 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-S3 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.

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-S3 Memory Map
- Add External RAM to theCapability Allocator
- Provide External RAM via malloc() (default)

Integrate RAM into the ESP32-S3 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 0x3D000000 (byte-accessible). The length of this region is the same as the SPI RAM size (up to the limit of 16 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 0x3D000000 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.
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 reads from or writes 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 cannot be used as a place to store DMA transaction descriptors or as a buffer for a DMA transfer to read from or write into. Any buffers that will be used in combination with DMA must be allocated using `heap_caps_malloc(size, MALLOC_CAP_DMA)` and can be freed using a standard `free()` call.
- 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 cannot be used as task stack memory. Due to this, `xTaskCreate()` and similar functions will always allocate internal memory for stack and task TCBs, and functions such as `xTaskCreateStatic()` will check if the buffers passed are internal.

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_SPIRAMIGNORE_NOTFOUND`.

4.13.6 Encryption

It is possible to enable automatic encryption for data stored in external RAM. When this is enabled any data read and written through the cache will automatically be encrypted/decrypted by the external memory encryption hardware.

This feature is enabled whenever flash encryption is enabled. For more information on how to enable and how it works see Flash Encryption.

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_ESP_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

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 two other configuration options.

- If CONFIG_ESP32S3_DEBUG_OCDAWARE 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_SYSTEM_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.

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>PC : 0x400e14ed</td>
</tr>
<tr>
<td>A2 : 0x00000000</td>
</tr>
<tr>
<td>A6 : 0x00000000</td>
</tr>
</tbody>
</table>

(continues on next page)
Fig. 35: 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-S3 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:

```
Core 0 register dump:
PC : 0x400e14ed PS : 0x00060030 A0 : 0x800d0805 A1 : ...
   0x3ffb5030
0x400e14ed: app_main at /Users/user/esp/example/main/main.cpp:36
A2 : 0x00000000 A3 : 0x00000001 A4 : 0x00000001 A5 : ...
   0x3ffb503c
A5 : 0x00000000 A7 : 0x00000001 A8 : 0x00000000 A9 : ...
   0x3ffb5000
A10 : 0x00000000 A11 : 0x3ffb2bac A12 : 0x40082d1c A13 : ...
   0x06ff1ff8
0x40082d1c: _calloc_r at /Users/user/esp/esp-idf/components/newlib/syscalls.c:51
A14 : 0x3ffb7078 A15 : 0x00000000 SAR : 0x00000014 EXCCAUSE:...
   0x00000001d
EXCVADDR: 0x00000000 LBEG : 0x4000c46c LEND : 0x4000c477 LCOUNT ...
   0x0fffffff
Backtrace: 0x400e14ed:0x3ffb5030 0x400d0802:0x3ffb5050
0x400e14ed: app_main at /Users/user/esp/example/main/main.cpp:36
0x400d0802: main_task at /Users/user/esp/esp-idf/components/esp32s3/cpu_start.c:470
```
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Entering gdb stub now.
$T0b#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-
→
→esp32s3-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.
Remote debugging using /dev/cu.usbserial-31301
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 Guru Meditation Errors

This section explains the meaning of different error causes, printed in parens after the Guru Meditation Error: 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-S3 and SPI flash.
• In C++ code, exiting from a non-void function without returning a value is considered to be an undefined behavior. When optimizations are enabled, the compiler will often omit the epilogue in such functions. This most often results in an IllegalInstruction exception. By default, ESP-IDF build system enables -Werror=return-type 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 IllegalInstruction 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 0x4xxxxxxx).

**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:

```
Debug exception reason: Stack canary watchpoint triggered (task_name)
```

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 watchpoint will not be triggered.

**Interrupt wdt timeout on CPU0 / CPU1**

Indicates that an interrupt watchdog timeout has occurred. See Watchdogs for more information.
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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.

4.14.6 Other Fatal Errors

Brownout

ESP32-S3 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_ESP32S3_BROWNOUT_DET and CONFIG_ESP32S3_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 0xbaad5678 got 0xbaac5678
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 0x4008eb7:0x3ffcc17a0 0x400d2138:0x3ffcc17c0...
  -0x400e79d5:0x3ffcc17e0 0x400e79a7:0x3ffcc1840 0x400e79df:0x3ffcc18a0...
  -0x400e2235:0x3ffcc18c0 0x400e1916:0x3ffcc18f0 0x400e19cd:0x3ffcc1910...
  -0x400e1a11:0x3ffcc1930 0x400e1bb2:0x3ffcc1950 0x400d2c44:0x3ffcc1a80 0

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")
```

UBSAN output

When UBSAN detects an error, a message and the backtrace are printed, for example:

```
Undefined behavior of type out_of_bounds
Backtrace:0x4008b383:0x3ffcd8b0 0x4008c791:0x3ffcd8d0 0x4008c587:0x3ffcd8f0...
```

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
```

(continues on next page)
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</td>
<td>Incorrect pointer value: null, unaligned, not compatible with the given type.</td>
</tr>
<tr>
<td>type_mismatch_v1</td>
<td></td>
</tr>
<tr>
<td>add_overflow, sub_overflow,</td>
<td>Integer overflow during addition, subtraction, multiplication, negation.</td>
</tr>
<tr>
<td>mul_overflow, negate_overflow</td>
<td></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-S3’s flash encryption feature. Using an application code 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-S3’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).
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-S3. 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-S3. The list of eFuses and their descriptions is given in the table below. The names in eFuse column are also used by espefuse.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>BLOCK_KEYN</td>
<td>AES key storage. N is between 0 and 5.</td>
<td>One 256 bit key block for XTS_AES_128, Two 256 bit key blocks for XTS_AES_256 (512 bit total)</td>
</tr>
<tr>
<td>KEY_PURPOSE_N</td>
<td>Controls the purpose of eFuse block BLOCK_KEYN, where N is between 0 and 5. Possible values: 2 for XTS_AES_256_KEY_1, 3 for XTS_AES_256_KEY_2, and 4 for XTS_AES_128_KEY. Final AES key is derived based on the value of one or two of these purpose eFuses. For a detailed description of the possible combinations, see ESP32-S3 Technical Reference Manual &gt; External Memory Encryption and Decryption (XTS_AES) [PDF].</td>
<td>4</td>
</tr>
<tr>
<td>DIS_DOWNLOAD_MANUAL_ENCRYPT</td>
<td>If set, disables flash encryption when in download boot-modes.</td>
<td>1</td>
</tr>
<tr>
<td>SPI_BOOT_CRYPT_CNT</td>
<td>Enables encryption and decryption, when an SPI boot mode is set. Feature is enabled if 1 or 3 bits are set in the eFuse, disabled otherwise.</td>
<td>3</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-S3 eFuses, see [eFuse manager](https://github.com/espressif/esp-idf). 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 SPI_BOOT_CRYPT_CNT eFuse value (0b000). Since the value is 0 (even number of bits set), it configures and enables the flash encryption block. For more information on the flash encryption block, see ESP32-S3 Technical Reference Manual > eFuse Controller (eFuse) > Auto Encryption Block [PDF].
3. Firmware bootloader uses RNG (random) module to generate an 256 bit or 512 bit key, depending on the value of Size of generated AES-XTS key, and then writes it into respectively one or two BLOCK_KEYN eFuses. The software also updates the KEY_PURPOSE_N for the blocks where the keys were stored. The key cannot be accessed via software as the write and read protection bits for one or two BLOCK_KEYN eFuses are set. KEY_PURPOSE_N field is write-protected as well. 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 SPI_BOOT_CRYPT_CNT (0b001) to mark the flash contents as encrypted. Odd number of bits is set.
6. For Development Mode, the firmware bootloader allows the UART bootloader to re-flash encrypted binaries. Also, the SPI_BOOT_CRYPT_CNT eFuse bits are NOT write-protected. In addition, the firmware bootloader by default sets the eFuse bits DIS_BOOT_REMAP, DIS_DOWNLOAD_ICACHE, DIS_DOWNLOAD_DCACHE, HARD_DIS_JTAG and DIS_LEGACY_SPI_BOOT.
7. For Release Mode, the firmware bootloader sets all the eFuse bits set under development mode as well as DIS_DOWNLOAD_MANUAL_ENCRYPT. It also write-protects the SPI_BOOT_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, as it does not prevent modification and readout of encrypted flash contents.
- **Release Mode** - recommended for manufacturing and production to prevent physical readout of encrypted flash contents.

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-S3 generated key or external host-generated key.

**Using ESP32-S3 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-S3 device with default flash encryption eFuse settings as shown in Relevant eFuses. See how to check ESP32-S3 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)
   - Set Size of generated AES-XTS key
   - 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.

   ```bash
   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-S3 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-S3 boot after enabling flash encryption is given below:

   ```bash
   ESP-ROM:esp32s3-20210327
   Build:Mar 27 2021
   rst:0x1 (POWERON),boot:0x8 (SPI_FAST_FLASH_BOOT)
   SPIWP:0xee
   mode:DIO, clock div:1
   load:0x3fcd0270,len:0x2598
   load:0x403b6000,len:0x878
   load:0x403ba000,len:0x3dd4
   entry 0x403b61c0
   I (27) boot: ESP-IDF v4.4-dev-2003-g72fdecc1b7-dirty 2nd stage bootloader
   I (28) boot: compile time 14:15:37
   I (28) boot: chip revision: 0
   I (32) boot.esp32s3: SPI Speed : 80GHz
   I (36) boot.esp32s3: SPI Mode : DIO
   I (41) boot.esp32s3: SPI Flash Size : 2MB
   I (46) boot: Enabling RNG early entropy source...
   I (58) boot: Partition Table:
   I (62) boot: ## Label Usage Type ST Offset Length
   I (69) boot: 0 nvs WiFi data 01 02 00000a000 00006000
   I (76) boot: 1 storage Unknown data 01 ff 00010000 00001000
   I (84) boot: 2 factory factory app 00 00 00020000 00100000
   I (91) boot: 3 nvs_key NVS keys 00 04 00120000 00001000
   I (99) boot: End of partition table
   I (103) esp_image: segment 0: paddr=00020000 vaddr=3c020000 size=08118h ( 33048)_
   map
   I (117) esp_image: segment 1: paddr=00028140 vaddr=3fc8fa30 size=023f4h ( 9204)_
   load
   I (122) esp_image: segment 2: paddr=0002a53c vaddr=40374000 size=05adch ( 23260)_
   load
   ```

   (continues on next page)
I (134) esp_image: segment 3: paddr=00030020 vaddr=42000020 size=1a710h (108304)...
  map
I (156) esp_image: segment 4: paddr=0004a738 vaddr=40379adc size=05f48h ( 24392)...
  load
I (162) esp_image: segment 5: paddr=00050688 vaddr=600fe000 size=0010h ( 16)...
  load
I (167) boot: Loaded app from partition at offset 0x20000
I (168) boot: Checking flash encryption...
I (173) efuse: Batch mode of writing fields is enabled
I (179) flash_encrypt: Generating new flash encryption key...
I (188) efuse: Writing EFUSE_BLK_KEY0 with purpose 4
W (194) flash_encrypt: Not disabling UART bootloader encryption
I (197) flash_encrypt: Disable UART bootloader cache...
I (203) flash_encrypt: Disable JTAG...
I (212) efuse: Batch mode. Prepared fields are committed
I (214) esp_image: segment 0: paddr=00000020 vaddr=3fcd0270 size=02598h ( 9624)
I (223) esp_image: segment 1: paddr=000025c0 vaddr=403b6000 size=00878h ( 2168)
I (230) esp_image: segment 2: paddr=00002e40 vaddr=403ba000 size=03dd4h ( 15828)
I (534) flash_encrypt: bootloader encrypted successfully
I (578) flash_encrypt: partition table encrypted and loaded successfully
I (578) flash_encrypt: Encrypting partition 1 at offset 0x10000 (length 0x1000)...
I (628) flash_encrypt: Done encrypting
I (629) esp_image: segment 0: paddr=00020020 vaddr=3c020020 size=08118h ( 33048)...
  map
I (636) esp_image: segment 1: paddr=00028140 vaddr=3fc8fa30 size=023f4h ( 9204)
I (640) esp_image: segment 2: paddr=0002a53c vaddr=40374000 size=05adch ( 23260)
I (651) esp_image: segment 3: paddr=00030020 vaddr=42000020 size=1a710h (108304)...
  map
I (675) esp_image: segment 4: paddr=0004a738 vaddr=40379adc size=05f48h ( 24392)
I (679) esp_image: segment 5: paddr=00050688 vaddr=600fe000 size=0010h ( 16)
I (680) flash_encrypt: Encrypting partition 2 at offset 0x20000 (length 0x100000)...
I (11571) flash_encrypt: Done encrypting
I (11571) flash_encrypt: Encrypting partition 3 at offset 0x120000 (length 0x1000).
  ...
I (11617) flash_encrypt: Done encrypting
I (11618) flash_encrypt: Flash encryption completed
I (11623) boot: Resetting with flash encryption enabled...

A sample output of subsequent ESP32-S3 boots just mentions that flash encryption is already enabled:

<table>
<thead>
<tr>
<th>ESP-ROM:esp32s3-20210327</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build:Mar 27 2021</td>
</tr>
<tr>
<td>rst:0x3 (RTC_SW_SYS_RST),boot:0x8 (SPI_FAST_FLASH_BOOT)</td>
</tr>
<tr>
<td>Saved PC:0x403bb1d6</td>
</tr>
<tr>
<td>SPIWP:0xee</td>
</tr>
<tr>
<td>mode:DIO, clock div:1</td>
</tr>
<tr>
<td>load:0x3fcd0270,len:0x2598</td>
</tr>
<tr>
<td>load:0x403b6000,len:0x878</td>
</tr>
<tr>
<td>load:0x403ba000,len:0x3cd4</td>
</tr>
<tr>
<td>entry 0x403b61c0</td>
</tr>
</tbody>
</table>

| (35) boot: ESP-IDF v4.4-dev-2003-g72fdecc1b7-dirty 2nd stage bootloader |
| (35) boot: compile time 14:15:37                                      |
| (35) boot: chip revision: 0                                           |
| (39) boot.esp32s3: SPI Speed : 80MHz                                  |
| (44) boot.esp32s3: SPI Mode : DIO                                      |
| (48) boot.esp32s3: SPI Flash Size : 2MB                              |
| (53) boot: Enabling RNG early entropy source...                        |
| (65) boot: Partition Table:                                           |
| (69) boot: ## Label Usage Type ST Offset Length                        |
| (76) boot: 0 nvs WiFi data 01 02 0000a000 00006000                      |
### Example to check Flash Encryption status

This is esp32s3 chip with 2 CPU core(s), WiFi/BLE, silicon revision 0, 2MB external flash

FLASH_CRYPT_CNT eFuse value is 1

Flash encryption feature is enabled in DEVELOPMENT mode

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-S3 encrypts the data in-place.
To use a host generated key, take the following steps:

1. Ensure that you have an ESP32-S3 device with default flash encryption eFuse settings as shown in *Relevant eFuses*.

   See how to check *ESP32-S3 Flash Encryption Status*.

2. Generate a random key by running:

   ```
   If Size of generated AES-XTS key is AES-128 (256-bit key):
   
   espsecure.py generate_flash_encryption_key my_flash_encryption_key.bin
   
   ```

   ```
   else if Size of generated AES-XTS key is AES-256 (512-bit key):
   
   espsecure.py generate_flash_encryption_key --keylen 512 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.

   ```
   espefuse.py --port PORT burn_key BLOCK my_flash_encryption_key.bin
   → KEYPURPOSE
   
   where BLOCK is a free keyblock between BLOCK_KEY0 and BLOCK_KEY5. And KEYPURPOSE is either AES_256_KEY_1, XTS_AES_256_KEY_2, XTS_AES_128_KEY. See *ESP32-S3 Technical Reference Manual* for a description of the key purposes.

   For AES-128 (256-bit key) - XTS_AES_128_KEY:

   ```
   espefuse.py --port PORT burn_key BLOCK my_flash_encryption_key.bin XTS_
   → AES_128_KEY
   
   ```

   For AES-256 (512-bit key) - XTS_AES_256_KEY_1 and XTS_AES_256_KEY_2. espefuse.py supports burning both these two key purposes together with a 512 bit key to two separate key blocks via the virtual key purpose XTS_AES_256_KEY. When this is used espefuse.py will burn the first 256 bit of the key to the specified BLOCK and burn the corresponding block key purpose to XTS_AES_256_KEY_1. The last 256 bit of the key will be burned to the first free key block after BLOCK and the corresponding block key purpose to XTS_AES_256_KEY_2

   ```
   espefuse.py --port PORT burn_key BLOCK my_flash_encryption_key.bin XTS_
   → AES_256_KEY
   
   ```

   If you wish to specify exactly which two blocks are used then it is possible to divide key into two 256 bit keys, and manually burn each half with XTS_AES_256_KEY_1 and XTS_AES_256_KEY_2 as key purposes:

   ```
   split -b 32 my_flash_encryption_key.bin my_flash_encryption_key.bin.
   
   espefuse.py --port PORT burn_key BLOCK my_flash_encryption_key.bin.aa_
   → XTS_AES_256_KEY_1
   
   espefuse.py --port PORT burn_key BLOCK+1 my_flash_encryption_key.bin.ab_
   → XTS_AES_256_KEY_2
   
   ```

   If the key is not burned and the device is started after enabling flash encryption, the ESP32-S3 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
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.

```bash
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-S3 will reset. On the next boot, the firmware bootloader decrypts: 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:

```bash
idf.py encrypted-app-flash monitor
```

If all partitions needs to be updated in encrypted format, run:

```bash
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-S3 device with default flash encryption eFuse settings as shown in **Relevant eFuses**.

   See how to check **ESP32-S3 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 EFUSE_DIS_DOWNLOAD_MANUAL_ENCRYPT eFuse bit will be burned to disable flash encryption hardware in ROM Download Mode.)
   - Select UART ROM download mode (Permanently switch to Secure mode (recommended)). This is the default option, and is recommended. It is also possible to change this configuration setting to permanently disable UART ROM download mode, if this mode is not needed.
   - 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-S3 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 SPI_BOOT_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`, 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.
- The UART ROM Download Mode should be disabled entirely if it is not needed, or permanently set to “Secure Download Mode” otherwise. Secure Download Mode permanently limits the available commands to basic flash read and write only. The default behaviour is to set Secure Download Mode on first boot in Release mode. To disable Download Mode entirely select the `CONFIG_SECURE_UART_ROM_DL_MODE` to “Permanently disable ROM Download Mode (recommended)” or call `esp_efuse_disable_rom_download_mode()` at runtime.
- 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 SPI_BOOT_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-S3 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)
invalid header: 0xb414f76b
invalid header: 0xb414f76b
invalid header: 0xb414f76b
invalid header: 0xb414f76b
invalid header: 0xb414f76b
invalid header: 0xb414f76b
```

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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:

```
rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configspi: 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:10464
ho 0 tail 12 room 4
load:0x40078000,len:19168
load:0x40080400,len:6664
entry 0x40080764
I (56) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (56) boot: compile time 15:37:14
I (58) boot: Enabling RNG early entropy source...
I (64) 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:

```
rst:0x3 (SW_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configspi: 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:13616
load:0x40078000,len:6664
entry 0x40080764
I (56) boot: ESP-IDF v4.0-dev-850-gc4447462d-dirty 2nd stage bootloader
I (56) boot: compile time 15:37:14
I (58) boot: Enabling RNG early entropy source...
I (64) boot: SPI Speed : 40MHz
I (68) boot: SPI Mode : DIO
I (72) boot: SPI Flash Size : 4MB
I (76) boot: Partition Table:
I (79) boot: # Label Usage Type ST Offset Length
I (87) boot: 0 nvs WiFi data 01 02 0000a000 00006000
I (94) boot: 1 phy_init RF data 01 01 000010000 00001000
I (102) boot: 2 factory factory app 00 00 000020000 00100000
I (109) boot: End of partition table
E (113) esp_image: image at 0x20000 has invalid magic byte
W (120) esp_image: image at 0x20000 has invalid SPI mode 108
W (126) esp_image: image at 0x20000 has invalid SPI size 11
E (132) boot: Factory app partition is not bootable
E (138) boot: No bootable app partitions in the partition table
```
4.15.6 ESP32-S3 Flash Encryption Status

1. Ensure that you have an ESP32-S3 device with default flash encryption eFuse settings as shown in Relevant eFuses.

To check if flash encryption on your ESP32-S3 device is enabled, do one of the following:

- flash the application example security/flash_encryption onto your device. This application prints the SPI_BOOT_CRYPT_CNT eFuse value and if flash encryption is enabled or disabled.
- Find the serial port name under which your ESP32-S3 device is connected, replace PORT with your port name in the following command, and run it:

```bash
espefuse.py -p PORT summary
```

4.15.7 Reading and Writing Data in Encrypted Flash

ESP32-S3 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 SPI_BOOT_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_readEncrypted()` to read and decrypt data

The ROM function SPIRead() can read data without decryption, however, this function is not supported in esp-idf applications.

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 Manually Encrypting Files.

4.15.9 Disabling Flash Encryption

If flash encryption was enabled accidentally, flashing of plaintext data will soft-brick the ESP32-S3. The device will reboot continuously, printing the error `flash read err, 1000 or invalid header: 0xXXXXXXX`.

For flash encryption in Development mode, encryption can be disabled by burning the `SPI_BOOT_CRYPT_CNT` eFuse. It can only be done one time 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 `SPI_BOOT_CRYPT_CNT` by running:
   ```
espefuse.py burn_efuse SPI_BOOT_CRYPT_CNT
   ```

Reset the ESP32-S3. 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 XTS-AES-128 or XTS-AES-256. The flash encryption key is 256 bits and 512 bits respectively and stored in one or two BLOCK_KEY eFuses internal to the chip and, by default, is protected from software access.
- Flash access is transparent via the flash cache mapping feature of ESP32-S3 - 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-S3 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).
- 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.

4.15.13  Advanced Features

The following section covers advanced features of flash encryption.
Chapter 4. API Guides

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:

- DIS_DOWNLOAD_MANUAL_ENCRYPT which disables flash encryption operation when running in UART bootloader boot mode.
- DIS_DOWNLOAD_ICACHE and DIS_DOWNLOAD_DCACHE which disables the entire MMU flash cache when running in UART bootloader mode.
- HARD_DIS_JTAG and DIS_USB_JTAG which disables JTAG.
- DIS_LEGACY_SPI_BOOT which disables Legacy SPI boot 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:

```bash
espefuse.py --port PORT burn_efuse DIS_DOWNLOAD_MANUAL_ENCRYPT
espefuse.py --port PORT write_protect_efuse DIS_DOWNLOAD_MANUAL_ENCRYPT
```

Note:  Set all appropriate bits before write-protecting!

Write protection of all the three eFuses is controlled by one bit. It means that write-protecting one eFuse bit will inevitably write-protect all unset eFuse bits.

Write protecting these eFuses to keep them unset is not currently very useful, as esptool.py does not support reading encrypted flash.

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.

Submit Document Feedback
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:

```
espsecure.py encrypt_flash_data --aes_xts --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-S3 when it boots, check that the keys match and that the command line arguments match exactly, including the correct offset.

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 External RAM

When Flash Encryption is enabled any data read from and written to external SPI RAM through the cache will also be encrypted/decrypted. This happens the same way and with the same key as for Flash Encryption. If Flash Encryption is enabled then encryption for external SPI RAM is also always enabled, it is not possible to separately control this functionality.

4.15.15 Technical Details

The following sections provide some reference information about the operation of flash encryption.

Flash Encryption Algorithm

- ESP32-S3 use the XTS-AES block cipher mode with 256 bit or 512 bit key size for flash encryption.
- XTS-AES is a block cipher mode specifically designed for disc encryption and addresses the weaknesses other potential modes (e.g. AES-CTR) have for this use case. A detailed description of the XTS-AES algorithm can be found in IEEE Std 1619-2007.
- The flash encryption key is stored in one or two BLOCK_KEYN eFuses and, by default, is protected from further writes or software readout.
- 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 SPI Flash and External SPI RAM Configuration

This page is a guide for configuring SPI Flash and external SPI RAM. Supported frequency and mode combination, error handling are also elaborated.
4.16.1 Terminology

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI</td>
<td>Serial Peripheral Interface</td>
</tr>
<tr>
<td>MSPI</td>
<td>Memory SPI Peripheral, SPI Peripheral dedicated for memory</td>
</tr>
<tr>
<td>SDR</td>
<td>Single Data Rate</td>
</tr>
<tr>
<td>DDR</td>
<td>Double Data Rate</td>
</tr>
<tr>
<td>line</td>
<td>Number of signals used to transfer data in the data phase of SPI transactions. e.g., for 4-bit-mode, the speed of the data phase would be 4 bit per clock cycle.</td>
</tr>
<tr>
<td>RxFx</td>
<td>F stands for Flash, R stands for PSRAM, x stands for line mode. e.g. F4R4 stands for an ESP32-S3 with Quad Flash and Quad PSRAM</td>
</tr>
</tbody>
</table>

**Note:** On ESP32-S3, MSPI stands for the SPI0/1. SPI0 and SPI1 share a common SPI bus. The main Flash and PSRAM are connected to the MSPI peripheral. CPU accesses them via Cache.

4.16.2 How to configure Flash and PSRAM

idf.py menuconfig is used to open the configuration menu.

Configure the Flash

The Flash related configurations are under Serial flasher config menu.

1. Flash type used on the board. For Octal Flash, select CONFIG_ESPTOOLPY_OCT_FLASH. For Quad Flash, uncheck this configuration.
2. Flash line mode. Select a line mode in CONFIG_ESPTOOLPY_FLASHMODE. The higher the line mode is, the faster the SPI speed is. See terminology above about the line mode.
3. Flash sample mode. Select a sample mode in CONFIG_ESPTOOLPY_FLASH_SAMPLE_MODE. DDR mode is faster than SDR mode. See terminology above about SDR and DDR mode.
4. Flash speed. Select a Flash frequency in CONFIG_ESPTOOLPY_FLASHFREQ.
5. Flash size. Flash size, in megabytes. Select a Flash size in CONFIG_ESPTOOLPY_FLASHSIZE.

Configure the PSRAM

To enable PSRAM, please enable the CONFIG_ESP32S3_SPIRAM_SUPPORT under Component config / ESP32-S3-Specific menu. Then all the PSRAM related configurations will be visible under SPI RAM config menu.

1. PSRAM type used on the board. Select a type in CONFIG_SPIRAM_MODE for Quad or Octal PSRAM.
2. PSRAM speed. Select a PSRAM frequency in CONFIG_SPIRAM_SPEED.

**Note:** Configuration 1 of Flash and PSRAM should be selected according to your actual hardware.

For the reset of the above configurations:

- Flash and PSRAM share the same internal clock.
- Quad Flash only supports STR mode. Octal Flash may support either/both STR/DTR modes under OPI mode, depending on the flash model and the vendor.
- Quad PSRAM only supports STR mode, while Octal PSRAM only supports DTR mode.

Therefore, some limitations should be noticed when configuring configuration 2, 3 and 4 of Flash, and configuration 2 of PSRAM. Please refer to All Supported Modes and Speeds.
Chapter 4. API Guides

**Note:** If a board with Octal Flash resets before the second-stage bootloader, please refer to *Error Handling Chapter*

### 4.16.3 All Supported Modes and Speeds

**Note:** For MSPi DDR mode, the data are sampled on both the positive edge and the negative edge. e.g.: if a Flash is set to 80 MHz and DDR mode, then the final speed of the Flash is 160 MHz. This is faster than the Flash setting to 120 Mhz and STR mode.

#### F8R8 Hardware

<table>
<thead>
<tr>
<th>Group</th>
<th>Flash mode</th>
<th>Group</th>
<th>PSRAM mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>120 MHz SDR</td>
<td>A</td>
<td>N.A.</td>
</tr>
<tr>
<td>B</td>
<td>80 MHz DDR</td>
<td>B</td>
<td>80 MHz DDR</td>
</tr>
<tr>
<td>C</td>
<td>80 MHz SDR</td>
<td>C</td>
<td>40 MHz DDR</td>
</tr>
<tr>
<td>C</td>
<td>40 MHz DDR</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>&lt; 40 MHz</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>D</td>
<td>disable</td>
</tr>
</tbody>
</table>

1. Flash mode in group A works with PSRAM mode in group A/D
2. Flash mode in group B/C works with PSRAM mode in group B/C/D

#### F4R8 Hardware

<table>
<thead>
<tr>
<th>Group</th>
<th>Flash mode</th>
<th>Group</th>
<th>PSRAM mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>120 MHz SDR</td>
<td>A</td>
<td>N.A.</td>
</tr>
<tr>
<td>B</td>
<td>80 MHz SDR</td>
<td>B</td>
<td>80 MHz DDR</td>
</tr>
<tr>
<td>C</td>
<td>40 MHz SDR</td>
<td>C</td>
<td>40 MHz DDR</td>
</tr>
<tr>
<td>C</td>
<td>20 MHz SDR</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>D</td>
<td>disable</td>
</tr>
</tbody>
</table>

1. Flash mode in group A works with PSRAM mode in group A/D
2. Flash mode in group B/C works with PSRAM mode in group B/C/D

#### F4R4 Hardware

<table>
<thead>
<tr>
<th>Type</th>
<th>Flash</th>
<th>Type</th>
<th>PSRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>120 MHz</td>
<td>A</td>
<td>120MHz</td>
</tr>
<tr>
<td>B</td>
<td>80 MHz</td>
<td>B</td>
<td>80MHz</td>
</tr>
<tr>
<td>C</td>
<td>40 MHz</td>
<td>C</td>
<td>40MHz</td>
</tr>
<tr>
<td>C</td>
<td>20 MHz</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>D</td>
<td></td>
</tr>
</tbody>
</table>

1. Flash in A works with PSRAM in A/C/D
2. Flash in B works with PSRAM in B/C/D
3. Flash in C works with PSRAM in A/B/C/D
Chapter 4. API Guides

4.16.4 Error handling

1. If a board with Octal Flash resets before the second-stage bootloader:

```
ESP-ROM:esp32s3-20210327
Build:Mar 27 2021
rst:0x7 (TG0WDT_SYS_RST),boot:0x18 (SPI_FAST_FLASH_BOOT)
Saved PC:0x400454d5
SPIWP:0xee
mode:DOUT, clock div:1
load:0x3fcd0108,len:0x171c
ets_loader.c 78
```

it may mean that the necessary efuses are not correctly burnt. please check the eFuse bits of the chip using command 
esefuse.py summary.

The 1st bootloader relies on an eFuse bit FLASH_TYPE to reset the Flash into the default mode (SPI mode). If this bit is not burnt and the flash is working in OPI mode, 1st bootloader may not be able to read from the flash and load the following images.

Run this command to burn the eFuse bit:

```
python3 ./esefuse.py -p /dev/<serial_device> --do-not-confirm burn_efuse FLASH_TYPE 1
```

**Note:** This step is irreversible. Please do check if your hardware is actually using an Octal Flash.

4.17 ESP-IDF FreeRTOS (SMP)

**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.

This document describes the API and behavioral differences between Vanilla FreeRTOS and ESP-IDF FreeRTOS that were made in order to support Symmetric Multiprocessing (SMP). This document is split into the following parts.

**Contents**

- **ESP-IDF FreeRTOS (SMP)**
  - Overview
  - Symmetric Multiprocessing
    - Basic Concepts
    - SMP on an ESP Target
  - Tasks
    - Creation
    - Execution
    - Deletion
  - SMP Scheduler
    - Fixed Priority
    - Preemption
    - Time Slicing
    - Tick Interrupts
    - Idle Tasks
    - Scheduler Suspension
    - Disabling Interrupts
4.17.1 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, numerous ESP targets (such as the ESP32 and ESP32-S3) are capable of dual core symmetric multiprocessing (SMP). Therefore, the version of FreeRTOS used in ESP-IDF (hereinafter referred to as ESP-IDF FreeRTOS) is a modified version of Vanilla FreeRTOS v10.4.3. These modifications allow ESP-IDF FreeRTOS to utilize the dual core SMP capabilities of ESP SoCs.

Note:
- For information regarding features that have been added to ESP-IDF FreeRTOS, see ESP-IDF FreeRTOS Additions.
- For a detailed ESP-IDF FreeRTOS API Reference, see FreeRTOS API reference.

4.17.2 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).

4.17.3 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 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 tasks 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.

### 4.17.4 SMP Scheduler

The Vanilla FreeRTOS scheduler is best described as a **Fixed Priority Preemptive scheduler with Time Slicing** meaning that:

- Each tasks 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 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. In other words, if the higher priority ready task is unpinned and has a higher priority than the current priority of both cores, the scheduler will always choose to preempt the current core. 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 (continues on next page)
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. Furthermore, the tick interrupt 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:

- Task switching is disabled only on the current core but interrupts for the current core are left enabled
- Calling any blocking/yielding function on the current core is forbidden. Time slicing is disabled on the current core.
- If suspending on CPU0, the tick count is frozen. The tick interrupt will still occur to execute the application tick hook.

When resuming the scheduler on CPU0, `xTaskResumeAll()` will catch up all of the lost ticks and unblock any timed out tasks.

**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.
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Startup and Termination

ESP-IDF FreeRTOS does not require users to call \texttt{vTaskStartScheduler()} to start the scheduler. The startup flow of an ESP-IDF application will already call this automatically. The entry point for user code is a user defined \texttt{void app\_main(void)} function. For more details regarding the startup of ESP-IDF FreeRTOS applications, see \textit{ESP-IDF FreeRTOS Applications}.

ESP-IDF FreeRTOS does not support scheduler termination. Calling \texttt{vTaskEndScheduler()} will simply cause the application to abort.

4.17.5 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:

- \texttt{taskENTER\_CRITICAL()} enters a critical section by disabling interrupts
- \texttt{taskEXIT\_CRITICAL()} exits a critical section by reenabling interrupts
- \texttt{taskENTER\_CRITICAL\_FROM\_ISR()} enters a critical section from an ISR by disabling interrupt nesting
- \texttt{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 \texttt{portMUX\_TYPE} (not to be confused to FreeRTOS mutexes)
- \texttt{taskENTER\_CRITICAL(&mux)} enters a critical section from a task context
- \texttt{taskEXIT\_CRITICAL(&mux)} exits a critical section from a task context
- \texttt{taskENTER\_CRITICAL\_ISR(&mux)} enters a critical section from an interrupt context
- \texttt{taskEXIT\_CRITICAL\_ISR(&mux)} exits a critical section from an interrupt context

\textbf{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.

Implementation

In ESP-IDF FreeRTOS, the process of a particular core entering and exiting a critical section is as follows:

- \texttt{For taskENTER\_CRITICAL(&mux) (or taskENTER\_CRITICAL\_ISR(&mux))}
  1. The core disables its interrupts (or interrupt nesting) up to \texttt{configMAX\_SYSCALL\_INTERRUPT\_PRIORITY}
  2. The core then spins on the spinlock using an atomic compare-and-set instruction until it acquires the lock. A lock is acquired when the core is able to set the lock’s owner value to the core’s ID.
  3. Once the spinlock is acquired, the function returns. The remainder of the critical section runs with interrupts (or interrupt nesting) disabled.
- \texttt{For taskEXIT\_CRITICAL(&mux) (or taskEXIT\_CRITICAL\_ISR(&mux))}
  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 kept 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

4.17.6 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.
4.18 Hardware Abstraction

Hardware abstraction in ESP-IDF are a group of API that allow users to control peripherals at differing levels of abstraction, as opposed to interfacing with hardware using only the ESP-IDF drivers. ESP-IDF Hardware abstraction will likely be useful for users writing high performance bare-metal drivers, or for those 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. Hardware abstraction API do 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).

4.18.1 Architecture

Hardware abstraction in ESP-IDF is comprised of the following layers, ordered from low level (closer to hardware) to high level (further away from hardware) of abstraction.

- 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 will generally consist of the header files described in the table below. Files that are **Target Specific** will have a separate implementation for each target (i.e., a separate copy for each chip). However, the #include directive will still be target-independent (i.e., will be the same for different targets) as the build system will automatically include the correct version of the header and source files.
Table 21: Hardware Abstraction Header Files

<table>
<thead>
<tr>
<th>Include Directive</th>
<th>Target Specificity</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-S3’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. Users can 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-S3, 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 a 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. |

4.18.2 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  
    hw->config.clk_sel = (source_clk == XXX_SCLK_APB) ? 0 : 1;  
}

(continues on next page)
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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.
- 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, 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.

4.18.3 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 modelling 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 will remain 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 will 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 will 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.

4.19 High-Level Interrupts

The Xtensa architecture has support for 32 interrupts, divided over 7 levels (levels 1 to 7, with 7 being an NMI), plus an assortment of exceptions. On the ESP32-S3, the interrupt mux allows most interrupt sources to be routed to these interrupts using the interrupt allocator. Normally, interrupts will be written in C, but ESP-IDF allows high-level interrupts to be written in assembly as well, resulting in very low interrupt latencies.

4.19.1 Interrupt Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Symbol</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N/A</td>
<td>Exception and level 0 interrupts. Handled by ESP-IDF</td>
</tr>
<tr>
<td>2-3</td>
<td>N/A</td>
<td>Medium level interrupts. Handled by ESP-IDF</td>
</tr>
<tr>
<td>4</td>
<td>xt_highint4</td>
<td>Normally used by ESP-IDF debug logic</td>
</tr>
<tr>
<td>5</td>
<td>xt_highint5</td>
<td>Free to use</td>
</tr>
<tr>
<td>NMI</td>
<td>xt_nmi</td>
<td>Free to use</td>
</tr>
<tr>
<td>dbg</td>
<td>xt_debugexception</td>
<td>Debug exception. Called on e.g. a BREAK instruction.</td>
</tr>
</tbody>
</table>

Using these symbols is done by creating an assembly file (suffix `.S`) and defining the named symbols, like this:

```
.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/esp32s3/highint_hdl.S` file; the panic handler interrupt is implemented there.

4.19.2 Notes

• Do not call C code from a high-level 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 will not continue to run after the panic handler), so breaking C code execution flow is not a problem.
• 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 will happen 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 should cause the linker to always include the file defining `\`ld_include_my_isr_file\`, causing the ISR to always be linked in.

• High-level interrupts can be routed and handled using `esp_intr_alloc()` and associated functions. The handler and handler argument 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.

4.20 JTAG Debugging

This document provides a guide to installing OpenOCD for ESP32-S3 and debugging using GDB. The document is structured as follows:

**Introduction** Introduction to the purpose of this guide.  
**How it Works?** Description how ESP32-S3, JTAG interface, OpenOCD and GDB are interconnected and working together to enable debugging of ESP32-S3.  
**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-S3 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-S3 with OpenOCD and GDB.

4.20.1 Introduction

Espressif has ported OpenOCD to support the ESP32-S3 processor and the multi-core FreeRTOS (which is the foundation of most ESP32-S3 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-S3 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.
4.20.2 How it Works?

The key software and hardware components that perform debugging of ESP32-S3 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-esp32s3-elf-gdb debugger, OpenOCD on chip debugger, and the JTAG adapter connected to ESP32-S3 target.

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-S3, as well as to provide means to monitor diagnostic messages from ESP32-S3.

“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.

The connection from PC to ESP32-S3 is done effectively with a single USB cable. This is made possible by the ESP32-S3 chip itself, which provides two USB channels, one for JTAG and the other for the USB terminal connection. The USB cable should be connected to the D+/D- USB pins of ESP32-S3 and not to the serial RxD/TxD through a USB-to-UART chip. The proper connection is explained later in subsection Configuring ESP32-S3 Target.

4.20.3 Selecting JTAG Adapter

The quickest and most convenient way to start with JTAG debugging is through a USB cable connected to the D+/D- USB pins of ESP32-S3. No need for an external JTAG adapter and extra wiring / cable to connect JTAG to ESP32-S3.

If you decide to use separate JTAG adapter, look for one that is compatible with both the voltage levels on the ESP32-S3 as well as with the OpenOCD software. The JTAG port on the ESP32-S3 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.

This page lists SWD-compatible adapters as well; take note that the ESP32-S3 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-S3 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-S3, 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-S3.

### 4.20.4 Setup of OpenOCD

If you have already set up ESP-IDF with CMakie build system according to the Getting Started Guide, 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 http://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 section for details.

### 4.20.5 Configuring ESP32-S3 Target

Once OpenOCD is installed, you can proceed to configuring the ESP32-S3 target (i.e ESP32-S3 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-S3 board you are using (see the two cases described below).

**Configure ESP32-S3 built-in JTAG Interface**

ESP32-S3 has a built-in JTAG circuitry and can be debugged without any additional chip. Only an USB cable connected to the D+/D- pins is necessary. The necessary connections are shown in the following section.
Configure Hardware

Table 22: ESP32-S3 pins and USB signals

<table>
<thead>
<tr>
<th>ESP32-S3 Pin</th>
<th>USB Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPIO19</td>
<td>D-</td>
</tr>
<tr>
<td>GPIO20</td>
<td>D+</td>
</tr>
<tr>
<td>5V</td>
<td>V_BUS</td>
</tr>
<tr>
<td>GND</td>
<td>Ground</td>
</tr>
</tbody>
</table>

Please verify that the ESP32-S3 pins used for USB communication are not connected to some other HW that may disturb the JTAG operation.

Configure USB Drivers JTAG communication should work on all supported platforms. Windows users might get LIBUSB_ERROR_NOT_FOUND errors. Please use version 2.8 (or newer) of the ESP-IDF Tools Installer and select the driver “Espressif - WinUSB support for JTAG (ESP32-C3/S3)” in order to resolve this issue. If you don’t want to re-run the installer then the same can be achieved with idf-env by running the following command from PowerShell:

```
Invoke-WebRequest 'https://dl.espressif.com/dl/idf-env/idf-env.exe' -OutFile \idf-env.exe; \idf-env.exe driver install --espressif
```

Configure Other JTAG Interface Refer to section Selecting JTAG Adapter for guidance what JTAG interface to select, so it is able to operate with OpenOCD and ESP32-S3. Then follow three configuration steps below to get it working.

Configure eFuses By default, ESP32-S3 JTAG interface is connected to the built-in USB_SERIAL_JTAG peripheral. To use an external JTAG adapter instead, you need to switch the JTAG interface to the GPIO pins. This can be done by burning eFuses using espefuse.py tool.

Burning eFuses is an irreversible operation, so consider both options below before starting the process.

- **Burning DIS_USB_JTAG eFuse** will permanently disable the connection between USB_SERIAL_JTAG and the JTAG port of the CPU. JTAG interface can then be connected to GPIO39-GPIO42. Note that USB CDC functionality of USB_SERIAL_JTAG will still be useable, i.e. flashing and monitoring over USB CDC will still work.
- **Burning JTAG_SEL_ENABLE eFuse** will enable selection of JTAG interface by a strapping pin, GPIO3. If the strapping pin is low when ESP32-S3 is reset, JTAG interface will use GPIO39-GPIO42. If the strapping pin is high, USB_SERIAL_JTAG will be used as the JTAG interface.

Configure Hardware

1. Identify all pins / signals on JTAG interface and ESP32-S3 board, that should be connected to establish communication.

   Table 23: ESP32-S3 pins and JTAG signals

<table>
<thead>
<tr>
<th>ESP32-S3 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTDO / GPIO40</td>
<td>TDO</td>
</tr>
<tr>
<td>MTDI / GPIO41</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK / GPIO39</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO42</td>
<td>TMS</td>
</tr>
</tbody>
</table>

2. Verify if ESP32-S3 pins used for JTAG communication are not connected to some other h/w that may disturb JTAG operation.

3. Connect identified pin / signals of ESP32-S3 and JTAG interface.
Chapter 4. API Guides

Configure Drivers You may need to install driver s/w to make JTAG work with computer. Refer to documentation of JTAG adapter, that should provide related details.

Connect Connect JTAG interface to the computer. Power on ESP32-S3 and JTAG interface boards. Check if JTAG interface is visible by 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):

```
openocd -f board/esp32s3-builtin.cfg
```

Note: The files provided after -f above are specific for ESP32-S3. You may need to provide different files depending on the hardware that is used. For guidance see Configuration of OpenOCD for specific target.

For example, board/esp32c3-ftdi.cfg can be used for a custom board with an FT2232H or FT232H chip used for JTAG connection, or with ESP-Prog.

You should now see similar output (this log is for ESP32-S3):

```
user-name@computer-name:~/esp/esp-idf$ openocd -f board/esp32s3-builtin.cfg
Open On-Chip Debugger v0.10.0-esp32-20210902 (2021-10-05-23:44)
Licensed under GNU GPL v2
For bug reports, read
  http://openocd.org/doc/doxygen/bugs.html
debug_level: 2

Info : only one transport option; autoselect 'jtag'
Warn : Transport "jtag" was already selected
Info : Listening on port 6666 for tcl connections
Info : Listening on port 4444 for telnet connections
Info : esp_usb_jtag: Device found. Base speed 40000KHz, div range 1 to 255
Info : clock speed 40000 kHz
Info : JTAG tap: esp32s3.cpu0 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
   part: 0x2003, ver: 0x1)
Info : JTAG tap: esp32s3.cpu1 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
   part: 0x2003, ver: 0x1)
Info : esp32s3.cpu0: Debug controller was reset.
Info : esp32s3.cpu0: Core was reset.
Info : esp32s3.cpu1: Debug controller was reset.
Info : esp32s3.cpu1: Core was reset.
Info : Listening on port 3333 for gdb connections
```

- 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/esp32s3-builtin.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-S3’s pins, and see if everything is powered on correctly.
Upload application for debugging

Build and upload your application to ESP32-S3 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:

```
openocd -f board/esp32s3-builtin.cfg -c "program_esp filename.bin 0x10000 verify..." -exit"
```

OpenOCD flashing command `program_esp` has the following format:

```
program_esp <image_file> <offset> [verify] [reset] [exit]
```

- `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.

You are now ready to start application debugging. Follow the steps described in the section below.

### 4.20.6 Launching Debugger

The toolchain for ESP32-S3 features GNU Debugger, in short GDB. It is available with other toolchain programs under filename: `xtensa-esp32s3-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.

Both options of using debugger are discussed under links below.

- `Eclipse`
- `Command Line`

It is recommended to first check if debugger works from `Command Line` and then move to using `Eclipse`.

### 4.20.7 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`.

Before proceeding to examples, set up your ESP32-S3 target and load it with `get-started/blink`.

### 4.20.8 Building OpenOCD from Sources

Please refer to separate documents listed below, that describe build process.
Building OpenOCD from Sources for Windows

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.

Note: Following instructions are assumed to be runnned in MSYS2 environment with MINGW32 subsystem!

Install Dependencies

Install packages that are required to compile OpenOCD:

```
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-winpthreads-git \ p7zip
```

Download Sources of OpenOCD

The sources for the ESP32-S3-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.

Download libus

Build and export variables for a following OpenOCD compilation:

```
wget https://github.com/libusb/libusb/releases/download/v1.0.22/libusb-1.0.22.7z
7z x -oibusb ./libusb-1.0.22.7z
export CPPFLAGS="$CPPFLAGS -I$PWD/libusb/include/libusb-1.0"
export LDFLAGS="$LDFLAGS -L$PWD/libusb/MinGW32/.libs/dll"
```

Build OpenOCD

Proceed with configuring and building OpenOCD:

```
cd ~/esp/openocd-esp32
export CPPFLAGS="$CPPFLAGS -D__USE_MINGW_ANSI_STDIO=1 -Wno-error"; export CFLAGS="-$CFLAGS -Wno-error".
./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
```

Optionally you can add 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. Also you could use export DESTDIR="/custom/install/dir"; make install.

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 OOCID_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 A complete described previously process is provided below for the faster execution, e.g. as a shell script:

```
pacman -S --noconfirm --needed autoconf automake git make mingw-w64-i686-gcc mingw-w64-i686-toolchain mingw-w64-1686-libtool mingw-w64-1686-pkg-config mingw-w64-i686-cross-winpthreads-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="-L$(PWD)/libusb/MinGW32/.libs/dll"
export CPPFLAGS="$CPPFLAGS -D__USE_MINGW_ANSI_STDIO=1 -Wno-error"; export CFLAGS="-Wno-error"
cd ~/esp/openocd-esp32
./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
# # optional
# export DESTDIR="SPWD"
# 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-S3 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-S3-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-S3 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-S3-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.
- 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-S3 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
export 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/esp32s3-builtin.cfg
```
4.20.9 Tips and Quirks

This section provides collection of links to all tips and quirks referred to from various parts of this guide.

Breakpoints and watchpoints available  ESP32-S3 debugger supports 2 hardware implemented breakpoints and 64 software ones. Hardware breakpoints are implemented by ESP32-S3 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-S3 also supports two watchpoints, so two 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 2nd watchpoint and will not provide expected results, if you also try to use it within OpenOCD / GDB. See menuconfig’s help for detailed description.

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-S3 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/esp32s3-built-in.cfg -c "init; halt; esp appimage_offset 0x210000"
```

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_ESP32S3_DEBUG_OCDAWARE` is enabled by default. If a panic or unhandled exception is thrown and a JTAG debugger is connected (i.e., 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.

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 20/26 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 20/26 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-S3. 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-S3:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>board/esp32s3-builtin.cfg</td>
<td>Board configuration file for ESP32-S3 for debugging via built-in USB JTAG, includes target and adapter configuration.</td>
</tr>
<tr>
<td>board/esp32s3-ftdi.cfg</td>
<td>Board configuration file for ESP32-S3 for via externally connected FTDI-based probe like ESP-Prog, includes target and adapter configuration.</td>
</tr>
<tr>
<td>target/esp32s3.cfg</td>
<td>ESP32-S3 target configuration file. Can be used together with one of the interface/configuration files.</td>
</tr>
<tr>
<td>interface/ftdi/esp_usb_jtag.cfg</td>
<td>JTAG adapter configuration file for ESP32-S3 built-in USB JTAG.</td>
</tr>
<tr>
<td>interface/ftdi/esp32_devkitj_v1.cfg</td>
<td>JTAG adapter configuration file for ESP-Prog debug adapter board.</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>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP_RTOS</td>
<td>Set to none 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>

**How debugger resets ESP32-S3?** The board can be reset by entering `mon reset` or `mon reset halt` into GDB.
Do not use JTAG pins for something else Operation of JTAG may be disturbed, if some other h/w is connected to JTAG pins besides ESP32-S3 module and JTAG adapter. ESP32-S3 JTAG is using the following pins:

<table>
<thead>
<tr>
<th>ESP32-S3 Pin</th>
<th>JTAG Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTD0 / GPIO40</td>
<td>TDO</td>
</tr>
<tr>
<td>MTD1 / GPIO41</td>
<td>TDI</td>
</tr>
<tr>
<td>MTCK / GPIO39</td>
<td>TCK</td>
</tr>
<tr>
<td>MTMS / GPIO42</td>
<td>TMS</td>
</tr>
</tbody>
</table>

Table 26: ESP32-S3 pins and JTAG signals

JTAG communication will likely fail, if configuration of JTAG pins is changed by user application. If OpenOCD initializes correctly (detects the two Tensilica cores), but loses sync and spews out a lot of DTR/DIR errors when the program is ran, it is likely that the application reconfigures the JTAG pins to something else, or the user forgot to connect Vtst to a JTAG adapter that needed it.

Below is an excerpt from series of errors reported by GDB after the application stepped into the code that reconfigured MTD0 pin to be an input:

```plaintext
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates target still busy!
cpu0: xtensa_resume (line 431): DSR (FFFFFFFF) indicates DIR instruction generated...
→ an exception!
```

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.

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.
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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:

```
openocd -l openocd_log.txt -d3 -f board/esp32s3-builtin.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:

```
openocd -d3 -f board/esp32s3-builtin.cfg 2>&1 | tee openocd.log
```

Debugger:

```
xtensa-esp32s3-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.

4.20.10 Related Documents

Using Debugger

This section covers configuration and running debugger using several methods:

- from Eclipse
- from Command Line
- using `idf.py debug targets`

Eclipse

**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 pluggins 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 section `Build and Flash with Eclipse IDE`. 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 `Build and Flash with Eclipse IDE` 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.
Fig. 37: Configuration of GDB Hardware Debugging - Main tab
6. Click “Debugger” tab. In field “GDB Command” enter xtensa-esp32s3-elf-gdb to invoke debugger.  
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.

![Debug Configurations](image)

Fig. 38: 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:

```sh
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:

```sh
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.
   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.
Fig. 39: Configuration of GDB Hardware Debugging - Startup tab
12. If you previously completed **Configuring ESP32-S3 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-S3 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.

![Debug Perspective in Eclipse](image)

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-S3 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-esp32s3-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-esp32s3-elf-gdb -x gdbinit build/--> blink.elf
GNU gdb (crosstool-NG crosstool-ng-1.22.0-61-gab8375a) 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--esp32s3-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 build/blink.elf...done.
0x400d10d8 in esp_vApplicationIdleHook () at /home/user-name/esp/esp-idf/
--> components/esp32s3/./freertos_hooks.c:52
52 asm("waiti 0");
JTAG tap: esp32s3.cpu0 tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
--> part: 0x2003, ver: 0x1)
JTAG tap: esp32s3.slave tap/device found: 0x120034e5 (mfg: 0x272 (Tensilica),
--> part: 0x2003, ver: 0x1)
estp32s3: Debug controller was reset (pwrstat=0x5F, after clear 0x0F).
estp32s3: Core was reset (pwrstat=0x5F, after clear 0x0F).
Target halted. PRO_CPU: PC=0x5000004B (active) APP_CPU: PC=0x00000000
estp32s3: target state: halted
esp32s3: Core was reset (pwrstat=0x1F, after clear 0x0F).
Target halted. PRO_CPU: PC=0x400000400 (active) APP_CPU: PC=0x400000400
estp32s3: 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=0x400DB717 (active) APP_CPU: PC=0x400D10D8
[New Thread 1073428656]
[New Thread 1073413708]
[New Thread 1073431316]
[New Thread 10734310672]
[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/esp32s3-built-in.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 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.
Fig. 41: Debug Perspective in Eclipse
Fig. 42: Target halted during debugging
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. 43: 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 click 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.

If you now click “Resume” (click blink_task() under “Thread #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.
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Fig. 44: Setting a breakpoint

1. Hold the Control key and double-click on a line number
2. A dialog with breakpoint at selected line will open
Fig. 45: Three breakpoints are set / maximum two are allowed
You will also be 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 thread and highlight the line of code where application halted.

Fig. 46: Target halted manually

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 subroutine 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.

If you press “Step Into (F5)” instead, then debugger will step inside subroutine calls.

In this particular case debugger stepped inside gpio_set_level(BLINK_GPIO, 0) and effectively moved to gpio.c driver code.
Fig. 47: Stepping through the code with “Step Over (F6)”
Fig. 48: Stepping through the code with “Step Into (F5)”
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-S3 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.

![Fig. 49: Observing memory location 0x3FF44004 changing one bit to “ON”](image)

You should see one bit being flipped over at memory location `0x3FF44004` (and LED changing the state) each time F8 is pressed.

![Fig. 50: Observing memory location 0x3FF44004 changing one bit to “OFF”](image)

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.

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.

![Image of Eclipse Debugging Interface](image-url)

**Fig. 51: Watching program variable “i”**

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():
Fig. 52: Setting a conditional breakpoint
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)

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

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 void app_main()
41 {
42    xTaskCreate(&blink_task, "blink_task", configMINIMAL_STACK_SIZE, NULL, 5,
        NULL);
43 }
44 }
(gdb)

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/
    esp32s3/./cpu_start.c:339
(gdb)

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/
    esp32s3/./cpu_start.c:339
    app_main();
(gdb)

Enter l and this will reveal the piece of code that called app_main() (in line 339):

(gdb) l
334 ;
335 )
(continues on next page)
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 }
342
(gdb)

By listing some lines before, you will see the function name `main_task` we have been looking for:

(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 }
(gdb)

To see the other code, enter `i threads`. This will show the list of threads running on target:

(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 107341156 (IDLE) prvIdleTask (pvParameters=0x0)
 2 Thread 1073413512 (IDLE) prvIdleTask (pvParameters=0x0)
 1 Thread 107341772 (main : Running) app_main () at /home/user-name/esp/blink/
(gdb)

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:

(gdb) thread 5

(continues on next page)
(continued from previous page)

```c
(Switching to thread 5 (Thread 1073410208))
#0 0x4000bfea in ?? ()
(gdb)
```

Then check the backtrace:

```c
(gdb) bt
#0 0x4000bfea in ?? ()
#1 0x40083a85 in vPortCPUReleaseMutex (mux=<optimized out>) at /home/user-name/
  → esp/esp-idf/components/freertos/.port.c:415
#2 0x40083fc8 in vTaskSwitchContext () at /home/user-name/esp/esp-idf/components/
  → freertos/.tasks.c:2846
#3 0x4008532b in _frxt_dispatch ()
#4 0x4008395c in xPortStartScheduler () at /home/user-name/esp/esp-idf/components/
  → freertos/.port.c:222
#5 0x4000000c in ?? ()
#6 0x4000000c in ?? ()
#7 0x4000000c in ?? ()
#8 0x4000000c in ?? ()
(gdb)
```

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:

```c
(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:

```c
(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=0x400DB6F6 (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);
(continues on next page)```
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`:

```
(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/esp32s3/.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.

**Note:** In MSYS2 shell Ctrl+C does not halt the target but exists debugger. To resolve this issue consider debugging with Eclipse or check a workaround under http://www.mingw.org/wiki/Workaround_for_GDB_Ctrl_C_Interrupt.

**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:

```
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB754 (active) APP_CPU: PC=0x400D1128
Breakpoint 3, blink_task (pvParameter=0x0) at /home/user-name/esp/blink/main/.
   → blink.c:36
36  gpio_set_level(BLINK_GPIO, 1);
(gdb)
```

Then enter `n` couple of times to see how debugger is stepping one program line at a time:

```
(gdb) n
Target halted. PRO_CPU: PC=0x400DB75E (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400D046FC (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04C (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB746 (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=0x400DB74E (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC046 (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) s
Target halted. PRO_CPU: PC=0x400DB748 (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DC04C (active) APP_CPU: PC=0x400D1128
Target halted. PRO_CPU: PC=0x400DB746 (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.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.
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For more information, see ESP32-S3 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) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB75E (active) APP_CPU: PC=0x400D1128
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB751 (active) APP_CPU: PC=0x400D1128
(gdb) x /1wx 0x3FF44004
0x3ff44004: 0x00000000
```

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: 0x00000000
```

Now, when the LED is off, that corresponds to 0x3ff44004: 0x00000000 being displayed, try using set command to set this bit by writing 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:
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
(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
(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
(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
(gdb) set var i = 0
(gdb) c
Continuing.
Target halted. PRO_CPU: PC=0x400DB755 (active)  APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB755 (active)  APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB755 (active)  APP_CPU: PC=0x400D112C
Target halted. PRO_CPU: PC=0x400DB755 (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)
```

### Obtaining help on commands

Commands presented so far should provide are very basis and intended to let you quickly get started with JTAG debugging. Check help what are the other commands at you 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. 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

### 4.21 Linker Script Generation

#### 4.21.1 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 or to place code in RTC memory for use in a wake stub or 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.

#### 4.21.2 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:

```
cOMPONENT my_component
  |- CMakeLists.txt
     |- component.mk
     |- Kconfig
```

(continues on next page)
• 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.

```c
# 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:

```ini
[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:
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:

```
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:

```
[mapping:my_component]
archive: libmy_component.a
entries:
  * (noflash)
```

Similarly, this places the entire component in RTC memory:

```
[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:

```
[mapping:my_component]
archive: libmy_component.a
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)
```

(continues on next page)
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:

```python
[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/constants is placed in flash, variables 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.

### 4.21.3 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:

- **comparision**
  - LessThan <
  - LessThanOrEqualTo <=
  - MoreThan >
  - MoreThanOrEqualTo >=
  - Equal =
  - NotEqual !=

- **logical**
  - Or ||
  - And &&
  - Negation !

- **grouping**
  - Parenthesis ()

Condition checking behaves as you would expect an if...else/elif...else block in other languages. Condition-checking is possible for both key values and entire fragments. The two sample fragments below are equivalent:

```
# Value for keys is dependent on config
[type:name]
key_1:
  if CONDITION = y:
    value_1
  else:
    value_2
key_2:
```

(continues on next page)
if CONDITION = y:
    value_a
else:
    value_b

# Entire fragment definition is dependent on config
if CONDITION = y:
    [type:name]
    key_1:
    value_1
    key_2:
    value_b
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.

[sections:name]
entries:
    .section+
    .section
...

Example:

# Non-preferred
[sections:text]
entries:
    .text
    .text.*
    .literal
    .literal.*

# 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
Example:

```
[scheme: noflash]
entries:
text -> iram0_text  # the entries under the sections fragment named...
.rodata -> dram0_data  # the entries under the sections fragment named...
```

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.
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,
```

(continues on next page)
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,

[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:

. = ALIGN(8)
_my_sym_start = ABSOLUTE(.)
KEEP(lib1.a:obj1.*( SORT(.rodata) SORT(.rodata.*) ))
_my_sym_end = ABSOLUTE(.)

Example:

```
[mapping:map]
archive: libfreertos.a
entries:
   * (noflash)
```

Example:

```
.section, # same should be done for these sections
... -> target,
...
# and so on
```
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:

```
_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:

```
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]
    _iram_text_end = ABSOLUTE(.);
} > irm0_0_seg
```

Suppose the generator collected the fragment definitions below:

```
[sections:text]
  .text+
  .literal+

[sections:iram]
  .iram1+

[scheme:default]
entries:
  text -> flash_text
```

(continues on next page)
Then the corresponding excerpt from the generated linker script will be as follows:

```
.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 */
    *(.iram1 .iram1.*)
    "libfreertos.a:(.literal .text .literal.* .text.*)"

    _iram_text_end = ABSOLUTE(.);
} > iram0_0_seg

*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/esp32s3/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.

## 4.22 Memory Types

ESP32-S3 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-S3 Technical Reference Manual > System and Memory [PDF].

4.22.1 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.

**Note:** The maximum statically allocated DRAM size is reduced by the IRAM (Instruction RAM) size of the compiled application. The available heap memory at runtime is reduced by the total static IRAM and DRAM usage of the application.

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.

Example:

```c
__NOINIT_ATTR uint32_t noinit_data;
```

4.22.2 IRAM (Instruction RAM)

**Note:** Any internal SRAM which is not used for Instruction RAM will be made available as DRAM (Data RAM) for static data and dynamic allocation (heap).

**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 latency associated with loading the code from flash. ESP32-S3 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:
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.

```c
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.

### 4.22.3 IROM (code executed from flash)

If a function is not explicitly placed into IRAM (Instruction RAM) or RTC memory, it is placed into flash. The mechanism by which Flash MMU is used to allow code execution from flash is described in ESP32-S3 Technical Reference Manual > Memory Management and Protection Units (MMU, MPU) [PDF]. As IRAM is limited, most of an application’s binary code must be placed into IROM instead.

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.

### 4.22.4 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.

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.

### 4.22.5 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.
4.22.6 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:

```c
RTC_NOINIT_ATTR uint32_t rtc_noinit_data;
```

4.22.7 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.

4.22.8 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:
```c
void app_main()
{
    uint8_t stuff;
    WORD_ALIGNED_ATTR uint8_t buffer[] = "I want to send something";  // or...

    // initialization code...
    spi_transaction_t temp = {
        .tx_buffer = buffer,
        .length = 8 * sizeof(buffer),
    };
    spi_device_transmit(spi, &temp);
    // other stuff
}
```

## 4.23 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.

### 4.23.1 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

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 supported via the lwip/include/apps/sntp/sntp.h lwip/lwp/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.

### 4.23.2 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()
- getssockopt() & 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 ioctl)

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 <https://github.com/espressif/newlib-esp32/blob/master/newlib/libc/include/sys/errno.h> and the platform-specific extensions newlib/platform_include/errno.h
Error code | Description
--- | ---
ECONNREFUSED | Connection refused
EADDRINUSE | Address already in use
ECONNABORTED | Software caused connection abort
ENETUNREACH | Network is unreachable
ENETDOWN | Network interface is not configured
ETIMEDOUT | Connection timed out
EHOSTDOWN | Host is down
EHOSTUNREACH | Host is unreachable
EINPROGRESS | Connection already in progress
EALREADY | Socket already connected
EDESTADDRREQ | Destination address required
EPROTONOSUPPORT | Unknown protocol

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_RXTOLALL`)
- `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, ...).

4.23.3 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.

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.

4.23.4 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:
Chapter 4. API Guides

- CONFIG_LWIP_TCPIP_RECVMBX_SIZE
- CONFIG_LWIP_TCPIP_TASK_STACK_SIZE
- CONFIG_LWIP_TCPIP_TASK_AFFINITY

4.23.5 IPv6 Support

Both IPv4 and IPv6 are supported as dual stack and enabled by default (IPv6 may be disabled if it’s 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 support 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 form 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

4.23.6 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.

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 project configuration may also help.

4.23.7 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/ipperf example in an RF sealed enclosure.

The wifi/ipperf/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_TCPIP_TASK_AFFINITY) and runs at fixed priority ESP_TASK_TCPIP_PRIO (18). Configure competing tasks to be pinned to a different core, or to run at a lower priority. See also 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 to improve TX/RX throughput.

If using a Wi-Fi network interface, please also refer to Wi-Fi 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_RECVMBOX_SIZE`, `CONFIG_LWIP_TCP_RECVMBOX_SIZE` and `CONFIG_LWIP_UDP_RECVMBOX_SIZE` reduce memory usage at the expense of throughput, depending on usage.

- Disable `CONFIG_LWIP_IPV6` can save about 39 KB for firmware size and 2KB RAM when system power up and 7KB RAM when TCP/IP stack running. If there is no requirement for supporting IPV6 then it 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).
4.24 OpenThread

OpenThread is a IP stack running on the 802.15.4 MAC layer which features mesh network and low power consumption.

4.24.1 Mode of the OpenThread stack

OpenThread can run under the following modes on Espressif chips:

**Standalone node**

The full OpenThread stack and the application layer runs on the same chip. This mode is available on chips with 15.4 radio such as ESP32-H2.

**Radio Co-Processor (RCP)**

The chip will be connected to another host running the OpenThread IP stack. It will send and received 15.4 packets on behalf of the host. This mode is available on chips with 15.4 radio such as ESP32-H2. The underlying transport between the chip and the host can be SPI or UART. For sake of latency, we recommend to use SPI as the underlying transport.

**OpenThread host**

For chips without 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:

![Fig. 53: OpenThread device modes](image)

4.24.2 How To Write an OpenThread Application

The OpenThread `openthread/ot_cli` example will be 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 filesystem. 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 will 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.

**4.24.3 The OpenThread border router**

The OpenThread border router connects the Thread network with other IP networks. It will provide IPv6 connectivity, service registration and commission functionality. To launch an OpenThread border router on a ESP chip, you need to connect an RCP to a Wi-Fi capable chip such as ESP32. Call `esp_openthread_border_router_init()` during the initialization will launch all the border routing functionalities.

You may refer to the openthread/ot_br example and the README for further border router details.

**4.25 Partition Tables**
4.25.1 Overview

A single ESP32-S3’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.

Partition table length is 0xC00 bytes (maximum 95 partition table entries). An MD5 checksum, which is used for checking the integrity of the partition table, is appended after the table data.

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.

4.25.2 Built-in Partition Tables

Here is the summary printed for the “Single factory app, no OTA” configuration:

```
# 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:

```
# ESP-IDF Partition Table
# Name, Type, SubType, Offset, Size, Flags
nvs, data, nvs, 0x9000, 0x4000,
ötadata, data, ota, 0xd000, 0x2000,
phy_init, data, phy, 0xf000, 0x1000,
factory, app, factory, 0x10000, 1M,
ota_0, app, ota_0, 0x110000, 1M,
ota_1, app, ota_1, 0x1210000, 1M,
```

- 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 “ötadata” slot, which holds the data for OTA updates. The bootloader consults this data in order to know which app to execute. If “ötadata” is empty, it will execute the factory app.

4.25.3 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:
# Name, Type, SubType, Offset, Size, Flags

<table>
<thead>
<tr>
<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>0x9000</td>
<td>0x4000</td>
<td></td>
</tr>
<tr>
<td>otadata</td>
<td>data</td>
<td>ota</td>
<td>0xd000</td>
<td>0x2000</td>
<td></td>
</tr>
<tr>
<td>phy_init</td>
<td>data</td>
<td>phy</td>
<td>0xf000</td>
<td>0x1000</td>
<td></td>
</tr>
<tr>
<td>factory</td>
<td>app</td>
<td>factory</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>1M</td>
<td></td>
</tr>
<tr>
<td>ota_1</td>
<td>app</td>
<td>ota_1</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>
</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-S3. Names longer than 16 characters 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:

```c
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 WiFi data if the esp_wifi_set_storage(WIFI_STORAGE_FLASH) initialisation 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 0x00-0xFE).

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.

Offset & Size

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 (64K). 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.
4.25.4 Generating Binary Partition Table

The partition table which is flashed to the ESP32-S3 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:

```bash
python gen_esp32part.py input_partitions.csv binary_partitions.bin
```

To convert binary format back to CSV manually:

```bash
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):

```bash
python gen_esp32part.py binary_partitions.bin
```

4.25.5 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.

4.25.6 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.
4.25.7 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.

```python
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:
parttool.py [command-args] [subcommand] [subcommand-args]

- command-args - These are arguments that are needed for executing the main command.
- subcommand - This is the operation to be performed
- subcommand-args - These are arguments that are specific to the chosen operation

# 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 "factory.bin"

# 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:

# Display possible subcommands and show main command argument descriptions
parttool.py --help

# Show descriptions for specific subcommand arguments
parttool.py [subcommand] --help

4.26 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).

4.26.1 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.

4.26.2 Guides

Maximizing Execution Speed

Overview Optimizing execution speed is a key element of software performance. Code that executes faster can also have other positive effects, like 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 application firmwares will only have a small set of functions which 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  If measuring performance relative to an external interaction with the world, you may be able to measure this directly (for example see the examples wifi/iperf and ethernet/iperf for measuring general network performance, or you can use an oscilloscope or logic analyzer to measure 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 %ull milliseconds (%ull microseconds per ~ invocation)\n",
           MEASUREMENTS, (end - start)/1000, (end - start)/MEASUREMENTS);
}
```

Executing the target multiple times can help average out factors like 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’s 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()` will return the number of CPU cycles executed. This function has lower overhead than the others. It 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.
- If making “microbenchmarks” (i.e. benchmarking only a very small routine of code that runs in less than 1-2 milliseconds) then 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 will improve the execution of nearly all code - including boot times, throughput, latency, etc:

- Set `CONFIG_ESPTOOLPY_FLASHMODE` to QIO or QOUT mode (Quad I/O). Both will 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-S3 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 will almost certainly increase performance of some code. Note that if your code contains C or C++ Undefined Behaviour then increasing the compiler optimization level may expose bugs that otherwise are not seen.
- Avoid using floating point arithmetic (`float`). Even though ESP32-S3 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’s 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 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`. (Unless using internal USB-CDC for serial console, in which case the serial throughput doesn’t depend on the configured baud rate.)

Not Recommended  The following options will 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 necessary to do this to optimize a particular function, consider adding `#define NDEBUG` in the top of that single source file instead.

Targeted Optimizations  The following changes will 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’s 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 will 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 don’t need to be placed in IRAM. For hot paths in large switch cases this will improve performance. For instructions on how to add the `-fjump-tables -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:
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- 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_MAXIMUM_LEVEL` as well and call `esp_log_set_level()` to restore higher level logs. The `system/startup_time` main function shows how to do this.
- If using deep sleep, 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 will not be performed on wake.
- Setting `CONFIG_BOOTLOADER_SKIP_VALIDATE_ON_POWER_ON` will skip verifying the binary on every boot from 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’s possible to save a small amount of time during boot by disabling RTC slow clock calibration. To do so, set `CONFIG_ESP32S3_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 files `system/startup_time/sdkconfig.defaults` and `system/startup_time/sdkconfig.defaults.esp32s3` 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’s 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’s 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` provides a mechanism to automatically detect if task starvation happens, however note that a Task WDT timeout does not always indicate a problem (sometimes the correct operation of the firmware requires some long-running computation). In these cases tweaking the Task WDT timeout or even disabling the Task WDT 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, some are started only if the application firmware initializes a particular feature. To optimize performance, structure application task priorities so that they are not delayed by 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.

Common priorities are:

- **Main task that executes app_main function** has minimum priority (1). This task is pinned to Core 0 by default (configurable).
- **High Resolution 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 Handling** system task to manage the default system event loop and execute callbacks has high priority (20, `ESP_TASK_EVENT_PRIO`) and pinned to Core 0. This configuration is only used if the application calls `esp_event_loop_create_default()`, it’s 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).
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.

**Bluetooth Controller** 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 close to the highest priority task assigned to a single CPU.

**NimBLE Bluetooth Host** host task has high priority (21) and is pinned to Core 0 by default (configurable).

- 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 mDNS component, it creates a task with default low priority 1 (configurable) and pinned to CPU0 (configurable).
- 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).

**Choosing application task priorities**  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 will guarantee 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 (this may reduce total TCP/IP throughput depending on what other tasks are running).

In general, it’s not recommended to set task priorities on Core 0 higher than the built-in Wi-Fi/BT operations as starving them of CPU may make the system unstable. Choosing priority 19 and Core 0 will allow lower layer Wi-Fi/BT functionality to run without delays, but still pre-empt the lwIP TCP/IP stack and other less time-critical internal functionality - this is an option for time-critical tasks that don’t 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 to Core 1. The task can be left unpinned - at priority 17 or lower - to optionally run on Core 0 as well, if no higher priority built-in task is running there. 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** will continue 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 will preempt lower priority ones.

Interrupt handlers will execute in preference to any task (provided the task is not inside a critical section). For this reason, it’s important to minimize the amount of time spent executing in 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/BT tasks are not configured to run (this means assigning 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’re 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’s 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 IPv6 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.esp32s3 and wifi/iperf/sdkconfig.ci.99 to your project `sdkconfig` file 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 this information to determine exactly which options are best suited for your app.

### 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:

```
$ idf.py size
[...]
Total sizes:
  DRAM .data size: 11584 bytes
  DRAM .bss size: 19624 bytes
  Used static DRAM: 0 bytes (0 available, nan% used)
  Used static IRAM: 0 bytes (0 available, nan% used)
  Used stat D/IRAM: 136276 bytes (519084 available, 20.8% used)
  Flash code: 630508 bytes
  Flash rodata: 177048 bytes
  Total image size:~ 924208 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, Used static IRAM - these options are kept for compatibility with ESP32 target, and currently read 0.
• Used stat D/IRAM - This is total internal RAM usage, the sum of static DRAM .data + .bss, and also static IRAM (Instruction RAM) used by the application for executable code. 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).

- **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
    libnet80211.a  1267  6044  0  5490  0  107445 [...]
    libc.a  4  0  0  0  0  57056 [...]
    libphy.a  1439  715  0  7798  0  33074 [...]
    0  43026 [...]
    libwpa_supplicant.a  12  848  0  0  0  35505 [...]
    libcxx.a  0  0  0  0  0  47 [...]
    0  17 [...]
    libtcip_adapter.a  0  233 [...]
    0  112 [...]
    0  47 [...]
    12  18 [...]
(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).
- **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 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:
  Object File DRAM .data & .bss & other IRAM D/IRAM Flash code &...
  x509.crt_bundle.S.o Total  0  0  0  0  0  8...
  wl.cnx.o  64212  64212  2  3183  0  221  0  13119...
  phy_chip_v7.o  3286  19811  721  614  0  1642  0  16820...
  ieee80211_ioctl.o  0  19797  2627  19225  740  96  0  437  0  15325...
  pp.o  537  15625  914  14671  1042  45  0  8871  0  5030...
(continues on next page)
```
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 least 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 idf.py, it’s necessary to run the idf-size.py Python tool directly.

To do so, first locate the linker map file in the build directory. It will have the name `PROJECTNAME.map`. The idf-size.py 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
$ $IDF_PATH/tools/idf_size.py --diff build_Og/https_request.map build_Os/https_request.map
<CURRENT> MAP file: build_Os/https_request.map
<REFERENCE> MAP file: build_Og/https_request.map
Difference is counted as <CURRENT> - <REFERENCE>, i.e. a positive number means...
that <CURRENT> is larger.
Total sizes of <CURRENT>:

<table>
<thead>
<tr>
<th>Section</th>
<th>Size (K)</th>
<th>Difference (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRAM .data</td>
<td>14516</td>
<td>440</td>
</tr>
<tr>
<td>DRAM .bss</td>
<td>15792</td>
<td>-16</td>
</tr>
<tr>
<td>Used static DRAM</td>
<td>30308</td>
<td>456 ( +456 available, +0 total)</td>
</tr>
<tr>
<td>Used static IRAM</td>
<td>78498</td>
<td>5420 ( +5420 available, +0 total)</td>
</tr>
<tr>
<td>Flash code</td>
<td>509183</td>
<td>-50760</td>
</tr>
<tr>
<td>Flash rodata</td>
<td>170592</td>
<td>-6144</td>
</tr>
<tr>
<td>Total image size</td>
<td>772789</td>
<td>-62764</td>
</tr>
</tbody>
</table>
```

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:

```bash
$ $IDF_PATH/tools/idf_size.py --archives --diff build_Og/https_request.map build_Os/https_request.map
```

Also at the individual source file level:

```bash
$ $IDF_PATH/tools/idf_size.py --files --diff build_Og/https_request.map build_Os/https_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 idf_size.py 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.
It is also possible to view the equivalent of size-components or size-files output:

```bash
$IDF_PATH/tools/idf_size.py build/project_name.map
$IDF_PATH/tools/idf_size.py --archives build/project_name.map
$IDF_PATH/tools/idf_size.py --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` 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`.
- 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.
- 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.

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_ESP32_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.

Bluetooth NimBLE  If using NimBLE Bluetooth Host then the following modifications can reduce binary size:

- `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.

**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-S3 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 also 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_SSL_PROTO_TLS1`
- `CONFIG_MBEDTLS_SSL_PROTO_TLS1_1`
- `CONFIG_MBEDTLS_CLIENT_SSL_SESSION_TICKETS`
- `CONFIG_MBEDTLS_SERVER_SSL_SESSION_TICKETS`
- `CONFIG_MBEDTLS_SSL_ALPN`
- `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_SSL_RENEGOTIATION`
- Change `CONFIG_MBEDTLS_TLS_MODE` if both Server & Client are not needed
- Consider disabling some ciphersuites 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-S3 device may become inaccessible if support changes.

**Note:** Not every combination of mbedTLS 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.
FreeModBus If using Modbus, enable or disable `CONFIG_FMB_COMM_MODE_TCP_EN`, `CONFIG_FMB_COMM_MODE_RTU_EN`, `CONFIG_FMB_COMM_MODE_ASCII_EN` as applicable for the necessary functionality.

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.

Bootloader 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 Bootloader 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’s necessary to tune the memory usage of the firmware application.

In general, firmware should aim to leave some “headroom” of free internal RAM in order to deal with extraordinary situations or changes in RAM usage in future updates.

Background Before optimizing ESP-IDF RAM usage, it’s necessary to understand the basics of ESP32-S3 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. Refer to the Binary Size chapter for more information.

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 allocation in C. In many instances (including: Wi-Fi library, Bluetooth controller) “static” buffers are still allocated from heap, but the allocation is done once when the feature is initialized and will be freed if the feature is deinitialized. This is done in order to maximize the amount of free memory at different points in the application life-cycle.

To minimize static memory use:

- Declare structures, buffers, or other variables `const` whenever possible. Constant data can be stored in flash not RAM. This may require changing functions in the firmware to take `const *` arguments instead of mutable pointer arguments. These changes can also reduce the stack usage of some 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 doesn’t necessarily reduce the peak memory usage, but changes it from static memory usage to runtime memory usage.

Reducing Stack Sizes

In FreeRTOS, task stacks are usually allocated from the heap. The stack size for each task is fixed (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 can substantially reduce RAM usage.

To determine optimum task stack sizes:

- Combine tasks. The best task stack size is 0 bytes, achieved by combining a task with another existing task. Anywhere that the firmware can be structured to perform multiple functions sequentially in a single task will increase free memory. In some cases, using a “worker task” pattern where jobs are serialized into a FreeRTOS queue (or similar) and then processed by generic worker tasks may help.
- Consolidate task functions. String formatting functions (like `printf`) are particularly heavy users of stack, so any task which doesn’t ever call these can usually have its stack size reduced.
- Enabling `Newlib nano formatting` will reduce 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 struct or array allocated as an “automatic” variable (i.e. default scope of a C declaration) will use space on the stack. Minimize the sizes of these, allocate them statically and/or see if you can save memory by allocating them from the heap only when they are needed.
- Avoid deep recursive function calls. Individual recursive function calls don’t 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.
- 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 this 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’s 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, set the `CONFIG_FREERTOS_WATCHPOINT_END_OF_STACK` option to trigger an immediate panic if a task writes the word at the end of its assigned stack. This is slightly
more reliable than the default `CONFIG_FREERTOS_CHECK_STACKOVERFLOW` option of “Check using canary bytes”, because the panic happens immediately, not on the next RTOS context switch. Neither option is perfect, it’s possible in some cases for stack pointer to skip the watchpoint or canary bytes and corrupt another region of RAM, instead.

**Internal 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 this information and the specific configuration that is being used.

- **Main task that executes app_main function** has stack size `CONFIG_ESP_MAIN_TASK_STACK_SIZE`.
- **High Resolution Timer** system task which executes callbacks has stack size `CONFIG_FREERTOS_TIMER_TASK_STACK_SIZE`.
- FreeRTOS Timer Task to handle FreeRTOS timer callbacks has stack size `CONFIG_FREERTOS_TIMER_TASK_STACK_DEPTH`.
- **Event Handling** 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`.
- Bluedroid Bluetooth Host have task stack sizes `CONFIG_BT_BTC_TASK_STACK_SIZE`, `CONFIG_BT_BTU_TASK_STACK_SIZE`.
- **NimBLE Bluetooth Host** has task stack size `CONFIG_BT_NIMBLE_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_STACKSIZE`.
- If using the `mDNS` and/or `MQTT` components, they create tasks with stack sizes configured by `CONFIG_MDNS_TASK_STACK_SIZE` and `CONFIG_MQTT_TASK_STACK_SIZE`, respectively. MQTT stack size can also be configured using `task_stack` field of `esp_mqtt_client_config_t`.

**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 aren’t 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 numbers of “static” buffers or reduce the maximum number of “dynamic” buffers in use, in order to minimize memory usage at possible cost of performance. Note that “static” Wi-Fi buffers are still allocated from heap when Wi-Fi is initialized and will be freed if Wi-Fi is deinitialized.
- **mbedtls TLS session memory usage** can be minimized by enabling the ESP-IDF feature `CONFIGMBEDTLS_DYNAMIC_BUFFER`. 

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Note: There are other configuration options that will increase heap usage at runtime if changed from the defaults. These are not listed here, but the help text for the configuration item will mention if there is some memory impact.

Optimizing IRAM Usage  The available DRAM at runtime (for heap usage) is also reduced by the static IRAM usage. Therefore, one way to increase available DRAM is to reduce IRAM usage.

If the app allocates more static IRAM than is 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.
- Enable CONFIG_FREERTOS_PLACE_SNAPSHOT_FUNS_INTO_FLASH. Enabling this option will place snapshot-related functions, such as vTaskGetSnapshot or uxTaskGetSnapshotAll, in flash.
- Disable Wi-Fi options CONFIG_ESP32_WIFI_IRAM_OPT and/or CONFIG_ESP32_WIFI_RX_IRAM_OPT. Disabling these options will free available IRAM at the cost of Wi-Fi performance.
- CONFIG_SPI_FLASH_ROM_IMPL enabling this option will free some IRAM but will mean that esp_flash bugfixes and new flash chip support is not available.
- Disabling CONFIG_ESP_EVENT_POST_FROM_IRAM_ISR prevents posting esp_event events from IRAM-Safe Interrupt Handlers but will save 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 will save some IRAM.
- Setting CONFIG_HAL_DEFAULT_ASSERTION_LEVEL to disable assertion for HAL component will save some IRAM especially for HAL code who calls HAL_ASSERT a lot and resides 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.

4.27 RF calibration

ESP32-S3 supports three RF calibration methods during RF initialization:

1. Partial calibration
2. Full calibration
3. No calibration

4.27.1 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.
4.27.2 Full calibration

Full calibration is triggered in the following conditions:

1. NVS does not exist.
2. The NVS partition to store calibration data is erased.
3. Hardware MAC address is changed.
4. PHY library version is changed.
5. The RF calibration data loaded from the NVS partition is broken.

It takes about 100ms more than partial calibration. If boot duration is not critical, it is suggested to use the full calibration method. 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 don’t 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 WiFi and BT/BLE based on some conditions (e.g. an option provided in some diagnostic mode). In this case, only phy namespace of the NVS partition is erased.

4.27.3 No calibration

No calibration method is only used when the device wakes up from deep sleep.

4.27.4 PHY initialization data

The PHY initialization data is used for RF calibration. There are two ways to get the PHY initialization data.

One is the default initialization data which is located in the header file components/esp_phy/esp32s3/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. Another is the initialization data which is stored in a partition. When using a custom partition table, make sure that PHY data partition is included (type: data, subtype: phy). With default partition table, this is done automatically. If initialization data is stored in a partition, it has to be flashed there, otherwise runtime error will occur. To switch to the initialization data stored in a partition, go to menuconfig and enable CONFIG_ESP_PHY_INIT_DATA_IN_PARTITION.

4.28 Secure Boot V2

Important: This document is about Secure Boot V2, supported on the following chips: ESP32 (ECO3 onwards), ESP32-S2, ESP32-S3 and ESP32-C3 (ECO3 onwards). Except for ESP32, it is the only supported Secure Boot scheme.

Secure Boot V2 uses RSA based app and bootloader verification. This document can also be used as a reference for signing apps using the RSA scheme without signing the bootloader.

4.28.1 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-S3, 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 new RSA based Secure Boot verification scheme (Secure Boot V2) has been introduced on the ESP32 (ECO3 onwards), ESP32-S2, ESP32-S3 and ESP32-C3 (ECO3 onwards).

The Secure Boot process on the ESP32-S3 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.

### 4.28.2 Advantages

- The RSA public key is stored on the device. The corresponding RSA private key is kept at a secret place and is never accessed by the device.
- Up to three public keys can be generated and stored in the chip during manufacturing.
- ESP32-S3 provides the facility to permanently revoke individual public keys. This can be configured conservatively or aggressively.
- Conservatively - The old key is revoked after the bootloader and application have successfully migrated to a new key. Aggressively - The key is revoked as soon as verification with this key fails.
- 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.)

### 4.28.3 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.

Up to 3 signature blocks can be appended to the bootloader or application image in ESP32-S3. 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.
### 4.28.4 Signature Block Format

The bootloader and application images are padded to the next 4096 byte boundary, thus the signature has a flash sector of its own. The signature is calculated over all bytes in the image including the padding bytes.

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, MFG1 function, salt length 32 bytes, default trailer field (0xBC).</td>
</tr>
<tr>
<td>1196</td>
<td>4</td>
<td>CRC32 of the preceding 1095 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.

### 4.28.5 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.

### 4.28.6 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.

### 4.28.7 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*. 
4.28.8 eFuse usage

- `SECURE_BOOT_EN` - Enables Secure Boot protection on boot.
- `KEY_PURPOSE_X` - Set the purpose of the key block on ESP32-S3 by programming `SECURE_BOOT_DIGESTX` (X = 0, 1, 2) into `KEY_PURPOSE_X` (X = 0, 1, 2, 3, 4, 5). Example: If `KEY_PURPOSE_2` is set to `SECURE_BOOT_DIGEST1`, then `BLOCK_KEY2` will have the Secure Boot V2 public key digest. The write-protection bit must be set (this field does not have a read-protection bit).
- `BLOCK_KEYX` - The block contains the data corresponding to its purpose programmed in `KEY_PURPOSE_X`. 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.
- `KEY_REVOKEX` - The revocation bits corresponding to each of the 3 key block. Ex. Setting `KEY_REVOKE2` revokes the key block whose key purpose is `SECURE_BOOT_DIGEST2`.
- `SECURE_BOOT_AGGRESSIVE_REVOKE` - Enables aggressive revocation of keys. The key is revoked as soon as verification with this key fails.

To ensure no trusted keys can be added later by an attacker, each unused key digest slot should be revoked (KEY_REVOKEX). It will be checked during app startup in `esp_secure_boot_init_checks()` and fixed unless `CONFIG_SECURE_BOOT_ALLOW_UNUSED_DIGEST_SLOTS` is enabled.

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.

4.28.9 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. The “Secure Boot V2” option will be selected and the “App Signing Scheme” would be set to RSA by default.
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, it is set to “Permanently switch to Secure mode” which is generally recommended. For production devices, the most secure option is to set it to “Permanently disabled”.
5. 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.
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 4.
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**Note:** `idf.py flash` doesn’t flash the bootloader if Secure Boot is enabled.

10. Reset the ESP32-S3 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-S3 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-S3 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).

### 4.28.10 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.
- 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.

### 4.28.11 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.

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 key generation utilities.

For example, to generate a signing key using the openssl command line:

```
`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.

### 4.28.12 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.

After the app image and partition table are built, the build system will print signing steps using `espsecure.py`:

```
espsecure.py sign_data --version 2 --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:
4.28.13 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.

4.28.14 Key Management

- Between 1 and 3 RSA-3072 public key pairs (Keys #0, #1, #2) should be computed independently and stored separately.
- The KEY_DIGEST eFuses should be write protected after being programmed.
- The unused KEY_DIGEST slots must have their corresponding KEY_REVOKE eFuse burned to permanently disable them. This must happen before the device leaves the factory.
- The eFuses can either be written by the software bootloader during during first boot after enabling “Secure Boot V2” from menuconfig or can be done using espefuse.py which communicates with the serial bootloader program in ROM.
- The KEY_DIGESTs should be numbered sequentially beginning at key digest #0. (i.e., if key digest #1 is used, key digest #0 should be used. If key digest #2 is used, key digest #0 & #1 must be used.)
- The software bootloader (non OTA upgradeable) is signed using at least one, possibly all three, private keys and flashed in the factory.
- Apps should only be signed with a single private key (the others being stored securely elsewhere), however they may be signed with multiple private keys if some are being revoked (see Key Revocation, below).

4.28.15 Multiple Keys

- The bootloader should be signed with all the private key(s) that are needed for the life of the device, before it is flashed.
- The build system can sign with at most one private key, user has to run manual commands to append more signatures if necessary.
- You can use the append functionality of espsecure.py, this command would also printed at the end of the Secure Boot V2 enabled bootloader compilation.
  ```
  espsecure.py sign_data --version 2 --keyfile PRIVATE_SIGNING_KEY --output SIGNED_BINARY_FILE BINARY_FILE
  ```
- While signing with multiple private keys, it is recommended that the private keys be signed independently, if possible on different servers and stored separately.
- You can check the signatures attached to a binary using - espsecure.py signature_info_v2 datafile.bin

4.28.16 Key Revocation

- Keys are processed in a linear order. (key #0, key #1, key #2).
- Applications should be signed with only one key at a time, to minimize the exposure of unused private keys.
- The bootloader can be signed with multiple keys from the factory.

Conservative approach:

Assuming a trusted private key (N-1) has been compromised, to update to new key pair (N).
1. Server sends an OTA update with an application signed with the new private key (#N).
2. The new OTA update is written to an unused OTA app partition.
3. The new application’s signature block is validated. The public keys are checked against the digests programmed in the eFuse & the application is verified using the verified public key.
4. The active partition is set to the new OTA application’s partition.
5. Device resets, loads the bootloader (verified with key #N-1) which then boots new app (verified with key #N).
6. The new app verifies bootloader with key #N (as a final check) and then runs code to revoke key #N-1 (sets KEY_REVOKE eFuse bit).
7. The API esp_ota_revoke_secure_boot_public_key() can be used to revoke the key #N-1.
   - A similar approach can also be used to physically re-flash with a new key. For physical re-flashing, the bootloader content can also be changed at the same time.

Aggressive approach:

ROM code has an additional feature of revoking a public key digest if the signature verification fails.

To enable this feature, you need to burn SECURE_BOOT_AGGRESSIVE_REVOKE eFuse or enable CONFIG_SECURE_BOOT_ENABLE_AGGRESSIVE_KEY_REVOKE

Key revocation is not applicable unless secure boot is successfully enabled. Also, a key is not revoked in case of invalid signature block or invalid image digest, it is only revoked in case the signature verification fails, i.e. revoke key only if failure in step 3 of Verifying an Image

Once a key is revoked, it can never be used for verifying a signature of an image. This feature provides strong resistance against physical attacks on the device. However, this could also brick the device permanently if all the keys are revoked because of signature verification failure.

4.28.17 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:

```bash
eespsecure.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.

4.28.18 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.

4.28.19 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 by 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.

Although multiple trusted keys are supported when using hardware Secure Boot, only the first public key in the signature block is used to verify updates if signature checking without Secure Boot is configured. If multiple trusted public keys are required, it’s necessary to enable the full Secure Boot feature instead.

**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*
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.

**4.28.20 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 Thread Local Storage**

**4.29.1 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 API**: ESP-IDF FreeRTOS native API.
- **Pthread API**: ESP-IDF’s pthread API.
- **C11 Standard**: C11 standard introduces special keyword to declare variables as thread local.
4.29.2 FreeRTOS Native API

The ESP-IDF FreeRTOS provides the following API to manage thread local variables:

- `vTaskSetThreadLocalStoragePointer()`  
- `pvTaskGetThreadLocalStoragePointer()`  
- `vTaskSetThreadLocalStoragePointerAndDelCallback()`

In this case maximum number of variables that can be allocated is limited by `CONFIG_FREERTOS_THREAD_LOCAL_STORAGE_POINTERS` configuration value. 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 that API user 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 user is responsible for allocating/deallocating memory for it. Variable’s deallocation is initiated by FreeRTOS when task is deleted, but user must provide function (callback) to do proper cleanup.

4.29.3 Pthread API

The ESP-IDF provides the following pthread API to manage thread local variables:

- `pthread_key_create()`  
- `pthread_key_delete()`  
- `pthread_getspecific()`  
- `pthread_setspecific()`

This API has all benefits of the one above, but eliminates some its limits. The number of variables is limited only by size of available memory on the heap. Due to the dynamic nature this API introduces additional performance overhead compared to the native one.

4.29.4 C11 Standard

The ESP-IDF FreeRTOS supports thread local variables according to C11 standard (ones specified with `__thread` keyword). For details on this GCC feature please see [https://gcc.gnu.org/onlinedocs/gcc-5.5.0/gcc/Thread-Local.html#Thread-Local](https://gcc.gnu.org/onlinedocs/gcc-5.5.0/gcc/Thread-Local.html#Thread-Local). Storage for that kind of variables is allocated on the task’s stack. Note that area for all such variables in the program will be 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 (like `ipc`, `timer` tasks etc.) will also have that extra stack space allocated. So this feature should be used with care. There is a tradeoff: C11 thread local variables are quite handy to use in programming and can be accessed using minimal CPU instructions, but this benefit goes with 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.

4.30 Tools

4.30.1 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

The `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/TOLER_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.
- `esp32.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

The 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. The `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:
  - **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.

  - **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: 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)
  ```

- **list**: Lists the known versions of the tools, and indicates which ones are installed.

- **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 and install there the required Python packages. An optional --features argument allows one to specify a comma-separated list of features. 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) the package version requirements for a given ESP-IDF version.

- **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 will be downloaded from https://dl.espressif.com if this step hasn’t been done already in the last day.

Install scripts

Shell-specific user-facing scripts are provided in the root of ESP-IDF repository to facilitate tools installation. These are:
• 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 IDFTOOLS_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 for ESP-IDF includes a menu item to set up the tools. Internally the plugin calls idf_tools.py.
• Visual Studio Code 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.
List of IDF Tools

**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](https://github.com/espressif/crosstool-NG)

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**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](https://github.com/espressif/crosstool-NG)
### 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](https://github.com/espressif/crosstool-NG)

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### xtensa-clang

LLVM for Xtensa (ESP32, ESP32-S2) based on clang

License: Apache-2.0

More info: [https://github.com/espressif/llvm-project](https://github.com/espressif/llvm-project)
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**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

<table>
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**esp32ulp-elf**  
Toolchain for ESP32 ULP coprocessor  
License: GPL-2.0-or-later  
More info: https://github.com/espressif/binutils-esp32ulp
### Platform Configuration

<table>
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### esp32s2ulp-elf

Toolchain for ESP32-S2 and ESP32-S3 ULP coprocessors

License: GPL-2.0-or-later

More info: [https://github.com/espressif/binutils-esp32ulp](https://github.com/espressif/binutils-esp32ulp)

<table>
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<tr>
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</table>

### 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](https://github.com/Kitware/CMake)
### Chapter 4. API Guides

<table>
<thead>
<tr>
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SHA256: e276cf7bb3e3e88bc666e183bc3ddaceb143a4c83f3b57b1dbb1a26fd6e4ea2 |

### 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
### Chapter 4. API Guides

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SHA256: bbde850d247d2737c5764c927d1071cbb1f1957c2aba4a130fa8547c12c695f |

**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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SHA256: 5816d76c68f3ac07b5ac9f9837c57d2efe45b6a80a2f2bbe6b40b1c15c470e |

### 4.30.2 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](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/](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-v4.0 idf.py -b
```

You can check the up-to-date list of available tags at [https://hub.docker.com/r/espressif/idf/tags](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 `-it` 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. 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).

4.30.3 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 AppData/Roaming. 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 PIP_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 allows to select custom Python and custom location of Python wheels:

```
esp-idf-tools-setup-x.x.exe /USEEMBEDDEDPYTHON=no /PYTHONWHEELSURL=https://pypi.org/simple/
```

### 4.30.4 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/

#### Activating the Component Manager

If CMake is started using `idf.py` or ESP-IDF VSCode Extension then the component manager will be activated by default.

If CMake is used directly or with some CMake-based IDE like CLion, it’s necessary to set the `IDF_COMPONENT_MANAGER` environment variable to 1 to enable the component manager integration with the build system.

#### 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`

#### 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

(continues on next page)
```
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(continued from previous page)

```yaml
# # For components maintained by Espressif only name can be used.
# # Same as 'espressif/cmp'
# component: "~1.0.0"
# # Or in a longer form with extra parameters
# component2:
#   version: ">=2.0.0"
# # For transient dependencies 'public' flag can be set.
# # 'public' flag doesn't affect the 'main' component.
# # All dependencies of 'main' are public by default.
# public: true

# # For components hosted on non-default registry:
# service_url: "https://componentregistry.company.com"

# # For components in git repository:
# test_component:
#   path: test_component
#   git: ssh://git@gitlab.com/user/components.git

# # For test projects during component development
# # components can be used from a local directory
# # with relative or absolute path
# # some_local_component:
#   path: ../../projects/component
```

4.30.5 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 xtensa-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`.

   **Note:** This file would be bundled in future toolchain releases. This is a temporary workaround.

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 ULP Coprocessor programming

**Warning:** This feature is not supported in v4.4

#### 4.31.1 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 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()
};
```

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 `ULP coprocessor instruction defines` section 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.

Load and store instructions use addresses expressed in 32-bit words. Address 0 corresponds to the first word of `RTC_SLOW_MEM` (which is address 0x50000000 as seen by the main CPUs).
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 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);
ulp_process_macros_and_load(load_addr, program, &size);
ulp_run(load_addr);
```

**Application Example**

Demonstration of entering into deep sleep mode and waking up using several wake up sources: `system/deep_sleep`.

**API Reference**

**Header File**

- ulp/ulp_fsm/include/esp32s3/ulp.h

**Functions**

`esp_err_t ulp_process_macros_and_load (uint32_t load_addr, const ulp_insn_t *program, size_t *size)`

Resolve all macro references in a program and load it into RTC memory.

**Return**

- ESP_OK on success
- ESP_ERR_NO_MEM if auxiliary temporary structure cannot be allocated
- one of ESP_ERR_ULT_xxx if program is not valid or can not be loaded

**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

`esp_err_t ulp_run (uint32_t entry_point)`

Run the program loaded into RTC memory.

**Return**

ESP_OK on success

**Parameters**

- entry_point: entry point, expressed in 32-bit words
Error codes

**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

**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)

**ULP coprocessor registers**
ULP co-processor has 4 16-bit general purpose registers. All registers have same functionality, with one exception. R0 register is used by some of the compare-and-branch instructions as a source register.

These definitions can be used for all instructions which require a register.

- **R0**
  general purpose register 0

- **R1**
  general purpose register 1

- **R2**
  general purpose register 2

- **R3**
  general purpose register 3

**ULP coprocessor instruction defines**

- **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_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_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 [20:16] = 5’b1
  - bits [15:0] are assigned the contents of reg_val
RTC_SLOW_MEM[addr + offset_] = { 5'b0, insn_PC[10:0], 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_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_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.

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_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.
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`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.

Defines

`RTC_SLOW_MEM`
RTC slow memory, 8k size

The ULP (Ultra Low Power) coprocessor is a simple FSM (Finite State Machine) 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 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.

4.31.2 Installing the Toolchain

The ULP 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 toolchain will already be installed.

4.31.3 Compiling the ULP Code

To compile the ULP code as part of the component, the following steps must be taken:

1. The ULP 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/`.

2. Call `ulp_embed_binary` from the component CMakeLists.txt after registration. For example:

   ```
   ...
   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 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 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 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 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 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.

4.31.4 Accessing the ULP Program Variables

Global symbols defined in the ULP program may be used inside the main program.

For example, the ULP 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:

```
.globl 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_measurement_count` 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_`.

The header file contains the declaration of the symbol:

```
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:

```
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:

```
#include "ulp_app_name.h"

void init_ulp_vars() {
    ulp_measurement_count = 64;
}
```

Note that the ULP program can only use 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 value into the lower 16 bits part of the 32-bit word. 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, the main application needs to mask the upper 16 bits, e.g.:

```
printf("Last measurement value: $d\n", ulp_last_measurement & UINT16_MAX);
```
4.31.5 Starting the ULP Program

To run a ULP program, the main application needs to load the ULP program into RTC memory using the \texttt{ulp_load_binary} function, and then start it using the \texttt{ulp_run} function.

Note that “Enable Ultra Low Power (ULP) Coprocessor” option must be enabled in menuconfig to reserve memory for the ULP. “RTC slow memory reserved for coprocessor” option must be set to a value sufficient 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 \texttt{ulp_app_name}):

\begin{verbatim}
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)));
}
\end{verbatim}

\begin{verbatim}
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):
1. MAGIC, (value 0x00706c75, 4 bytes)
2. TEXT_OFFSET, offset of .text section from binary start (2 bytes)
3. TEXT_SIZE, size of .text section (2 bytes)
4. DATA_SIZE, size of .data section (2 bytes)
5. BSS_SIZE, size of .bss section (2 bytes)
6. (TEXT_OFFSET - 12) bytes of arbitrary data (will not be loaded into RTC memory)
7. .text section
8. .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.

Return
• 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

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
\end{verbatim}

Once the program is loaded into RTC memory, the application can start it, passing the address of the entry point to the \texttt{ulp_run} function:

\begin{verbatim}
ESP_ERROR_CHECK( ulp_run(&ulp_entry - RTC_SLOW_MEM) );
\end{verbatim}

\begin{verbatim}
esp_err_t ulp_run(uint32_t entry_point)
Run the program loaded into RTC memory.
Return ESP_OK on success
Parameters
• entry_point: entry point, expressed in 32-bit words
\end{verbatim}
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 application, this symbol must be marked as .global:

```
.globl entry
entry:
    /* code starts here */
```

4.32 ULP-RISC-V Coprocessor programming

**Warning:** This feature is not supported in v4.4

The ULP-RISC-V coprocessor is a variant of the ULP, present in ESP32-S2. Similar to ULP, ULP RISC-V coprocessor can perform tasks such as sensor readings while the main CPU stays in low power modes. The main difference from the FSM ULP is this variant can be programmed in C using standard GNU tools. The ULP-RISC-V coprocessor can access the RTC_SLOW_MEM memory region, and registers in RTC_CNTL, RTC_IO, and SARADC peripherals. The RISC-V processor is a 32-bit, fixed point machine. Its instruction set is based on RV32IMC which includes hardware multiplication and division, and compressed code.

4.32.1 Installing the ULP-RISC-V Toolchain

The ULP-RISC-V coprocessor code is written in C (assembly is also possible) and compiled using RISC-V toolchain based on GCC.

If you have already set up ESP-IDF with CMake build system according to the Getting Started Guide, then the toolchain should already be installed.

4.32.2 Compiling the ULP-RISC-V Code

To compile the ULP-RISC-V code as part of the component, the following steps must be taken:

1. The ULP-RISC-V code, written in C or assembly (must use the .S extension), must be placed into a separate directory inside the component directory, for instance ulp/.

2. Call \texttt{ulp_embed_binary} from the component CMakeLists.txt after registration. For example:

   ```
   ... 
   idf_component_register()
   set(ulp_app_name ulp_${COMPONENT_NAME})
   set(ulp_sources "ulp/ulp_c_source_file.c" "ulp/ulp_assembly_source_file.S")
   set(ulp_exp_dep_srcs "ulp_c_source_file.c")
   ulp_embed_binary(ulp_app_name "ulp_sources" "ulp_exp_dep_srcs")
   ```

   The first argument to \texttt{ulp_embed_binary} specifies the ULP 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 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 section below for the concept of generated header files for ULP applications.

3. Build the application as usual (e.g. \texttt{idf.py app})

   Inside, the build system will take the following steps to build ULP program:
   1. **Run each source file through the C compiler and assembler.** This step generates the object files (.obj.c or .obj.S depending of source file processed) in the component build directory.
2. **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 `riscv32-elf-nm`.

7. **Create an LD export script and 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.

### 4.32.3 Accessing the ULP-RISC-V Program Variables

Global symbols defined in the ULP-RISC-V program may be used inside the main program.

For example, the ULP-RISC-V 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
volatile int measurement_count;

int some_function()
{
    // read the measurement count for use it later.
    int temp = measurement_count;
    ...
    do something.
}
```

The main program can access the global ULP-RISC-V program variables, 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_`.

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:

```c
PROVIDE ( ulp_measurement_count = 0x50000060 );
```

To access the ULP-RISC-V 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"

void init_ulp_vars() {
    ulp_measurement_count = 64;
}
```

### 4.32.4 Starting the ULP-RISC-V Program

To run a ULP-RISC-V program, the main application needs to load the ULP program into RTC memory using the `ulp_riscv_load_binary()` function, and then start it using the `ulp_riscv_run()` function.
Note that `CONFIG_ULP_COPROC_ENABLED` and `CONFIG_ULP_COPROC_TYPE_RISCV` options must be enabled in menuconfig to reserve memory for the ULP. “RTC slow memory reserved for coprocessor” option must be set to a value sufficient 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-RISC-V 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_riscv_load_binary( bin_start, (bin_end - bin_start)) );
}
```

`esp_err_t ulp_riscv_load_binary(const uint8_t *program_binary, size_t program_size_bytes)`  
Load ULP-RISC-V program binary into RTC memory.

Different than ULP FSM, the binary program has no special format, it is the ELF file generated by RISC-V toolchain converted to binary format using objcopy.

Linker script in components/ulp/ld/ulp_riscv.ld produces ELF files which correspond to this format. This linker script produces binaries with load_addr == 0.

**Return**
- ESP_OK on success
- ESP_ERR_INVALID_SIZE if program_size_bytes is more than 8KiB

**Parameters**
- program_binary: pointer to program binary
- program_size_bytes: size of the program binary

Once the program is loaded into RTC memory, the application can start it, calling the `ulp_riscv_run()` function

```c
ESP_ERROR_CHECK( ulp_riscv_run() );
```

`esp_err_t ulp_riscv_run(void)`  
Run the program loaded into RTC memory.

**Return** ESP_OK on success

### 4.32.5 ULP-RISC-V Program Flow

The ULP-RISC-V coprocessor is started by a timer. The timer is started once `ulp_riscv_run()` is called. The timer counts the number of RTC_SLOW_CLK ticks (by default, produced by an internal 150kHz RC oscillator). The number of ticks is set using `RTC_CNTL_ULP_CP_TIMER_1_REG` register. When starting the ULP, `RTC_CNTL_ULP_CP_TIMER_1_REG` will be used to set the number of timer ticks.

The application can set ULP timer period values (RTC_CNTL_ULP_CP_TIMER_1_REG) using the `ulp_set_wakeup_period()` function.

Once the timer counts the number of ticks set in the `RTC_CNTL_ULP_CP_TIMER_1_REG` register, the ULP coprocessor will power up and start running the program from the entry point set in the call to `ulp_riscv_run()`.

The program runs until the field `RTC_CNTL_COCPU_DONE` in register `RTC_CNTL_COCPU_CTRL_REG` gets written or when a trap occurs due to illegal processor state. Once the program halts, the ULP coprocessor will power down, and the timer will be started again.

To disable the timer (effectively preventing the ULP program from running again), please clear the `RTC_CNTL_ULP_CP_SLP_TIMER_EN` bit in the `RTC_CNTL_STATE0_REG` register. This can be done both from the ULP code and from the main program.
4.33 Unit Testing in ESP32-S3

ESP-IDF provides the following methods to test software.

- Target based tests using a central unit test application which runs on the esp32s3. These tests use the Unity (https://www.throwtheswitch.org/unity) unit test framework. They can be integrated into an ESP-IDF component by placing them in the component’s test subdirectory. For the most part, this document is about target based tests.
- Linux-host based unit tests in which all the hardware is abstracted via mocks. Linux-host based tests are still under development and only a small fraction of IDF components support them, currently. They are covered here: target based unit testing.

4.33.1 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:

```cmake
idf_component_register(SRC_DIRS "."
                       INCLUDE_DIRS "."
                       REQUIRES unity)
```

See http://www.throwtheswitch.org/unity for more information about writing tests in Unity.

4.33.2 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 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:
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.

### 4.33.3 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:

```
static void trigger_deepsleep(void)
{
    esp_sleep_enable_timer_wakeup(2000);
    esp_deep_sleep_start();
}
```
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(continued from previous page)

```c
void check_deepsleep_reset_reason()
{
  soc_reset_reason_t reason = esp_rom_get_reset_reason(0);
  TEST_ASSERT(reason == RESET_REASON_CORE_DEEP_SLEEP);
}
```

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.

### 4.33.4 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 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.

4.33.5 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.

4.33.6 Running Unit Tests

After flashing reset the ESP32-S3 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:

Here’s the test menu, pick your combo:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>&quot;esp_ota_begin() verifies arguments&quot; [ota]</td>
</tr>
<tr>
<td>(2)</td>
<td>&quot;esp_ota_get_next_update_partition logic&quot; [ota]</td>
</tr>
<tr>
<td>(3)</td>
<td>&quot;Verify bootloader image in flash&quot; [bootloader_support]</td>
</tr>
<tr>
<td>(4)</td>
<td>&quot;Verify unit test app image&quot; [bootloader_support]</td>
</tr>
<tr>
<td>(5)</td>
<td>&quot;can use new and delete&quot; [cxx]</td>
</tr>
<tr>
<td>(6)</td>
<td>&quot;can call virtual functions&quot; [cxx]</td>
</tr>
<tr>
<td>(7)</td>
<td>&quot;can use static initializers for non-POD types&quot; [cxx]</td>
</tr>
<tr>
<td>(8)</td>
<td>&quot;can use std::vector&quot; [cxx]</td>
</tr>
<tr>
<td>(9)</td>
<td>&quot;static initialization guards work as expected&quot; [cxx]</td>
</tr>
<tr>
<td>(10)</td>
<td>&quot;global initializers work in the correct order&quot; [cxx]</td>
</tr>
<tr>
<td>(11)</td>
<td>&quot;before scheduler has started, static initializers work correctly&quot; [cxx]</td>
</tr>
<tr>
<td>(12)</td>
<td>&quot;adc2 work with wifi&quot; [adc]</td>
</tr>
<tr>
<td>(13)</td>
<td>&quot;gpio master/slave test example&quot; [ignore][misc][test_env=UT_T2_1][multi_→device]</td>
</tr>
</tbody>
</table>

(continues on next page)
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 multiple devices or multiple stages of test case. These tags are automatically added by `TEST_CASE_MULTIPLE_STAGES` and `TEST_CASE_MULTIPLE_DEVICES` 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.

### 4.33.7 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).

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 tech-
nique 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.

### 4.33.8 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 mockable. This will also include mocking when running on the ESP32-S3.

One of the biggest problems regarding unit testing of embedded systems are the strong hardware dependencies. Running unit tests directly on the ESP32-S3 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), software mocking allows the dependencies of the component under test to be substituted (i.e., mocked) entirely in software. To allow software mocking, ESP-IDF integrates the CMock mocking framework as a component. With the addition of some CMake functions in the ESP-IDF’s 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 tests 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 common knowledge that unit tests often 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.
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Requirements

The following requirements are necessary to generate the mocks:

- Installed ESP-IDF with all its requirements
- ruby
- On the Linux target, which is the only target where mocking currently works, libbsd is required, too

Mock a Component

To create a mock version of a component, called 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 let the build system discover it later than the original component (see Multiple components with the same name <cmake-components-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`:

```cmake
idf_component_get_property(original_component_dir <original-component-name> _
 -->COMPONENT_OVERRIDEN_DIR)
...
idf_component_mock(INCLUDE_DIRS "${original_component_dir}/include"
 REQUIRES freertos
 MOCK_HEADER_FILES ${original_component_dir}/include/header_containing_
 -->functions_to_mock.h)
```

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/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 under the section “Multiple components with the same name” in the IDF build system documentation.

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:
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 should 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.

### 4.34 Unit Testing on Linux

**Note:** Host testing with IDF is experimental for now. We try our best to keep interfaces stable but can’t guarantee it for now. Feedback via github or the forum on esp32.com is highly welcome, though and may influence the future design of the host-based tests.

This article provides an overview of unit tests with IDF on Linux. For using unit tests on the target, please refer to target based unit testing.

#### 4.34.1 Embedded Software Tests

Embedded software tests are challenging due to the following factors:

- Difficulties running tests efficiently.
- Lack of many operating system abstractions when interfacing with hardware, making it difficult to isolate code under test.

To solve these two problems, Linux host-based tests with CMock are introduced. Linux host-based tests are more efficient than unit tests on the target since they:

- Compile the necessary code only
- Don’t need time to upload to a target
- Run much faster on a host-computer, compared to an ESP

Using the CMock framework also solves the problem of hardware dependencies. Through mocking, hardware details are emulated and specified at run time, but only if necessary.

Of course, using code on the host and using mocks does not fully represent the target device. Thus, two kinds of tests are recommended:

1. Unit tests which test program logic on a Linux machine, isolated through mocks.
2. System/Integration tests which test the interaction of components and the whole system. They run on the target, where irrelevant components and code may as well be emulated via mocks.

This documentation is about the first kind of tests. Refer to target based unit testing for more information on target tests (the second kind of tests).

#### 4.34.2 IDF Unit Tests on Linux Host

The current focus of the Linux host tests is on creating isolated unit tests of components, while mocking the component’s dependencies with CMock.

A complete implementation of IDF to run on Linux does not exist currently.

There are currently two examples for running IDF-built code on Linux host:

- An example hello-world application
- A unit test for NVS.

Inside the component which should be tested, there is a separate directory host_test, besides the “traditional” test directory or the test_apps directory. It has one or more subdirectories:
Chapter 4. API Guides

- host_test/
  - fixtures/
    contains test fixtures (structs/functions to do test case set-up and tear-down).
    If there are no fixtures, this can be omitted.
  - <test_name>/
    IDF applications which run the tests
  - <test_name2>/
    Further tests are possible.

The IDF applications inside host_test set the mocking configuration as described in the IDF unit test documentation.

The NVS page unit test provides some illustration of how to control the mocks.

Requirements

- Installed IDF including all IDF requirements
- CMock requirements (Ruby)
- libbsd

The host tests have been tested on Ubuntu 20.04 with GCC version 9 and 10.

4.35 USB OTG Console

On chips with an integrated USB peripheral, it is possible to use USB Communication Device Class (CDC) to implement the serial console, instead of using UART with an external USB-UART bridge chip. ESP32-S3 ROM code contains a USB CDC implementation, which supports for some basic functionality without requiring the application to include the USB stack:

- Bidirectional serial console, which can be used with IDF Monitor or another serial monitor
- Flashing using esptool.py and idf.py flash.
- Device Firmware Update (DFU) interface for flashing the device using dfu-util and idf.py dfu.

Note: At the moment, this “USB Console” feature is incompatible with TinyUSB stack. However, if TinyUSB is used, it can provide its own CDC implementation.

4.35.1 Hardware Requirements

Connect ESP32-S3 to the USB port as follows

<table>
<thead>
<tr>
<th>GPIO</th>
<th>USB</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>D+ (green)</td>
</tr>
<tr>
<td>19</td>
<td>D- (white)</td>
</tr>
<tr>
<td>GND</td>
<td>GND (black)</td>
</tr>
<tr>
<td></td>
<td>+5V (red)</td>
</tr>
</tbody>
</table>

Some development boards may offer a USB connector for the internal USB peripheral—in that case, no extra connections are required.

By default, USB_SERIAL_JTAG module is connected to the internal PHY of the ESP32-S3, while USB_OTG peripheral can be used only if the external USB PHY is connected. Since CDC console is provided via USB_OTG peripheral, it cannot be used through the internal PHY in this configuration.
You can permanently switch the internal USB PHY to work with USB_OTG peripheral instead of USB_SERIAL_JTAG by burning USB_PHY_SEL eFuse. See ESP32-S3 Technical Reference Manual for more details about USB_SERIAL_JTAG and USB_OTG.

Note however that USB_SERIAL_JTAG also provides a CDC console, so enabling the CDC console shouldn’t be the primary reason for switching from USB_SERIAL_JTAG to USB_CDC.

### 4.35.2 Software Configuration

USB console feature can be enabled using CONFIG_ESP_CONSOLEDUSB_CDC option in menuconfig tool (see CONFIG_ESP_CONSOLE_UART).

Once the option is enabled, build the project as usual.

### 4.35.3 Uploading the Application

**Initial Upload**

If the ESP32-S3 is not yet flashed with a program which enables USB console, we can not use idf.py flash command with the USB CDC port. There are 3 alternative options to perform the initial upload listed below.

Once the initial upload is done, the application will start up and a USB CDC port will appear in the system.

**Note:** The port name may change after the initial upload, so check the port list again before running idf.py monitor.

**Initial upload using the ROM download mode, over USB CDC**

- Press ESP32-S3 into download mode. To do this, keep GPIO0 low while toggling reset. On many development boards, the “Boot” button is connected to GPIO0, and you can press “Reset” button while holding “Boot”.
- A serial port will appear in the system. On most operating systems (Windows 8 and later, Linux, macOS) driver installation is not required. Find the port name using Device Manager (Windows) or by listing /dev/ttyACM* devices on Linux or /dev/cu* devices on macOS.
- Run idf.py flash -p PORT to upload the application, with PORT determined in the previous step

**Initial upload using the ROM download mode, over USB DFU**

- Press ESP32-S3 into download mode. To do this, keep GPIO0 low while toggling reset. On many development boards, the “Boot” button is connected to GPIO0, and you can press “Reset” button while holding “Boot”.
- Run idf.py dfu-flash.

See Flashing the Chip with the DFU Image for details about DFU flashing.

**Initial upload using UART** On development boards with a USB-UART bridge, upload the application over UART: idf.py flash -p PORT where PORT is the name of the serial port provided by the USB-UART bridge.

**Subsequent Usage**

Once the application is uploaded for the first time, you can run idf.py flash and idf.py monitor as usual.
4.35.4 Limitations

There are several limitations to the USB console feature. These may or may not be significant, depending on the type of application being developed, and the development workflow. Most of these limitations stem from the fact that USB CDC is implemented in software, so the console working over USB CDC is more fragile and complex than a console working over UART.

1. If the application crashes, panic handler output may not be sent over USB CDC in some cases. If the memory used by the CDC driver is corrupted, or there is some other system-level issue, CDC may not work for sending panic handler messages over USB. This does work in many situations, but is not guaranteed to work as reliably as the UART output does. Similarly, if the application enters a boot loop before the USB CDC driver has a chance to start up, there will be no console output.

2. If the application accidentally reconfigures the USB peripheral pins, or disables the USB peripheral, USB CDC device will disappear from the system. After fixing the issue in the application, you will need to follow the Initial Upload process to flash the application again.

3. If the application enters light sleep (including automatic light sleep) or deep sleep mode, USB CDC device will disappear from the system.

4. USB CDC driver reserves some amount of RAM and increases application code size. Keep this in mind if trying to optimize application memory usage.

5. By default, the low-level \texttt{esp\_rom\_printf} feature and \texttt{ESP\_EARLY\_LOG} are disabled when USB CDC is used. These can be enabled using \texttt{CONFIG\_ESP\_CONSOLE\_USB\_CDC\_SUPPORT\_ETS\_PRINTF} option. With this option enabled, \texttt{esp\_rom\_printf} can be used, at the expense of increased IRAM usage. Keep in mind that the cost of \texttt{esp\_rom\_printf} and \texttt{ESP\_EARLY\_LOG} over USB CDC is significantly higher than over UART. This makes these logging mechanisms much less suitable for “printf debugging”, especially in the interrupt handlers.

6. If you are developing an application which uses the USB peripheral with the TinyUSB stack, this USB Console feature can not be used. This is mainly due to the following reasons:
   \begin{itemize}
   \item This feature relies on a different USB CDC software stack in ESP32-S3 ROM.
   \item USB descriptors used by the ROM CDC stack may be different from the descriptors used by TinyUSB.
   \item When developing applications which use USB peripheral, it is very likely that USB functionality will not work or will not fully work at some moments during development. This can be due to misconfigured USB descriptors, errors in the USB stack usage, or other reasons. In this case, using the UART console for flashing and monitoring provides a much better development experience.
   \end{itemize}

7. When debugging the application using JTAG, USB CDC may stop working if the CPU is stopped on a breakpoint. USB CDC operation relies on interrupts from the USB peripheral being serviced periodically. If the host computer doesn’t receive valid responses from the USB device side for some time, it may decide to disconnect the device. The actual time depends on the OS and the driver, and ranges from a few hundred milliseconds to a few seconds.

4.36 USB Serial/JTAG Controller Console

On chips with an integrated USB Serial/JTAG Controller, it is possible to use the part of this controller that implements a serial port (CDC) to implement the serial console, instead of using UART with an external USB-UART bridge chip. ESP32-S3 contains this controller, providing the following functions:

\begin{itemize}
   \item Bidirectional serial console, which can be used with \texttt{IDF Monitor} or another serial monitor.
   \item Flashing using \texttt{esptool.py} and \texttt{idf.py flash}.
   \item JTAG debugging using e.g. OpenOCD, simultaneous with serial operations.
\end{itemize}

Note that, in contrast with the USB OTG peripheral in some Espressif chips, the USB Serial/JTAG Controller is a fixed function device, implemented entirely in hardware. This means it cannot be reconfigured to perform any function other than to provide a serial channel and JTAG debugging functionality.

4.36.1 Hardware Requirements

Connect ESP32-S3 to the USB port as follows:
Some development boards may offer a USB connector for the USB Serial/JTAG Controller — in that case, no extra connections are required.

### 4.36.2 Software Configuration

USB console feature can be enabled using `CONFIG_ESP_CONSOLE_USB_SERIAL_JTAG` option in menuconfig tool (see `CONFIG_ESP_CONSOLE_UART`).

Once the option is enabled, build the project as usual.

Alternatively, you can access the output through `usb_serial_jtag` port but make sure the option `CONFIG_ESP_CONSOLE_SECONDARY_USB_SERIAL_JTAG` in choice `ESP_CONSOLE_SECONDARY` is selected.

**Warning:** Besides output, if you also want to input or use REPL with console, please select `CONFIG_ESP_CONSOLE_USB_SERIAL_JTAG`.

### 4.36.3 Uploading the Application

The USB Serial/JTAG Controller is able to put the ESP32-S3 into download mode automatically. Simply flash as usual, but specify the USB Serial/JTAG Controller port on your system: `idf.py flash -p PORT` where `PORT` is the name of the proper port.

### 4.36.4 Limitations

There are several limitations to the USB console feature. These may or may not be significant, depending on the type of application being developed, and the development workflow.

1. If the application accidentally reconfigures the USB peripheral pins, or disables the USB Serial/JTAG Controller, the device will disappear from the system. After fixing the issue in the application, you will need to manually put the ESP32-S3 into download mode by pulling low GPIO0 and resetting the chip.
2. If the application enters deep sleep mode, USB CDC device will disappear from the system.
3. The behavior between an actual USB-to-serial bridge chip and the USB Serial/JTAG Controller is slightly different if the ESP-IDF application does not listen for incoming bytes. An USB-to-serial bridge chip will just send the bytes to a (not listening) chip, while the USB Serial/JTAG Controller will block until the application reads the bytes. This can lead to a non-responsive looking terminal program.
4. If the application enters light-sleep (including automatic light-sleep) or software reset, etc. The USB CDC device will still work on the system. But be aware that this might increase the power consumption, if you don’t need USB CDC in sleep and want to keep low power consumption, please disable the menuconfig `CONFIG_RTC_CLOCK_BBPLL_POWER_ON_WITH_USB`. Moreover, the power consumption will only increase when your USB CDC port is really in use (like data transaction), therefore, if your USB CDC just connects with power bank or battery, rather than something like computer, you don’t need to care about the increasing power consumption mentioned above.

### 4.37 Wi-Fi Driver
4.37.1 ESP32-S3 Wi-Fi Feature List

- Support station-only mode, AP-only mode, station/AP-coexistence mode
- Support IEEE 802.11b, IEEE 802.11g, IEEE 802.11n and APIs to configure the protocol mode
- Support WPA/WPA2/WPA3/WPA2-Enterprise and WPS
- Support AMPDU, HT40, QoS and other key features
- Support Modem-sleep
- Support 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
- Support Sniffer
- Support both fast scan and all-channel scan
- Support multiple antennas
- Support channel state information

4.37.2 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-S3 Wi-Fi station General Scenario, ESP32-S3 Wi-Fi AP General Scenario.

Start/Connect Wi-Fi

Refer to ESP32-S3 Wi-Fi station General Scenario, ESP32-S3 Wi-Fi AP General Scenario.

Event-Handling

Generally, it is easy to write code in “sunny-day” scenarios, such as WIFI_EVENT_STA_START, WIFI_EVENT_STA_CONNECTED etc. The hard part is to write routines in “rainy-day” scenarios, such as WIFI_EVENT_STA_DISCONNECTED etc. Good handling of “rainy-day” scenarios is fundamental to robust Wi-Fi applications. Refer to ESP32-S3 Wi-Fi Event Description, ESP32-S3 Wi-Fi station General Scenario, ESP32-S3 Wi-Fi AP General Scenario. See also an overview of event handling 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-S3 Wi-Fi API Error Code.
4.37.3 ESP32-S3 Wi-Fi API Error Code

All of the ESP32-S3 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, etc.
- 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, 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_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, we strongly recommend that API users write their own error-handling code.

4.37.4 ESP32-S3 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 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 IDF is updated to a new release.

4.37.5 ESP32-S3 Wi-Fi Programming Model

The ESP32-S3 Wi-Fi programming model is depicted as follows:

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, event task, etc. 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).

4.37.6 ESP32-S3 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-S3 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, authentication times out, etc. If there are more than one AP with the same SSID, the disconnected event is 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, the AP’s authentication mode is changed, etc.

Upon receiving this event, the default behavior of the event task is:

- shuts down the station’s LwIP netif.
- Notifies 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’s application’s responsibility to distinguish whether the event is caused by `esp_wifi_disconnect()` or other reasons. Sometimes a better reconnect strategy is required, refer to [Wi-Fi Reconnect and Scan When Wi-Fi Is Connecting](#).

Another thing deserves our attention is that the default behavior of LwIP is to abort all TCP socket connections on receiving the disconnect. Most of the time it is not a problem. However, for some special application, this may not be what they want, consider 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 NOT care about 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 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-S3, or when this address changes. The event means that everything is ready and the application can begin its tasks (e.g., creating sockets).

IP_STA_LOST_IP

This event arises when the IPv4 address become invalid.

IP_STA_LOST_IP doesn’t 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 doesn’t happen. Otherwise, the event arises when IPv4 address lost timer expires.

Generally the application don’t need to care about this event, it is just a debug event to let the application know 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-S3 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, etc.

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, etc. 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, etc.

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.

4.37.7 ESP32-S3 Wi-Fi Station General Scenario

Below is a “big scenario” which describes some small scenarios in station mode:
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Fig. 55: Sample Wi-Fi Event Scenarios in Station Mode

Espressif Systems

1919  Release v5.0-dev-1648-g94089edbc3
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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 initializations 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, country code, bandwidth, etc. Refer to ESP32-S3 Wi-Fi Configuration.

Generally, we configure the Wi-Fi driver before setting up the Wi-Fi connection, 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.

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, etc.

In step 4.2, the Wi-Fi connection may fail because, for example, the password is wrong, the AP is not found, etc. 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, etc. 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. because the AP is powered off, the RSSI is poor, etc., 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. We recommend that esp_wifi_connect() be called to reconnect the Wi-Fi, close all sockets and re-create them if necessary. 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.

4.37.8 ESP32-S3 Wi-Fi AP General Scenario

Below is a “big scenario” which describes some small scenarios in AP mode:

4.37.9 ESP32-S3 Wi-Fi Scan

Currently, the esp_wifi_scan_start() API is supported only in station or station/AP mode.
Fig. 56: Sample Wi-Fi Event Scenarios in AP Mode
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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 scan_type field of wifi_scan_config_t.</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 wifi_scan_config_t is set to 0, it is an all-channel scan.</td>
</tr>
<tr>
<td>Specific Channel Scan</td>
<td>It scans specific channels only. If the channel field of wifi_scan_config_t 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 we totally have 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.

<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>
<tr>
<td>scan_time</td>
<td>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.</td>
</tr>
</tbody>
</table>
  - 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 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:

Fig. 57: Foreground Scan of all Wi-Fi Channels

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 case the scan type is WIFI_SCAN_TYPE_ACTIVE, and broadcasts a probe request. 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 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.
- s3.2: The application’s event callback function notifies the application task that `WIFI_EVENT_SCAN_DONE` is received. `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 `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 `esp_wifi_scan_get_ap_records()` is called. Do not call `esp_wifi_scan_get_ap_records()` twice for a single scan-done event. If `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 `esp_wifi_scan_get_ap_records()`, yet only once.

**Scan All APs on All Channels (Background)**

Scenario:
The scenario above is an all-channel background scan. Compared to 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.

**Scan for Specific AP on All Channels**

Scenario:
This scan is similar to 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 ~ 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 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.

If there are multiple APs which match the target AP info, for example, if we happen to scan two APs whose SSID is “ap”. If the scan is WIFI_FAST_SCAN, then only the first scanned “ap” will be found, if the scan is WIFI_ALL_CHANNEL_SCAN, both “ap” will be found and the station will connect the “ap” according to the configured strategy, refer to Station Basic Configuration.

You can scan a specific AP, or all of them, in any given channel. These two scenarios are very similar.

**Scan in Wi-Fi Connect**

When `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 Scan for Specific AP On All Channels, except that no scan-done event will be generated
Fig. 58: Background Scan of all Wi-Fi Channels
Fig. 59: Scan of specific Wi-Fi Channels
when the scan is completed. If the target AP is found, the Wi-Fi driver will start the Wi-Fi connection; otherwise, 
\texttt{WIFI\_EVENT\_STA\_DISCONNECTED} will be generated. Refer to \textit{Scan for Specific AP On All Channels}.

\section*{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.

\section*{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. \textbf{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-S3’s Wi-Fi functionality 
 improves continuously.

\section*{Scan When Wi-Fi is Connecting}

The \texttt{esp\_wifi\_scan\_start()} fails immediately if the Wi-Fi is in connecting process because the connecting 
has higher priority than the scan. If scan fails because of connecting, the recommended strategy is to delay sometime 
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 following scenario:

- The station is connecting a non-existed AP or if the station connects the existed AP with a wrong password, it 
  always raises the event \texttt{WIFI\_EVENT\_STA\_DISCONNECTED}.
- The application call \texttt{esp\_wifi\_connect()} to do reconnection on receiving the disconnect event.
- Another application task, e.g. the console task, call \texttt{esp\_wifi\_scan\_start()} to do scan, the scan always 
  fails immediately because the station is keeping connecting.
- When scan fails, the application simply delay sometime and retry the scan.

In above scenario the scan will never succeed because the connecting is in process. So if the application supports 
similar scenario, it needs to implement a better reconnect strategy. E.g.

- The application can choose to define a maximum continuous reconnect counter, stop reconnect once the re-
  connect reaches the max counter.
- The application can choose to do reconnect immediately in the first N continuous reconnect, then give a delay 
  sometime and reconnect again.

The application can define its own reconnect strategy to avoid the scan starve to death. Refer to \textit{Wi-Fi Reconnect}.

\section*{ESP32-S3 Wi-Fi Station Connecting Scenario}

This scenario only depicts the case when there is only one target AP are found in scan phase, for the scenario that 
more than one AP with the same SSID are found, refer to \textit{ESP32-S3 Wi-Fi Station Connecting When Multiple APs 
Are Found}.

Generally, the application does not need to care about the connecting process. Below is a brief introduction to the 
process for those who are really interested.

Scenario:

\section*{Scan Phase}

- s1.1. The Wi-Fi driver begins scanning in “Wi-Fi Connect”. Refer to \textit{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 WIFI\_REASON\_NO\_AP\_FOUND. Refer to \textit{Wi-Fi Reason Code}. 
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Fig. 60: 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
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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, WIFI_EVENT_STA_DISCONNECTED will arise and the reason-code will be 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 WIFI_EVENT_STA_DISCONNECTED arises, while the reason-code is 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, WIFI_EVENT_STA_DISCONNECTED will arise and the reason-code will be WIFI_REASON_ASSOC_EXPIRE. Refer to Wi-Fi Reason Code.
- 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, 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-S3. The first column is the macro name defined in esp_wifi_types.h. The common prefix WIFI_REASON is removed, which means that 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 8.4.1.7 of IEEE 802.11-2012. (For more information, refer to the standard mentioned above.) The last column is a description of the reason.

<table>
<thead>
<tr>
<th>Reason Code</th>
<th>Value</th>
<th>Standard Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIFI_REASON_UNSPECIFIED</td>
<td>0x0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_DEFAULT</td>
<td>0x0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_ASSOC</td>
<td>0x0002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_ASSOC_FAIL</td>
<td>0x0003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_ASSOC_TIMEOUT</td>
<td>0x0004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_AUTH</td>
<td>0x0005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_AUTH_FAIL</td>
<td>0x0006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_AUTH_TIMEOUT</td>
<td>0x0007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_DISCONNECT</td>
<td>0x0008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_HANDSHAKE_TIMEOUT</td>
<td>0x0009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_REASON_UNSPECIFIED</td>
<td>0x0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reason Code</td>
<td>Value</td>
<td>Mapped To</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>-------</td>
<td>-----------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>UNSPECIFIED</td>
<td>1</td>
<td></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, etc.</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: • auth is timed out. • the reason is received from the AP. For the ESP AP, this reason is reported when: • the AP has not received any packets from the station in the past five minutes. • the AP is stopped by calling esp_wifi_stop(). • the station is de-authed by calling esp_wifi_deauth_sta().</td>
</tr>
<tr>
<td>AUTH_BEADE</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: • it is received from the AP.</td>
</tr>
<tr>
<td>ASSOC_EXPIRE</td>
<td>4</td>
<td></td>
<td>Disassociated due to inactivity. 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 has not received any packets from the station in the past five minutes. • the AP is stopped by calling esp_wifi_stop(). • the station is de-authed by calling esp_wifi_deauth_sta().</td>
</tr>
<tr>
<td>ASSOC_STOOMANY</td>
<td>5</td>
<td></td>
<td>Disassociated, because the AP is unable to handle all currently associated STAs at the same time. 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 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></td>
<td>Class-2 frame received from a non-authenticated STA. 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 receives a packet with data from a non-authenticated station.</td>
</tr>
<tr>
<td>NOT_ASSOCED</td>
<td>7</td>
<td></td>
<td>Class-3 frame received from a non-associated STA. 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 receives a packet with data from a non-associated station.</td>
</tr>
<tr>
<td>ASSOC_LEAVE</td>
<td>8</td>
<td></td>
<td>Disassociated, because the sending station is leaving (or has left) BSS. For the ESP station, this reason is reported when: • it is received from the AP. • the station is disconnected by esp_wifi_disconnect() and other APIs.</td>
</tr>
<tr>
<td>ASSOC_NOT_AUTHED</td>
<td>9</td>
<td></td>
<td>The station is not authenticated by the responding STA. For the ESP station, this reason is reported when: • the station is not associated with the AP.</td>
</tr>
<tr>
<td>INVALID_RSN_IE_CAP</td>
<td>10</td>
<td></td>
<td>The invalid RSN IE is received from the AP.</td>
</tr>
<tr>
<td>PRPW_CAP_BAD</td>
<td>11</td>
<td></td>
<td>The information in the Power Capability element is invalid.</td>
</tr>
<tr>
<td>DISASSOC_PWRCAP_BAD</td>
<td>12</td>
<td></td>
<td>The information in the Power Capability element is invalid.</td>
</tr>
<tr>
<td>IE_IN_4WAY_DIFFERS</td>
<td>13</td>
<td></td>
<td>The four-way handshake IE differs.</td>
</tr>
<tr>
<td>HANDSHAKE_TIMEOUT</td>
<td>14</td>
<td></td>
<td>The previous authentication is no longer valid. The reason is received from the AP.</td>
</tr>
<tr>
<td>ASSOC_NOT_AUTHED</td>
<td>15</td>
<td></td>
<td>The reason is received from the AP.</td>
</tr>
<tr>
<td>ASSOC_EXPIRE</td>
<td>16</td>
<td></td>
<td>The previous authentication is no longer valid. The reason is received from the AP.</td>
</tr>
<tr>
<td>INVALID_RSN_IE_CAP</td>
<td>17</td>
<td></td>
<td>The invalid RSN IE is received from the AP.</td>
</tr>
<tr>
<td>DISASSOC сделать</td>
<td>18</td>
<td></td>
<td>The reason is received from the AP.</td>
</tr>
<tr>
<td>GROUP_CIPHER_INVALID</td>
<td>19</td>
<td></td>
<td>The invalid group cipher is received from the AP.</td>
</tr>
<tr>
<td>DISASSOC_PWRCAP_BAD</td>
<td>20</td>
<td></td>
<td>The invalid Power Capability IE is received from the AP.</td>
</tr>
<tr>
<td>ASSOC_EXPIRE</td>
<td>21</td>
<td></td>
<td>The previous authentication is no longer valid. The reason is received from the AP.</td>
</tr>
<tr>
<td>AUTH_EXPIRE</td>
<td>22</td>
<td></td>
<td>The previous authentication is no longer valid. The reason is received from the AP.</td>
</tr>
<tr>
<td>HANDSHAKE_TIMEOUT</td>
<td>23</td>
<td></td>
<td>The previous authentication is no longer valid. The reason is received from the AP.</td>
</tr>
</tbody>
</table>

Note: The table above lists various reason codes and their corresponding descriptions. Each reason code is associated with a specific event or condition that triggers the authentication failure or disassociation from an ESP station or AP.
4.37.11 ESP32-S3 Wi-Fi Station Connecting When Multiple APs Are Found

This scenario is similar to ESP32-S3 Wi-Fi Station Connecting Scenario, the difference is the station will not raise the event WiFi_EVENT_STA_DISCONNECTED unless it fails to connect all of the found APs.

4.37.12 Wi-Fi Reconnect

The station may disconnect due to many reasons, e.g. the connected AP is restarted etc. It’s the application’s responsibility to do the reconnect. The recommended reconnect strategy is to call esp_wifi_connect() on receiving event WIFI_EVENT_STA_DISCONNECTED.

Sometimes the application needs more complex reconnect strategy:

- If the disconnect event is raised because the esp_wifi_disconnect() is called, the application may not want to do reconnect.
- If the esp_wifi_scan_start() may be called at anytime, a better reconnect strategy is necessary, refer to Scan When Wi-Fi is Connecting.

Another thing we need to consider is the reconnect may not connect the same AP if there are more than one APs with the same SSID. The reconnect always select current best APs to connect.

4.37.13 Wi-Fi Beacon Timeout

The beacon timeout mechanism is used by ESP32-S3 station to detect whether the AP is alive or not. If the station continuously loses 60 beacons of the connected AP, the beacon timeout happens.

After the beacon timeout happens, the station sends 5 probe requests to AP, it disconnects the AP and raises the event WiFi_EVENT_STA_DISCONNECTED if still no probe response or beacon is received from AP.

4.37.14 ESP32-S3 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 `esp_wifi_set_mode()` to set the Wi-Fi mode.

<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 esp_wifi_deinit() to unload the whole Wi-Fi driver.</td>
</tr>
<tr>
<td>WIFI_MODE_STA</td>
<td>Station mode: in this mode, esp_wifi_start() will init the internal station data, while the station’s interface is ready for the RX and TX Wi-Fi data. After esp_wifi_connect(), the station will connect to the target AP.</td>
</tr>
<tr>
<td>WIFI_MODE_AP</td>
<td>AP mode: in this mode, esp_wifi_start() 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_APB</td>
<td>Station/AP coexistence mode: in this mode, esp_wifi_start() will simultaneously init 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. 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 to.</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 bssid_set 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 bssid_set 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 others to find the target AP. 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 sort_method is WIFI_CONNECT_AP_BY_SIGNAL, all matched APs are sorted by signal, for AP with best signal will be connected firstly. E.g. if the station want to connect AP whose ssid is “apxx”, the scan finds two AP whose ssid equals to “apxx”, the first AP’s signal is -90 dBm, the second AP’s signal is -30 dBm, the station connects the second AP firstly, it doesn’t connect the first one unless it fails to connect the second one. If the sort_method is WIFI_CONNECT_AP_BY_SECURITY, all matched APs are sorted by security. E.g. if the station wants to connect AP whose ssid is “apxx”, the scan finds two AP whose ssid is “apxx”, the security of the first found AP is open while the second one is WPA2, the stations connects to the second AP firstly, it doesn’t connect the second one unless it fails to connect the first 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 discard. If the RSSI set to 0, it means default threshold, the default RSSI threshold is -127 dBm. If the authmode threshold is set to 0, it means default threshold, the default authmode threshold is 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. The table below describes the fields in detail.
### Chapter 4. API Guides

<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 the channel 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 Wi-Fi 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>Currently, ESP Wi-Fi supports up to 10 Wi-Fi connections. If max_connection &gt; 10, AP defaults the value to 10.</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 IDF supports the following protocol modes:

<table>
<thead>
<tr>
<th>Protocol Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11b</td>
<td>Call esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_11B) to set the station/AP to 802.11b-only mode.</td>
</tr>
<tr>
<td>802.11bg</td>
<td>Call esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_11B</td>
</tr>
<tr>
<td>802.11bgn</td>
<td>Call esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_11B</td>
</tr>
<tr>
<td>802.11 BGNLR</td>
<td>Call esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_11B</td>
</tr>
<tr>
<td>802.11 LR</td>
<td>Call esp_wifi_set_protocol(ifx, WIFI_PROTOCOL_LR) to set the station/AP only to the Espressif-specific mode.</td>
</tr>
</tbody>
</table>

**This mode is an Espressif-patented mode which can achieve a one-kilometer line of sight range. Please, make sure both the station and the AP are connected to an ESP device.**

### Long Range (LR)

Long Range (LR) mode is an Espressif-patented Wi-Fi mode which can achieve a one-kilometer line of sight range. It has better reception sensitivity, stronger anti-interference ability and longer transmission distance than the traditional 802.11b mode.

**LR Compatibility** Since LR is Espressif unique Wi-Fi mode, only ESP32-S3 devices can transmit and receive the LR data. In other words, the ESP32-S3 device should NOT transmit the data in LR data rate if the connected device doesn’t support LR. The application can achieve this by configuring suitable Wi-Fi mode. If the negotiated mode supports LR, the ESP32-S3 may transmit data in LR rate, otherwise, ESP32-S3 will transmit all data in traditional Wi-Fi data rate.

Following table depicts the Wi-Fi mode negotiation:
In 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, we can conclude that:

- For LR enabled in ESP32-S3 AP, it’s incompatible with traditional 802.11 mode because the beacon is sent in LR mode.
- For LR enabled in ESP32-S3 station and the mode is NOT LR only mode, it’s compatible with traditional 802.11 mode.
- If both station and AP are ESP32-S3 devices and both of them enable LR mode, the negotiated mode supports LR.

If the negotiated Wi-Fi mode supports both traditional 802.11 mode and LR mode, it’s the Wi-Fi driver’s responsibility to automatically select the best data rate in different Wi-Fi mode and the application don’t need to care about 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 impact transmission in LR mode is similar as the impact in 802.11b mode.

**LR Transmission Distance**  The reception sensitivity of LR has about 4 dB gain than 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 Mbits and 1/4 Mbits.

**When to Use LR**  The general conditions for using LR are:

- Both the AP and station are devices.
- Long distance Wi-Fi connection and data transmission is required.
- Data throughput requirements are very small, such as remote device control, etc.
## 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>
</table>
| cc[3]  | Country code string, this attributes identify the country or noncountry entity in which the station/AP is operating. If it’s a country, the first two octets of this string is the two character country info as described in document ISO/IEC3166-1. The third octect is one of the following:  
  • an ASCII space character, if the regulations under which the station/AP is operating encompass all environments for the current frequency band in the country.  
  • an ASCII ‘O’ character if the regulations under which the station/AP is operating are for an outdoor environment only.  
  • an ASCII ‘I’ character if the regulations under which the station/AP is operating are for an indoor environment only.  
  • an ASCII ‘X’ character if the station/AP is operating under a noncountry entity. The first two octets of the noncountry entity is two ASCII ‘XX’ characters.  
  • the binary representation of the Operating Class table number currently in use. Refer to Annex E, IEEE Std 802.11-2012. |
| schan  | Start channel, it’s the minimum channel number of the regulations under which the station/AP can operate. |
| nchan  | Total number of channels as per the regulations, e.g. if the schan=1, nchan=13, it means the station/AP can send data from channel 1 to 13. |
| policy | Country policy, this field control which country info will be used if the configured country info is conflict with the connected AP’s. More description about policy is provided in following section. |

The default country info is `.cc=“ CN” , .schan=1 , .nchan=13 , 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 `.cc=“ JP” , .schan=1 , .nchan=14 , policy=WIFI_COUNTRY_POLICY_AUTO`, but the connected AP has country info `.cc=“ CN” , .schan=1 , .nchan=13`, then country info of connected AP’s is used.

Following table depicts which country info is used in different Wi-Fi Mode and different country policy, also describe the impact to active scan.
Wi-Fi Mode | Policy | Description
--- | --- | ---
Station | WIFI_COUNTRY_POLICY_AUTO | If the connected AP has country IE in its beacon, the country info equals to the country info in beacon, otherwise, use default country info.
For scan:
- If \( \text{schann+chann-1} > 11 \):
  Use active scan from \( \text{schann} \) to \( 11 \) and use passive scan from \( 12 \) to \( \text{schann+chann-1} \).
- If \( \text{schann+chann-1} \leq 11 \):
  Use active scan from \( \text{schann} \) to \( \text{schann+chann-1} \).
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.

Station | WIFI_COUNTRY_POLICY_MANUAL | Always use the configured country info. For scan, scans channel \( \text{schann} \) to \( \text{schann+nchann-1} \) with active scan.

AP | WIFI_COUNTRY_POLICY_AUTO | Always use the configured country info.

AP | WIFI_COUNTRY_POLICY_MANUAL | Always use the configured country info.

Station/AP-coexistence | WIFI_COUNTRY_POLICY_AUTO | If the station doesn’t connect to any external AP, the AP use the configured country info. If the station connects to an external AP, the AP has the same country info as the station. Same as station mode with policy WIFI_COUNTRY_POLICY_AUTO.

**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, if they are different, the station’s home channel is always in priority. Take the following as an example: 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 make sure that it has the same home channel as the station. While switching channel, the ESP32-S3 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 does not need to care about them. Some applications, however, 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-S3, `esp_wifi_set_vendor_ie()` and `esp_wifi_set_vendor_ie_cb()` are responsible for this kind of tasks.

4.37.15 **Wi-Fi Easy Connect™ (DPP)**

Wi-Fi Easy Connect™ (or Device Provisioning Protocol) is a secure and standardized provisioning protocol for configuration of Wi-Fi Devices. More information can be found on the API reference page `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 like TLS, TTLS, PEAP.
etc. RADIUS server authenticates the users based on their credentials (username and password), digital certificates or both. When ESP32-S3 in station mode tries to connect to 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_Earprise is supported by ESP32-S3 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-S3 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-S3 currently supports the following EAP methods:**
- **EAP-TLS:** This is certificate based method and only requires SSID and EAP-IDF.
- **PEAP:** This is Protected EAP method. Username and Password are mandatory.
- **EAP-TTLS:** This is credentials based method. Only server authentication is mandatory while user authentication is optional. Username and Password are mandatory. It supports different Phase2 methods like,
  - **PAP:** Password Authentication Protocol.
  - **CHAP:** Challenge Handshake Authentication Protocol.
  - **MSCHAP and MSCHAP-V2.**
- **EAP-FAST:** This is a Protected Access Credentials (PAC) based authentication method 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-S3 can be found in `wifi/wifi_enterprise`.

### 4.37.16 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 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.

### 4.37.17 Radio Resource Measurement

Radio Resource Measurement (802.11k) is intended to improve the way traffic is distributed within a network. In a wireless LAN, 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 IDF example `examples/wifi/roaming/README.md` to set up and use these APIs. Example code only demonstrates how these APIs can be used, the application should define its own algorithm and cases as required.

### 4.37.18 ESP32-S3 Wi-Fi Power-saving Mode

**Station Sleep**

Currently, ESP32-S3 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 save modes. In minimum power save mode, station wakes up every DTIM to receive beacon. Broadcast data will not be lost because it is transmitted after DTIM. However, it can not save much more power if DTIM is short for DTIM is determined by AP.

In maximum power save mode, station wakes up every listen interval to receive beacon. This listen interval can be set 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 \texttt{esp_wifi_set_config()} before connecting to AP.

Call \texttt{esp_wifi_set_ps(WIFI_PS_MIN_MODEM)} to enable Modem-sleep minimum power save mode or \texttt{esp_wifi_set_ps(WIFI_PS_MAX_MODEM)} to enable Modem-sleep maximum power save mode after calling \texttt{esp_wifi_init()}. When station connects to AP, Modem-sleep will start. When station disconnects from AP, Modem-sleep will stop.

Call \texttt{esp_wifi_set_ps(WIFI_PS_NONE)} to disable modem sleep entirely. This has much higher power consumption, but provides minimum latency for receiving Wi-Fi data in real time. When modem sleep is enabled, received Wi-Fi data can be delayed for as long as the DTIM period (minimum power save mode) or the listen interval (maximum power save mode). Disabling modem sleep entirely is not possible for Wi-Fi and Bluetooth coexist mode.

The default Modem-sleep mode is WIFI_PS_MIN_MODEM.

**AP Sleep**

Currently ESP32-S3 AP doesn’t support all of the power save feature defined in Wi-Fi specification. To be specific, the AP only caches unicast data for the stations connect to this AP, but doesn’t cache the multicast data for the stations. If stations connected to the ESP32-S3 AP are power save enabled, they may experience multicast packet loss.

In the future, all power save features will be supported on ESP32-S3 AP.

### 4.37.19 ESP32-S3 Wi-Fi Throughput

The table below shows the best throughput results we got in Espressif’s lab and in a shield box.

<table>
<thead>
<tr>
<th>Type/Packet</th>
<th>Throughput 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>N/A</td>
<td>130 MBit/s</td>
<td>Internal tool</td>
<td>NA</td>
</tr>
<tr>
<td>Raw 802.11</td>
<td>UDP RX</td>
<td>30 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>Packet TX</td>
<td>UDP TX</td>
<td>30 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>TCP RX</td>
<td>TCP TX</td>
<td>20 MBit/s</td>
<td>iperf example</td>
<td>15575346</td>
</tr>
<tr>
<td>TCP TX</td>
<td></td>
<td>83 MBit/s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the throughput is tested by iperf example, the sdkconfig is examples/wifi/iperf/sdkconfig.defaults.esp32s3.

### 4.37.20 Wi-Fi 80211 Packet Send

The \texttt{esp_wifi_80211_tx()} API can be used to:

- Send the beacon, probe request, probe response, 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 we need to make sure that Wi-Fi hardware is initialized before `esp_wifi_80211_tx()` is called. In ESP32-S3, 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

- If there is no Wi-Fi connection, the data rate is 1 Mbps.
- If there is Wi-Fi connection and the packet is from station to AP or from AP to station, the data rate is same as the Wi-Fi connection. Otherwise the data rate is 1 Mbps.

Side-Effects to Avoid in Different Scenarios

Theoretically, if we do not consider the side-effects the API imposes on the Wi-Fi driver or other stations/APs, we can send a raw 802.11 packet over the air, with any destination MAC, any source MAC, any BSSID, or any other type of packet. However, robust/useful applications should avoid such side-effects. The table below provides some tips/recommendations on how to avoid the side-effects of `esp_wifi_80211_tx()` in different scenarios.
### Scenario

#### 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, say “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, we recommend 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 for doing this.

#### 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_WIFI_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 and the MAC address 1 is the MAC of AP to which the station is connected, the MAC address 2 is the MAC of station interface, we say the packets is from the station to AP. On the other hand, if the Wi-Fi mode is AP mode and the MAC address 1 is the MAC of the station who connects to this AP, the MAC address 2 is the MAC of AP interface, we say the packet is 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 from the station to AP, the ToDS bit in IEEE 80211 frame control should be 1, the FromDS bit should be 0, otherwise the packet will be discarded by Wi-Fi driver.
- If the packet type is data and is from the AP to station, the ToDS bit in IEEE 80211 frame control should be 0, the FromDS bit should be 1, otherwise the packet will be discarded by Wi-Fi driver.
- If the packet is from station to AP or from AP to station, the Power Management, More Data, Re-Transmission bits should be 0, otherwise the packet will be discarded by Wi-Fi driver.

ESP_ERR_WIFI_ARG is returned if any check fails.

### 4.37.21 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, AMSDU, etc.
- 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, or WIFI_MODE_STA, or 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, we should NOT enable the sniffer, when the station/AP Wi-Fi connection experiences heavy traffic unless we have special reasons.

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.

### 4.37.22 Wi-Fi Multiple Antennas

The Wi-Fi multiple antennas selecting can be depicted as following picture:

```
+----------+     +-----------+     +-------------+     +-----------------+     +-----------------+     +-----------------+     +-----------------+
| Enabled  |     | Antenna 0 |     | \___________|     \___________|     \___________|     \___________|     \___________|
|__________|     | \       |     | \__________|     \__________|     \__________|     \__________|     \__________|
|----|     |\_____|     |\_____|     |\_____|     |\_____|     |\_____|     |\_____|     |\_____|
|-----|     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|-----|     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
|     |     |-----|     |-----|     |-----|     |-----|     |-----|     |-----|
```

ESP32-S3 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. E.g. the value ‘0b1011’ means the antenna 11 is selected. The default value of antenna_select[3:0] is ‘0b0000’, it means the antenna 0 is selected by default.

Up to four GPIOs are connected to the four active high antenna_select pins. ESP32-S3 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.

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 antenna that has better signal from the enabled antennas.

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, e.g. the RX antenna starts to switch if the RSSI is lower than -65 dBm and if another antenna has better signal etc, 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 as the default RX antenna.

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.
• Currently Bluetooth® doesn’t support the multiple antennas feature, please don’t use multiple antennas related APIs.

Following is the recommended scenarios to use the multiple antennas:

• In Wi-Fi mode WIFI_MODE_STA, both RX/TX antenna modes are configured to WIFI_ANT_MODE_AUTO. The Wi-Fi driver selects the better RX/TX antenna automatically.
• The RX antenna mode is configured to WIFI_ANT_MODE_AUTO. The TX antenna mode is configured to WIFI_ANT_MODE_ANT0 or WIFI_ANT_MODE_ANT1. The applications can choose to always select a specified antenna for TX, or implement their own TX antenna selecting algorithm, e.g. selecting the TX antenna mode based on the channel switch information etc.
• 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 config = {
  { .gpio_select = 1, .gpio_num = 20 },
  { .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
};
```

### 4.37.23 Wi-Fi Channel State Information

Channel state information (CSI) refers to the channel information of a Wi-Fi connection. In ESP32-S3, 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 is shown in the following 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 cbw 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-S3.
- More information like RSSI, noise floor of RF, receiving time and antenna is in the rx_ctrl field.

**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 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) * 2 + 2 = 244, the result is aligned to four bytes and the last two bytes is invalid).

### 4.37.24 Wi-Fi Channel State Information Configure

To use Wi-Fi CSI, the following steps need to be done.
• Select Wi-Fi CSI in menuconfig. It is “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, pass 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()`.

4.37.25 Wi-Fi HT20/40

ESP32-S3 supports Wi-Fi bandwidth HT20 or HT40, it doesn’t 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-S3 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’s HT20. If the bandwidth of connected AP is changes, the actual bandwidth is negotiated 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’s HT40 if the AP and one of the stations support HT40, otherwise it’s HT20.

In station/AP coexist mode, the station/AP can configure HT20/40 separately. 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-S3. E.g. 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 150Mbps while it’s 72Mbps 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-S3 device, the performance of HT40 may be degraded. So if the applications need to support same or similar scenarios, it’s recommended that the bandwidth is always configured to HT20.

4.37.26 Wi-Fi QoS

ESP32-S3 supports all the mandatory features required in WFA Wi-Fi QoS Certification.

Four ACs (Access Category) are defined in Wi-Fi specification, 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, such as 802.11D or TCP/IP precedence to Wi-Fi AC.

Below is a table describes how the IP Precedences are mapped to Wi-Fi ACs in ESP32-S3, it also indicates whether the AMPDU is supported for this AC. The table is sorted with priority descending order, namely, the AC_VO has highest priority.

<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:
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 low priority AC, however, it’s not always true, here are some suggestions about how to use the Wi-Fi QoS:

- For some really important application traffic, can put it into AC_VO queue. Avoid sending big traffic via AC_VO queue. On one hand, the AC_VO queue doesn’t support AMPDU and it can’t get better performance than other queue if the traffic is big, on the other hand, it may impact the the management frames that also use AC_VO queue.
- Avoid using more than two different AMPDU supported precedences, e.g. socket A uses precedence 0, socket B uses precedence 1, socket C uses precedence 2, this is a bad design because it may need much more memory. To be detailed, the Wi-Fi driver may generate a Block Ack session for each precedence and it needs more memory if the Block Ack session is setup.

### 4.37.27 Wi-Fi AMSDU

ESP32-S3 supports receiving and transmitting AMSDU.

### 4.37.28 Wi-Fi Fragment

ESP32-S3 supports Wi-Fi receiving and transmitting fragment.

### 4.37.29 WPS Enrollee

ESP32-S3 supports WPS enrollee feature in Wi-Fi mode WIFI_MODE_STA or WIFI_MODE_APSTA. Currently ESP32-S3 supports WPS enrollee type PBC and PIN.

### 4.37.30 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, we need to consider the memory usage/configuration very carefully, because:

- the available memory in ESP32-S3 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”.
- it is very dangerous to run out of heap memory, as this will cause ESP32-S3 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, Wi-Fi RX/TX dynamic buffer number, etc.
- the peak heap memory that the ESP32-S3 LwIP/Wi-Fi may consume depends on a number of factors, such as the maximum TCP/UDP connections that the application may have, etc.
- 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, we have 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:

- the number of dynamic rx buffers that are configured: wifi_rx_dynamic_buf_num
- the number of dynamic tx buffers that are configured: wifi_tx_dynamic_buf_num
- the maximum packet size that the Wi-Fi driver can receive: wifi_rx_pkt_size_max
- the maximum packet size that the Wi-Fi driver can send: wifi_tx_pkt_size_max

So, the peak memory that the Wi-Fi driver consumes can be calculated with the following formula:

\[
\text{wifi\_dynamic\_peek\_memory} = (\text{wifi\_rx\_dynamic\_buf\_num} \times \text{wifi\_rx\_pkt\_size\_max}) + (\text{wifi\_tx\_dynamic\_buf\_num} \times \text{wifi\_tx\_pkt\_size\_max})
\]

Generally, we do not need to care about the dynamic tx long buffers and dynamic tx long long buffers, because they are management frames which only have a small impact on the system.

4.37.31 How to improve Wi-Fi performance

The performance of ESP32-S3 Wi-Fi is affected by many parameters, and there are mutual constraints between each parameter. A proper configuration can not only improve performance but also increase available memory for applications and improve stability.

In this section, we will briefly explain the operating mode of the Wi-Fi/LWIP protocol stack and explain the role of each parameter. We will give several recommended configuration ranks, user can choose the appropriate rank according to the usage scenario.

Protocol stack operation mode

![ESP32-S3 dataproduct](image)

Fig. 61: ESP32-S3 datapath
The ESP32-S3 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, 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_ESP32_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_ESP32_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_ESP32_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_ESP32_WIFI_STATIC_RX_BUFFER_NUM** and **CONFIG_ESP32_WIFI_DYNAMIC_RX_BUFFER_NUM**.
- **CONFIG_LWIP_TCPWND_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_ESP32_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_ESP32_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:

CACHE:

- **CONFIG_ESPS3_INSTRUCTION_CACHE_SIZE** Configure the size of the instruction Cache.
- **CONFIG_ESPS3_INSTRUCTION_CACHE_LINE_SIZE** Configure the size of the instruction Cache bus.
- **CONFIG_ESPS3_ICACHE_ASSOCIATED_WAYS** Configure the associated ways of the instruction Cache.
- **CONFIG_ESPS3_DATA_CACHE_SIZE** Configure the size of the Data Cache.
- **CONFIG_ESPS3_DATA_CACHE_LINE_SIZE** Configure the line size of the Data Cache.
- **CONFIG_ESPS3_DCACHE_ASSOCIATED_WAYS** Configure the associated ways of the Data Cache.

Note: The buffer size mentioned above is fixed as 1.6 KB.
## How to configure parameters

ESP32-S3’s memory is shared by protocol stack and applications.

Here, we have given several configuration ranks. 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>Default</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available memory (KB)</td>
<td>133.9</td>
<td>183.9</td>
<td>273.6</td>
</tr>
<tr>
<td>WIFI_STATIC_RX_BUFFER_NUM</td>
<td>24</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>WIFI_DYNAMIC_RX_BUFFER_NUM</td>
<td>64</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>WIFI_DYNAMIC_TX_BUFFER_NUM</td>
<td>64</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>WIFI_RX_BA_WIN</td>
<td>32</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>TCP_SND_BUF_DEFAULT (KB)</td>
<td>64</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>TCP_WND_DEFAULT (KB)</td>
<td>64</td>
<td>32</td>
<td>6</td>
</tr>
<tr>
<td>WIFI_IRAM_OPT</td>
<td>15</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>WIFI_RX_IRAM_OPT</td>
<td>16</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>LWIP_IRAM_OPTIMIZATION</td>
<td>32</td>
<td>32</td>
<td>16</td>
</tr>
<tr>
<td>INSTRUCTION_CACHE_LINE</td>
<td>32</td>
<td>32</td>
<td>4</td>
</tr>
<tr>
<td>INSTRUCTION_CACHE_WAYS</td>
<td>8</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>TCP TX throughput (Mbit/s)</td>
<td>83.93</td>
<td>64.28</td>
<td>23.17</td>
</tr>
<tr>
<td>TCP RX throughput (Mbit/s)</td>
<td>73.98</td>
<td>60.39</td>
<td>18.11</td>
</tr>
<tr>
<td>UDP TX throughput (Mbit/s)</td>
<td>98.69</td>
<td>96.28</td>
<td>48.78</td>
</tr>
<tr>
<td>UDP RX throughput (Mbit/s)</td>
<td>88.58</td>
<td>86.57</td>
<td>59.45</td>
</tr>
</tbody>
</table>

**Note:** The test was performed with a single stream in a shielded box using an ASUS RT-N66U router. ESP32-S3’s CPU is dual core with 240 MHz, ESP32-S3’s flash is in QIO mode with 80 MHz.

### Ranks:
- **Iperf rank** ESP32-S3 extreme performance rank used to test extreme performance.
- **Default rank** ESP32-S3’s default configuration rank, the available memory, and performance are in balance.
- **Minimum rank** This is the minimum configuration rank of ESP32-S3. The protocol stack only uses the necessary memory for running. It is suitable for scenarios that have 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_ESP32_WIFI_TX_BUFFER` is forced to be static. `CONFIG_ESP32_WIFI_STATIC_TX_BUFFER_NUM` indicates the number of DMA buffers at the hardware layer, increase this parameter can improve performance. The following are the recommended ranks for using PSRAM:

**PSRAM with 4 lines:**
<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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WIFI_STATIC_RX_BUFFER_NUM</td>
<td>50.3</td>
<td>158.7</td>
<td>198.2</td>
<td>228.9</td>
</tr>
<tr>
<td>WIFI_DYNAMIC_RX_BUFFER_NUM</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>WIFI_STATIC_TX_BUFFER_NUM</td>
<td>32</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>WIFI_RX_BA_WIDTH</td>
<td>INF</td>
<td>16</td>
<td>12</td>
<td>Disable</td>
</tr>
<tr>
<td>TCP_SND_BUF_DEFAULT (KB)</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>TCP_WND_DEFAULT (KB)</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>0</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>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LWIP_IRAM_OPT</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>LWIP_UDP_RECVMBOX_SIZE</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>INSTRUCTION_CACHE</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>INSTRUCTION_CACHE_LINE</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>DATA_CACHE</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>DATA_CACHE_LINE</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>DATA_CACHE_WAYS</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>TCP TX throughput (Mbit/s)</td>
<td>93.1</td>
<td>62.5</td>
<td>41.3</td>
<td>42.7</td>
</tr>
<tr>
<td>TCP RX throughput (Mbit/s)</td>
<td>88.9</td>
<td>46.5</td>
<td>46.2</td>
<td>37.9</td>
</tr>
<tr>
<td>UDP TX throughput (Mbit/s)</td>
<td>106.4</td>
<td>106.2</td>
<td>60.7</td>
<td>50</td>
</tr>
<tr>
<td>UDP RX throughput (Mbit/s)</td>
<td>99.8</td>
<td>92.6</td>
<td>94.3</td>
<td>53.3</td>
</tr>
</tbody>
</table>

**PSRAM with 8 lines:**
### 4.37.32 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:

![TX Buffer Allocation Diagram](image)

**Description:**
- The application allocates the data which needs to be sent out.
- The application calls TCP/IP-/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:

![RX Buffer Allocation Diagram]

**Fig. 63: RX Buffer Allocation**

**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 the application wants to reduce the memory statically allocated by Wi-Fi, they can reduce this value from 10 to 6 to save 6400 Bytes memory. It’s 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 menuconfig, is used to limit the total un-freeed 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. Since the TX buffer must be DMA buffer, so when 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 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 AMPDU

ESP32-S3 supports both receiving and transmitting AMPDU, the AMPDU can greatly improve the Wi-Fi throughput. Generally, the AMPDU should be enabled. Disabling AMPDU is usually for debugging purposes.

4.37.33 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

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**

![Wireshark Capture Interface](image)

**Fig. 64: Wireshark 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.

![Fig. 65: Setting up Filters in Wireshark](image)

Click `Filter`, the top left blue button in the picture below. The `display filter` dialogue box will appear.

![Fig. 66: Display Filter Dialogue Box](image)

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.
Chapter 4. API Guides

Fig. 67: Filter Expression Dialogue Box

Fig. 68: Filter Toolbar

Fig. 69: Example of MAC Addresses applied in the Filter Toolbar
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.

![Example of Packet List Details](image)

f) Stop/Start Packet Capture

As shown in the picture below, click the red button to stop capturing the current packet.

![Stopping Packet Capture](image)

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.

4.38 Wi-Fi Security

Espressif Systems

1958

Release v5.0-dev-1648-g94089edbc3
Fig. 72: Starting or Resuming the Packets Capture

Fig. 73: Saving Captured Packets
4.38.1 ESP32-S3 Wi-Fi Security Features

- Support for Protected Management Frames (PMF)
- Support for WPA3-Personal

In addition to traditional security methods (WEP/WPA-TKIP/WPA2-CCMP), ESP32-S3 Wi-Fi supports state-of-the-art security protocols, namely Protected Management Frames based on 802.11w standard and Wi-Fi Protected Access 3 (WPA3-Personal). Together, PMF and WPA3 provide better privacy and robustness against known attacks on traditional modes.

4.38.2 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 the following attacks in case of unprotected management frame exchanges.

- DOS attack on one or all clients in the range of the attacker.
- Tearing down existing association on AP side by sending association request.
- Forcing a client to perform 4-way handshake again in case PSK is compromised in order to get PTK.
- Getting SSID of hidden network from association request.
- Launching man-in-the-middle attack by forcing clients to deauth from legitimate AP and associating to a rogue one.

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

Depending on PMF configurations on Station and AP side, the resulting connection will behave differently. The table below summarises all possible outcomes -

<table>
<thead>
<tr>
<th>STA Setting</th>
<th>AP Setting</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMF Optional</td>
<td>PMF Optional/Required</td>
<td>Mgmt Frames Protected</td>
</tr>
<tr>
<td>PMF Optional</td>
<td>PMF Disabled</td>
<td>Mgmt Frames Not Protected</td>
</tr>
<tr>
<td>PMF Required</td>
<td>PMF Optional/Required</td>
<td>Mgmt Frames Protected</td>
</tr>
<tr>
<td>PMF Required</td>
<td>PMF Disabled</td>
<td>STA refuses Connection</td>
</tr>
<tr>
<td>PMF Disabled</td>
<td>PMF Optional/Disabled</td>
<td>Mgmt Frames Not Protected</td>
</tr>
<tr>
<td>PMF Disabled</td>
<td>PMF Required</td>
<td>AP refuses Connection</td>
</tr>
</tbody>
</table>

API & Usage

ESP32-S3 supports PMF in both Station and SoftAP mode. For both, the default mode is PMF Optional and disabling PMF is not possible. 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.

Attention: capable flag in pmf_cfg is deprecated and set to true internally. This is to take the additional security benefit of PMF whenever possible.
4.38.3 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.

Please refer to Security section of Wi-Fi Alliance’s official website for further details.

Setting up WPA3 with ESP32-S3

In IDF Menuconfig under Wi-Fi component, a config option “Enable WPA3-Personal” is provided to Enable/Disable WPA3. By default it is kept enabled, if disabled ESP32-S3 will not be able to establish a WPA3 connection. Currently, WPA3 is supported only in the Station mode. Additionally, since PMF is mandated by WPA3 protocol, PMF Mode should be set to either Optional or Required while setting WiFi config.

Refer to Protected Management Frames (PMF) on how to set this mode.

After these settings are done, Station is ready to use WPA3-Personal. 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 WPA3 is used.
Chapter 5

ESP-IDF 5.0 Migration Guides

5.1 Migrate Build System to ESP-IDF 5.0

5.1.1 Migrating from make to cmake

Please follow the build system guide for migrating make-based projects no longer supported in ESP-IDF v5.0.

5.1.2 Update fragment file grammar

Please follow the migrate linker script fragment files grammar chapter for migrating v3.x grammar to the new one.

5.2 Migrate Windows Environment to ESP-IDF 5.0

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.

5.3 Migrate Ethernet Drivers to ESP-IDF 5.0

5.3.1 esp_eth_ioctl() API

`esp_eth_ioctl()` third argument could take `int (bool)` number as an input in some cases. However, it was not properly documented and, in addition, the number had to be “unnaturally” type casted to `void *` datatype to prevent compiler warnings as shown in below example:

```
esp_eth_ioctl(eth_handle, ETH_CMD_S_FLOW_CTRL, (void *)true);
```

This could lead to misuse of the `esp_eth_ioctl()`. Therefore, ESP-IDF 5.0 unified usage of `esp_eth_ioctl()`. Its third argument now always acts as pointer to a memory location of specific type from/to where the configuration option is read/stored.

Usage example to set Ethernet configuration:

```
eth_duplex_t new_duplex_mode = ETH_DUPLEX_HALF;
esp_eth_ioctl(eth_handle, ETH_CMD_S_DUPLEX_MODE, &new_duplex_mode);
```

Usage example to get Ethernet configuration:
5.3.2 KSZ8041/81 and LAN8720 Driver Update

KSZ8041/81 and LAN8720 Drivers were updated to support more devices (generations) from associated product family. The drivers are able to recognize particular chip number and its potential support by the driver.

As a result, the specific “chip number” functions calls were replaced by generic ones as follows:

- `esp_eth_phy_new_ksz8041()` and `esp_eth_phy_new_ksz8081()` were removed, use `esp_eth_phy_new_ksz80xx()` instead
- `esp_eth_phy_new_lan8720()` was removed, use `esp_eth_phy_new_lan87xx()` instead

5.3.3 ESP NETIF Glue Event Handlers

`esp_eth_set_default_handlers()` and `esp_eth_clear_default_handlers()` functions were removed. Registration of the default IP layer handlers for Ethernet is now handled automatically. If users have already followed the recommendation to fully initialize the Ethernet driver and network interface prior to registering their Ethernet/IP event handlers, then no action is required (except for deleting the affected functions). Otherwise, users should ensure that they register the user event handlers as the last thing prior to starting the Ethernet driver.

5.4 Migrate FreeRTOS to ESP-IDF 5.0

5.4.1 Legacy API and Data Types

Previously, the `configENABLE_BACKWARD_COMPATIBILITY` option was set by default, thus allowed pre FreeRTOS v8.0.0 function names and data types be used. The `configENABLE_BACKWARD_COMPATIBILITY` is now disabled by default, thus legacy FreeRTOS names/types are no longer supported by default. Users should either:

- 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

5.4.2 Tasks Snapshot

The header `task_snapshot.h` has been removed from `freertos/task.h`. ESP-IDF developers should include "freertos/task_snapshot.h" in case they need tasks snapshot API.

5.4.3 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`.

5.5 Migrate Peripherals to ESP-IDF 5.0

5.5.1 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`.

### 5.5.2 SPI Flash Interface

Version before v5.0, spi flash functions in rom can be included by `esp32**/rom/spi_flash.h`. However, your code written for different chips may be filled with ROM headers of different versions. At the meantime not all the APIs can be used on all chips.

Therefore, the common APIs are extracted to `esp_rom_spiflash.h`. Although it’s not a breaking change, it is strongly recommended to only use the functions with prefix `esp_rom_spiflash` included by `esp_rom_spiflash.h` for better cross-compatibility.

To make the API clearer, we renamed the function `esp_rom_spiflash_lock` to `esp_rom_spiflash_set_bp`. We renamed `esp_rom_spiflash_unlock` to `esp_rom_spiflash_clear_bp`.

### 5.5.3 ADC

Previous `driver/adc2_wifi_private.h` has been moved to `esp_private/adc2_wifi.h`.

### 5.5.4 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.

### 5.5.5 Timer Group Driver

Timer Group driver has been redesigned into GTimer, which aims to unify and simplify the usage of general purpose timer. Although it’s recommended to use the 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 bring a build warning like “legacy timer group driver is deprecated, please migrate to driver/gptimer.h”. The warning can be suppressed by the Kconfig option `CONFIG_GPTIMER_SUPPRESS_DEPRECATE_WARN`.

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 source clock 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 `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, alarm event specific configurations are not needed during the driver install stage.
- 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 form user’s side as the timer resolution is also known to the user.

• The driver will install the interrupt service as well if `on_alarm` is set to a valid callback function. In the callback, user doesn’t 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 `auto_reload_on_alarm` is set to true.

**UART**

• `uart_isr_register` and `uart_isr_free` have been removed as the UART interrupt handling is closely related to the driver implementation.

**I2C**

• `i2c_isr_register` and `i2c_isr_free` have been removed as the I2C interrupt handling is closely related to the driver implementation.

### 5.6 Removed or deprecated components

Following components are removed from ESP-IDF and moved to IDF Component Registry:

- `libsodium`
- `cbor`
- `jsmn`
- `esp_modem`
- `nghttp`

**Note:** Please note that http parser functionality which was previously part of `nghttp` component is now part of `http_parser` component.

- `shlib`
- `expat`

These components can be installed using `idf.py add-dependency` command.

For example, to install `libsodium` component with exact version X.Y, run: `idf.py add-dependency lib-sodium==X.Y`.

To install `libsodium` component with the latest version compatible to X.Y according to semver rules, run: `idf.py add-dependency lib-sodium~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.

### 5.7 Migrate System to ESP-IDF 5.0

#### 5.7.1 Inter-Processor Call

IPC (Inter-Processor Call) component has been moved to `esp_system`. 
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 `esp_system` component is included by default.

### 5.7.2 ESP Clock

The old headers `ESP32-S3/clk.h, esp_clk.h` have been removed.

Therefore, if you want to use the function with the prefix `esp_clk` please include `esp_private/esp_clk.h` instead.

### 5.7.3 Cache Error Interrupt

The old headers `ESP32-S3/cache_err_int.h` have been removed. Please include `esp_private/cache_err_int.h` instead.

### 5.7.4 Brownout

The header `brownout.h` has been made private. ESP-IDF developers should include `esp_private/brownout.h` instead.

### 5.7.5 Trax

The header `trax.h` has been made private. ESP-IDF developers should include `esp_private/trax.h` instead.

### 5.7.6 ROM

Deprecated ROM related header files from `components/esp32/rom/` (old include path: `rom/*.h`) have been deleted. Please update to use the new target-specific path from `components/esp_rom/include/ESP32-S3/` (new include path: `ESP32-S3/rom/*.h`).

### 5.7.7 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 file `esp_intr.h` has been deleted. Please include `esp_intr_alloc.h` to allocate and manipulate interrupts.
- The header file `esp_panic.h` has been deleted. ESP-IDF developers should include `esp_private/panic_reason.h` to get supported panic reasons. And should include `esp_debug_helpers.h` to use any debug related helper functions, e.g. print backtrace.

### 5.7.8 SOC dependency

- Public API headers who are listed in the Doxyfiles won’t expose unstable and unnecessary soc header files like `soc/soc.h, 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.
5.7.9 APP Trace

One of the timestamp sources has changed from the legacy timer group driver to the new GPTimer. Kconfig choices like APPTRACE_SV_TS_SOURCE_TIMER00 has been changed to APPTRACE_SV_TS_SOURCE_GPTIMER. User doesn’t need to choose the group and timer ID any more.

5.7.10 ESP Timer

Removed the FRC2 based legacy implementation of esp_timer available on ESP32. The simpler and more efficient implementation based on the LAC timer is now the only option.

5.8 Migrate Tools to ESP-IDF 5.0

5.8.1 IDF Monitor

IDF Monitor follows the custom console baud-rate (CONFIG_ESP_CONSOLE_UART_BAUDRATE) by default instead of 115200. Setting a custom baud rate is not supported from menuconfig anymore. 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.
Chapter 6

Libraries and Frameworks

6.1 Cloud Frameworks

ESP32-S3 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-S3 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-S3 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-S3 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-S3 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-S3 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-S3 based on Tencent’s welink SDK.

6.1.8 Tencent IoT

https://github.com/espressif/esp-qcloud is an open source repository for ESP32-S3 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-S3 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`. 
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 onto the public github repository.
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. ie 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 (ie 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.

```
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);
    }
```
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) {
    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)
void function(int arg) {
}

• 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](<github-line-endings>).
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):

```
git rebase --exec 'git diff-tree --no-commit-id --name-only -r HEAD | xargs --dos2unix && git commit -a --amend --no-edit --allow-empty' master
```

(Note that this line rebases on master, change the branch name 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 `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" {
#endif
/* declarations go here */
#ifndef __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.
• 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:

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
    }

    Sojuz::Sojuz() : SpaceShip(3)
    {
    }

    (continues on next page)
template <typename T>
CargoShip<T>::CargoShip(const T &cargo) : cargo(cargo) { }
} // namespace spaceships

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.

Documenting Code

Please see the guide here: Documenting Code.

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`
Chapter 7. Contributions Guide

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` command

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

/\usr/bin/env: python: Permission denied.

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:

```
/**
 * @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.
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.

6. To provide well formatted lists, break the line after command (like `@return` in example below).

```plaintext
// @return ESP_OK if erase operation was successful
```
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.

   ```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.
   */
   ```

   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`.

   ```
   /*
   * @attention
   * 1. This API only impact WIFI_MODE_STA or WIFI_MODE_AP_STA 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:

   ```
   /**@*
   **
   * @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/include/driver/gpio.h.

5. Use markdown to make your documentation even more readable. You will add headers, links, tables and more.
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.

![Fig. 1: One line for one paragraph (click to enlarge)](image1)

![Fig. 2: No line breaks within the same paragraph (click to enlarge)](image2)

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.

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:

```
built-docs build
```

or for specific target and language with:

```
built-docs -t esp32 -l en build
```

For more in-depth documentation about `esp-docs` features please see the documentation in the `esp-docs` repository.

**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 an example_test.py file for running an automated example test. If submitting a GitHub PullRequest which includes an example, it’s OK not to include this file initially. The details can be discussed as part of the Pull Request.

General Guidelines

Example code should follow the Espressif IoT Development Framework Style 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:

```markdown
## Wi-Fi - API Reference
##
../components/esp32/include/esp_wifi.h \
../components/esp32/include/esp_smartconfig.h \
```

1. 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.
2. 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`.
3. To show contents of `*.inc` file in documentation, include it as follows:

```markdown
.. include-build-file:: inc/esp_wifi.inc
```

For example see `docs/en/api-reference/network/esp_wifi.rst`
Chapter 7. Contributions Guide

1. Optionally, rather than using *.inc files, you may want to describe API in your own way. See docs/en/api-guides/ulp.rst for example.

Below is the list of common .. doxygen:: directives:

- Functions .. doxygenfunction:: name_of_function
- Unions .. doxygenunion:: name_of_union
- Structures .. doxygenstruct:: name_of_structure together with :members:
- Macros .. doxygenmacro:: name_of_define
- Type Definitions .. doxygentypedef:: name_of_type
- Enumerations .. doxygenenum:: 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`
```

1. In any case, to generate API reference, the file docs/doxygen/Doxyfile should be updated with paths to *.h headers that are being documented.

1. 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

Thank you for your interest in contributing to Espressif IoT Development Framework (esp-idf) ( “We” or “Us” ). The purpose of this contributor agreement ( “Agreement” ) is to clarify and document the rights granted by contributors to Us. To make this document effective, please follow the instructions at CONTRIBUTING.rst

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“Submission Date” means the date You Submit a Contribution to Us.

“Documentation” means any non-software portion of a Contribution.

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7. Term  7.1 This Agreement shall come into effect upon Your acceptance of the terms and conditions.

7.2 In the event of a termination of this Agreement Sections 4, 5, 6, 7 and 8 shall survive such termination and shall remain in full force thereafter. For the avoidance of doubt, Contributions that are already licensed under a free and open source license at the date of the termination shall remain in full force after the termination of this Agreement.
8. Miscellaneous  8.1 This Agreement and all disputes, claims, actions, suits or other proceedings arising out of this agreement or relating in any way to it shall be governed by the laws of People’s Republic of China excluding its private international law provisions.

8.2 This Agreement sets out the entire agreement between You and Us for Your Contributions to Us and overrides all other agreements or understandings.

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.

You

<table>
<thead>
<tr>
<th>Date:</th>
<th>Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Title:</td>
<td>Address:</td>
</tr>
<tr>
<td></td>
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</tbody>
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Us

<table>
<thead>
<tr>
<th>Date:</th>
<th>Name:</th>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Title:</td>
<td>Address:</td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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:

```c
/*
 * SPDX-FileCopyrightText: 2015-2022 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: 2015-2022 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: 2019-2022 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.

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.
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.

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

<table>
<thead>
<tr>
<th>Version String</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>v3.2-dev-306-gbeb3611ca</td>
<td>Master branch pre-release.</td>
</tr>
<tr>
<td>- v3.2-dev - in development for version 3.2.</td>
<td></td>
</tr>
<tr>
<td>- 306 - number of commits after v3.2 development</td>
<td></td>
</tr>
<tr>
<td>started.</td>
<td></td>
</tr>
<tr>
<td>- beb3611ca - commit identifier.</td>
<td></td>
</tr>
<tr>
<td>v3.0.2</td>
<td>Stable release, tagged v3.0.2.</td>
</tr>
<tr>
<td>v3.1-beta1-75-g346d6b0ea</td>
<td>Beta version in development (on a release branch).</td>
</tr>
<tr>
<td>- v3.1-beta1 - pre-release tag.</td>
<td></td>
</tr>
<tr>
<td>- 75 - number of commits after the pre-release beta</td>
<td></td>
</tr>
<tr>
<td>tag was assigned.</td>
<td></td>
</tr>
<tr>
<td>- 346d6b0ea - commit identifier.</td>
<td></td>
</tr>
<tr>
<td>v3.0.1-dirty</td>
<td>Stable release, tagged v3.0.1.</td>
</tr>
<tr>
<td>- dirty means that there are modifications in the</td>
<td></td>
</tr>
<tr>
<td>local ESP-IDF directory.</td>
<td></td>
</tr>
</tbody>
</table>

#### 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.
• **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](#) 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:

```bash
cd $IDF_PATH
git fetch
git checkout vX.Y.Z

git submodule update --init --recursive
```

- 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](#). 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:

- Check out the master branch locally:

  ```bash
  cd $IDF_PATH
  git checkout master
  git pull
  git submodule update --init --recursive
  ```

- 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.
- 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, 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
```

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

• What is PlatformIO?
• Installation
• Configuration
• Tutorials
• Project Examples
• Next Steps

9.1.1 What is 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.

9.1.2 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-S3 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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• **ESP-MQTT** MQTT Package (contiki-mqtt) - Copyright (c) 2014, Stephen Robinson, MQTT-ESP - Tuan PM <tuannpm at live dot com> is licensed under Apache License 2.0 as described in LICENSE file.

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• **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.

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### 10.1.2 Build Tools

This is the list of licenses for tools included in this repository, which are used to build applications. The tools do not become part of the application (firmware), so their license does not affect licensing of the application.

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Chapter 11

About

This is documentation of ESP-IDF, the framework to develop applications for ESP32-S3.
The ESP32-S3 is a 2.4 GHz Wi-Fi Bluetooth Low Energy combo SoC, which integrates a Xtensa® 32-bit LX7 CPU.

Fig. 1: Espressif IoT Integrated Development Framework

The ESP-IDF, Espressif IoT Development Framework, provides toolchain, API, components and workflows to develop applications for ESP32-S3 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.

Fatal Errors

[中文]

Overview

In certain situations, execution of the program can not be continued in a well defined way. In ESP-IDF, these situations include:

- genindex
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